Master Thesis

Solar Thermal Energy Systems for Heating Houses in the Netherlands

Social Acceptance, Energy Management

and

New System Design with feasibility study for Friesland

Supervisors:

Prof. Dr. Joy Clancy

Dr. Maarten Arentsen

Javanshir Fouladvand

Master of Environmental and Energy Management

University of Twente

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Abstract

The background of the research is Decreasing Energy Demand due to implementation of Renewable Energy Technology small projects, based on European regulations and National targets in the Netherlands. EU have defined targets on Renewable Energy production shares for all member states. The average of this share for whole of the EU countries is 20% in 2020 and 14% specifically for the Netherlands (33,34,41,49). It seems, due to problems related to "Social Acceptance", "Improper Energy Systems" and "Lack of Knowledge" these targets could not be achieved at the deadline. (41,50,52) This research is focused on the "Social Acceptance" and "System Design" of one of Renewable Energy Technologies, "Solar Thermal Energy", in the Netherlands. The data come from, in-depth literature study, mathematical modeling, interviews and survey. Additionally, due to analyze the data the mixed methods will be applied. Qualitative and Quantitative analysis will be done and the results will be used directly to generate recommendation.

In addition, the other aim is define and assess the Criteria which have influence on Design a new "Solar Thermal System for Heating the Houses" in the Netherlands. Due to 50% of the energy which consume in the houses is related to the heating and cooling of the space and also, lack of proper thermal design for houses in the Netherlands, this thesis is focused on this area. Furthermore, a conceptual model design which could be developed and installed in Friesland Province, the City of Leeuwarden for instance, will be recommended.

Keywords: Sustainable Energy Technology, Energy Transition, Social Acceptance, Energy Demand Reduction, Solar Thermal Energy, Solar Thermal Energy System Design, Energy Transition, Energy Security, Energy Policy, Households, the Netherlands

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Chapter 1: Introduction

In the introduction the background information related to the subject (Renewable Energy Technologies (RET) in the Netherlands and Solar Thermal Energy in specific) and problem statement are presented. Also, general knowledge about the Social Acceptance and Energy Security of RET will be discussed. Furthermore, the research objective description is included and the significance of this research will be explained.

1.1. Background Information

Nowadays, due to depletion of the world's fossil fuel reserves and environmental impact based on fossil fuel consumption the energy sector all around the world is facing the serious problems (29,37,52). These issues have not just been discussed on the governmental level and influenced the policy makers, but also, there is increasing support and understanding of society and business about the urgent need for sustainable energy transition. Different stakeholders believe the current consumption pattern will cause huge problems for humanity such as Global Warming and also will affect the future generation (41,56). It seems among different solutions for these problems and due to address other concerns about current and future status of Energy, the most suitable possible one which be clean and accessible for most of the people is Renewable Energy Technology.

One of the actions which have taken place to tackle these problems are the European Commission targets on Renewable Energy production shares for all member countries which on the average is 20% for whole Europe for 2020. It seems, these targets which are based on different aspects have a significant influence on the development of Renewable Energy production projects (28,33,41). For example, for the countries such as the Netherlands which has cheap natural resources and also do not have certain policy and infrastructure for RET before these targets, their contribution on the share of Renewable Energy will be less (14,15). Based on these targets the Netherlands's target is 14% for 2020. Although, different states and municipalities have their plans to aid the Dutch government to get to this goal, the current Renewable Energy share is less than 5.5% in 2014 (34,42,43). For instance, the Municipality of Leeuwarden has the ambitious goal to be fossil fuel free up to 2020 (59). As a result, the developments of Renewable Energy projects are not as fast as it should be.

Also, one of the most important aims of RET projects implementation is to reduce the CO2 emission. Energy consumption have a directly influence on environmental issues (15,28). On one hand Energy is fundamental of economic growth and on the other hand, due to the fossil fuel combustion, one of the outputs is CO2 which is one of the main causes of Climate Change the effects of which are found all around the world. EU have made policies and regulations which based on these regulations there is, target of carbon emissions reduction between 80% and 95% by 2050 compared with 1990 levels (19,26,28,38). Based on the current situation the Netherlands is one of the 25 countries worldwide with the largest CO2 emission per year. Implementation of Renewable Energy Technologies could help the Netherlands to achieve this target and reduce the CO2 emission (28,38).

1.2. Problem Statement

Despite the broad support of society and governments in the EU and especially in the Netherlands for Renewable Energy, there are problems with the implementation of Renewable Energy projects on small scale level (18,28,52). It seems, the main challenge for the Netherland and also all other countries around EU is the Social Acceptance and Participation for the National Energy Transition and involving more citizen, businesses and civil societies. This might be related to the lack of knowledge about RET, especially the new technologies for heating or might be because of the unsuitable available Energy Systems which the society could not accept it as an alternative energy supplier for their needs.

Renewable Energy Technology has only 5.5% share in Energy production in the Netherlands in 2014 (34). Solar Thermal is only one present of the total RET production in Netherlands which shows very little share. Due to the average 1025 kWh per Square meters available solar energy in the Netherlands, this share could increase and develop (47,48). This 1% produce annually heat equal to Natural Gas usage of 21000 households and the CO2 emission from18000 petrol cars. (33,34) The little share could be because of low Social Acceptance due to lack of Knowledge or improper Energy Systems.

1.3. Research Objectives

To organize the research and define an external goal, the research objective have been defined as follow:

The main objective for this study is related to assess the main criteria which have strong impact on the Social Acceptance and Energy System Design of Solar Thermal Energy Systems in the Netherlands. For this purpose there are three sub research objectives which are mentioned below:

1. To assess the current status and identify the barriers of the Solar Thermal Energy adoption in relation to Households in the Netherlands
2. To identify and assess the different criteria which have influence on Social Acceptance and Energy System Design of Solar Thermal Energy in the Netherlands
3. To assess the importance of the new system design on Social Acceptance in the Netherlands and recommend proper Solar Thermal Energy System Design

1.4. Significance of the research

This research have been focused on the social aspect of certain Renewable Energy source, Solar Thermal Energy in the Netherlands which could have an added value for the existing body of knowledge. The study tries to be an academic bridge between technical and social part of Renewable Energies in the Netherlands and discuss the impact of Social Acceptance of these systems on the System Design and technical part which could have practical results and outputs for energy experts in different levels, such as Dutch government and policy makers, businesses and academic institutes. The nexus between technical and social aspect of Solar Thermal Energy systems could be the main key for development and adaption of these systems in the Netherlands which this research tries to address.

Chapter 2: Literature review

In this part the information and data based on the Literature Review related to the subject is presented. Firstly, the general Energy, Solar Thermal Energy and Environment in the Netherland are discussed. Then, the Social Acceptance theory, different aspect and dimensions of this theory and important criteria which have a strong influence have been explained. Finally, the Energy Security and it's relation to the social acceptance will be presented.

2.1. Energy

During recent years there have been various serious global environmental issues such as Climate Change, which are linked to the global increase in the use of fossil fuels. Also, there are some problems for supply part of fossil fuel which have influence on the both Energy Producers and Energy Consumers countries and also, have an impact on the Energy Price. To solve these problems, the world shows greater interest in new different Renewable Energy sources (37,38,52) As Figure 1 shows, the Renewable Energy sources have a great potential to be considered as a reliable energy source for human society (24).

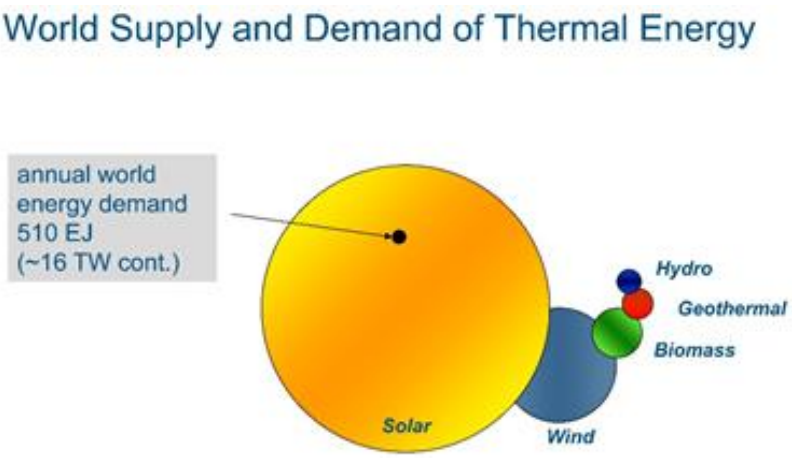

Figure 1: World Supply and Demand of Thermal Energy

As Figure 1 presents, the available Renewable Energy sources are more than enough to support annual Energy Demand all around the World. However, even though this huge potential is available, due to technical and social problems, this goal has not been achieved yet. (14,24). Due to these issues and also, availability of instructors the Fossil Fuels are still the main Energy Source.

One of the most important actions which have taken place to tackle energy problems based on Renewable Energy sources are the European Commission targets 20% average on Renewable Energy production shares for all member countries. These targets have strong influence on the development of renewable energy production projects (41). Furthermore, in October 2014, the European Union present the new target for Renewable Energy share in 2030 which is 27% (26).

Based on these targets each country forced to rich a certain Renewable Energy. For the Netherlands, this target is 14% for 2020. Although, different stakeholders such as states and municipalities have their plans to aid the country to get this goal, the current Renewable Energy share is less than 5.5% in 2014 (26,33,34). Some studies show that, due to different population scenarios, climate issues and current energy consumption pattern these targets are hardly achievable for the Netherlands. Due to attain these targets there is a need for in renovation measures and policies (23,26,35).

Furthermore, the Netherlands' energy industry is one of the main industries in the country that generates an annual output of EUR 41 billion which is more than 6% of Dutch GDP and have more than 100,000 employee (28). In this huge and strong industry, government try to promote the production of Renewable Energy in different ways such as Sustainable Energy Incentive Scheme Plus (SDE+) which is the developed version of original Sustainable Energy Incentive Scheme (SDE) (34).

On the other hand, the Energy Consumers are important too. One of the main energy consumers in the Netherlands are households. As it shows in Figure 2, households are the second biggest energy consumers in the Netherlands after Manufacturing. Household's share is around 25% of total energy consumption in the Netherlands. In addition, buildings (both Commercial and Domestic) share of energy consumption is 30% of total energy consumption. Due to these energy consumption share, this specific sector, buildings specially houses, offers potential for Renewable Energy and Energy Efficient systems implementation (28,38). Also, due to Energy Crisis, such as Oil Crisis in 1973, there have been an attempt among Policy Makers to conserve Energy in Residual Sector and among Households (15,18).

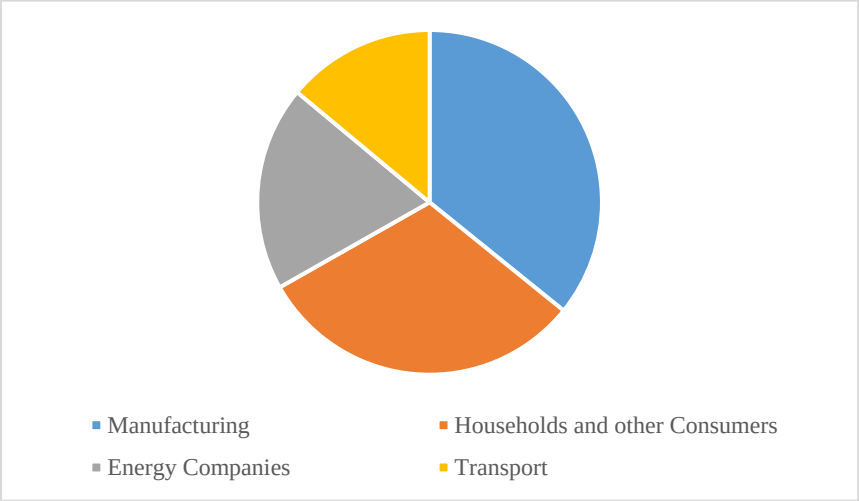

Figure 2: Energy Consumption Share in the Netherlands

Based on Households energy consumption share and also European Performance of Building Directives (EPBD) the Dutch government make policies to reduce the energy demand. Base on

EPBD which the main goal is toward net zero Energy Building (zEB) by 2020, the main focus of all developments and refurbishment are energy efficiency of the buildings and use of Renewable Energy systems (4,20,46). Due to this purpose, the first priority is to decrease the basic needed energy in housing. This needed energy could be electricity, district heating and other sources and it could be decreased by social and technical solutions such as strong insulation of the houses. However, these kind of activities are effective and could decline the energy demand but they are not enough to achieve the reduction goals. As a result, another supportive step for the solution is needed. The next step to reduction of energy demand in houses is implementation of on-site Renewable Energy sources. Installation of Renewable Energy Technologies could have a huge impact on the household's energy demand. It could even change the consumption pattern. For instance, the energy consumption during the day could be changed due to available Sun or Wind (4,19,28).

Although, the Renewable Energy Sources have many advantage in comparison with fossil fuels, but they have some disadvantages which have a strong influence on the development and installation of these systems. For instance, the "changes in the aesthetics of landscape" is one of the most important challenges which Renewable Energies, mostly Wind Energy is facing all around the world. The most important advantage and disadvantage of the Renewable Energy Sources for this study in the EU countries, specifically the Netherlands could be listed as below:

Table 1: Advantages and Disadvantages of Renewable Energy Sources in the EU and the Netherlands

Advantage	Disadvantage
Addressing Environmental Concerns	Impacts on Flora and Fauna
Reducing Dependence on Fossil Fuels, Energy Security	Changes in the Aesthetics of the Landscape and Visual Intrusion of Facilities
Reliability of Energy Systems	Noise Pollution
Better Quality of Life	High Installation Costs
Conservation of Natural Resources	New Technology and on-understandable
Creating New Jobs	Life-Style Changing
Decreasing Operating Costs	

As this table shows, the Renewable Energy sources have serious disadvantages which make their development hard and slow. Most of these disadvantages could have a strong influence on the Social Acceptance of Renewable Energy Technologies mostly on the local level. On the other hand, due to reliable energy supply and reduction of fossil fuel consumption and CO2 emission, the advantages of Renewable Energies are strongly promising. The answer could be a Renewable Energy source which maximize the advantages and minimize the disadvantages such as offshore Wind farms or Solar Thermal Energy source. For instance, the on-site Solar Thermal Energy systems for the houses do not have noise pollution or huge impact on the Landscape. The main disadvantage of these systems is high installation cost which mostly is related to the collectors and storage systems (4,6,11,14).

2.2. Solar Thermal Energy

The Solar Thermal Energy refers to the usage of Solar Radiation energy to heat the specific liquid (mostly water) due to use this liquid for heating and cooling. As a technical point of view, the Solar Thermal Energy system consist of solar collector, thermal reservoir, auxiliary heater, heat exchanger, and a series of junction tubes which connect solar collector into storage tank. One of the most important part in this system is the solar collector which absorb the solar energy and heat the liquid. (10,24,55) In Figure 3 a schematic picture of these systems have been presented which should be mentioned it do not have a Storage System. The Storage System is needed when the Produced Energy is more than the Energy which is needed. Then the extra Energy will be stored in the Storage System and will be used in the future when there is a need for extra heat energy.

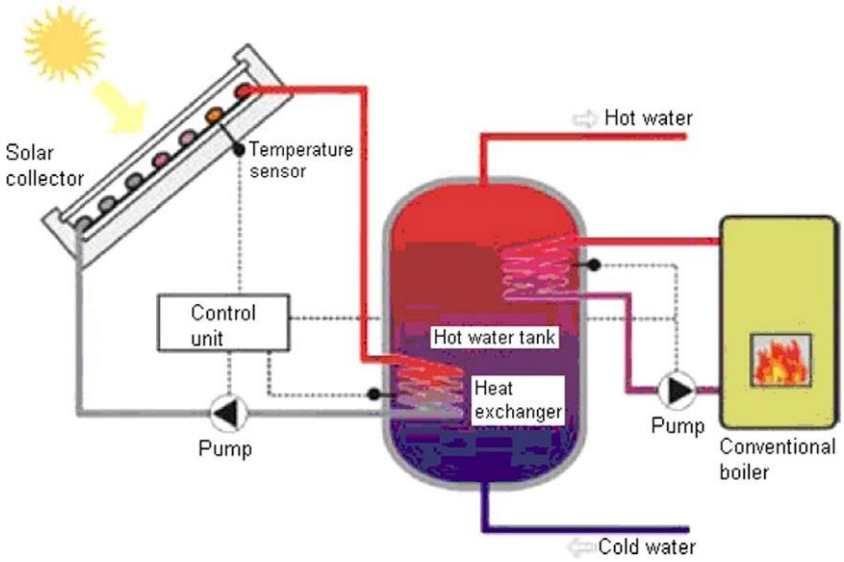

Figure 3: Schematic Solar Thermal Energy System for domestic usage

The important factors which have strong influence on the design of Solar Thermal Energy systems are "Solar Radiation" and "Climate". There are other factors which have influence such as the Capacity and Economic aspect. (10,24,54,55,58)

The economic and technical analysis shows that Solar Thermal heating systems are more feasible in hot climates such as Middle East than in moderate European climates. The studies about Europe concern about different points such as Financial Feasibility and Security of Energy Supply of these systems. Due to achieve payback times of 10 years with today's energy prices, the investment costs have to be reduced by 30% to 70% depending on the location and dimensioning. Mainly the two most important criteria which should be considered for install Solar Thermal systems are the "Cost of the System (Investment)" and the "Value of the Delivered Energy by the system over its lifetime" which could be categorized as most important economic and technical terms. (24,26,50,54,58)

In the Europe, the Solar Energy is growing steadily. This growth is mainly related to PV systems which produce Electricity from sun. However, the Solar Thermal Energy systems are growing with

lower speed. The installed capacity of Solar Thermal Energy from 2000 to 2010 have a 12% annual growth, which with comparison with other Renewable Energy sources is not fast but still happening. This growth is mainly because of following reasons. First, the decreases in the Solar Energy system prices which is because of improvements in the technology and also, market developments. The second reason is the supporting policy and regulations which the EU commission have been make due to support development in Renewable Energy share as discussed before. (1,6,12,27,42,43)

All these improvements and developments in Solar Energy systems which are happening in the EU, are limited by some factors such as "Climate" and "Solar Radiation" in this area. In Figure 4, the "Solar Radiation" for the Europe have been shown which with comparison with Middle East or North of Africa, the Solar Radiation is less.

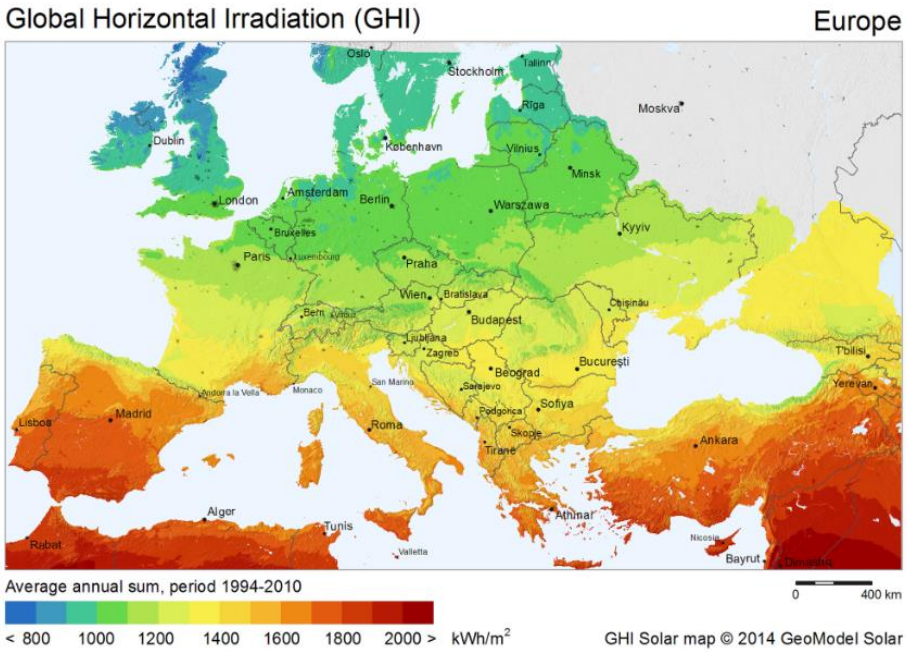

Figure 4: Solar Radiation in the EU (48)

As Figure 4 shows, the Netherlands, Belgium, England and north of France that have mostly same radiation and based on their maritime temperate climate, almost same Solar Thermal Energy System design could be used for these countries (48).

In the Netherland specifically, Solar Thermal Energy production was 1,087 Tera joule which the share of production is only 1% of total Renewable Energy production in 2013. This Produced Energy is equal the basic Natural Gas needed for the 21000 households in a year. (33). However, the share of this specific type of Renewable Energy is low in the Netherlands, the statistics indicate a promising growth during next decade. In the last 10 years, annual increase is between 3 up to 10 percent. (1,33,34) Based on these increase during last decade and due to Dutch government policy, there have been defined a target for these systems. The target for 2023 is to expand the installed Solar Thermal Energy Systems to 6 times more than the 2012. (1)

Due to have a better understanding about the status of the Solar Energy in the Netherlands, the different provinces should be considered. Among the different states in the Netherlands, the North Brabant produce more Solar Energy (both Thermal and Electrical) than other states (Renewable Energy report 2014, 2013). The Seven most Solar Energy producer states in the 2014 and 2013 are shown in the table below:

Table 2: The Seven most Solar Energy producer states in the Netherlands

State	Solar Energy (million kWh) 2014	Solar Energy (million kWh) 2013
North Brabant	10.8	9.3
North Holland	8.7	7.4
South Holland	8.1	6.7
Gelderland	7.5	6.1
Overijssel	6.9	5.8
Friesland	6.2	6.2
Limburg	6.1	5.4

As the table shows all the states have experienced increase in Solar Energy Production except Friesland which stays the same during 2013-2014. The average increase is 1 million kWh which is 11% increase for all these seven states. It seems this growth shows promising future for the Solar Energy in the Netherlands (33,34).

2.3. Social Acceptance

Social Acceptance is a term which refers to the acceptance and participation for specific product and service by the public. Social acceptance is increasingly used in connection with new energy sources and technologies (11,56). In broader view, the social acceptance addressing and achieving specific subjects such as Social Concern, Social Information and actual usage of the new product. There are several definition and factors for Social Acceptance which could influence the direction of the study (18,50). Based on the topic of this research which is related to Renewable Energy, the Social Acceptance is existing when the flowing terms have been achieved:

1. There is support for the technology among the expert community and national and local policy-makers;

2. The general public has an informed and largely positive view of the technology;

3. Concrete applications do not meet significant obstacles from local policymakers, residents, the NGO community or other representatives of social interests and

4. When the opportunity arises, ordinary people are willing and prepared to adopt the applications in their own contexts and to support them with positive actions.

As these four specific terms shows, the expert community which for this study are energy experts and academic institutes are so important. Also, the application and installation of these new

systems should not face difficulty from local community such as prevention against implementation of local Wind Park. Furthermore, ordinary people should participate and support applications. (11,41,50,56). Also, participation of other different stakeholders could have an impact on these four terms. Based on these terms and due to the purpose of this topic, the Social Acceptance could be defined as "The positive supporting act by different stakeholders due to implementation and adaption of Renewable Energy (Solar Thermal) initiatives".

This is crucial to consider the Social Acceptance as an important factor which can influence the design and development of the Renewable Energy Technology. Many of the barriers for achieving successful projects at the implementation level can be considered as a manifestation of lack of Social Acceptance. During the 1980s, when the Renewable Energy policies have been started, Social Acceptance as a part of Renewable Energy Implementation has been neglected largely (56). Although, the first surveys show the public support of these new technologies, in the installation step of Renewable Energy Technology there were strong local opposition which had faced this step with problems which later studies mention the factor, NIMBY (Not in my back yard) as the main problem for this contrast between Survey's results and people's act. NIMBY is used for describe the phenomenon that people support the Renewable Energy Technologies in general but they don't want them to be implanted in their local area. In other words, they want to use the advantages of these systems without involving in the disadvantages. Most of researches now seems to be agreed that this phenomenon is complex which different terms such as "selfish" element or "knowledge" have influence on it. (17,34,39)

In addition, there are other important issues and features which influence the Social Acceptance of Renewable Energy Sources development. Some of these issues and factors are mentioned below:

- It seems the Renewable Energy plants tend to be in smaller-scale than conventional power plants which needs more individual places to implant the systems. As a result, more stakeholders, mostly local associates will get involved.
- In some cases such as Local Solar Park and micro-generation in buildings, these projects will have an influence of the individual investment decision.
- As it mentioned in Energy part of literature review, the Renewable Energy Systems have negative visual impact on the local inhabitant's daily life.
- The individuals who are going to invest on these systems need to have knowledge to compare different systems and choose between them, which is harder than to get needed energy from the grid.
- Due to long term pay back and insensible environmental impact on the daily life, implanting of Renewable Energy Technologies needs to have a long-term view and planning (33,38,56)

Due to have a better understanding about the Social Acceptance of Renewable Energy Technologies, specifically Solar Thermal Energy, the subject could be divided in two main point of view: Social Acceptance Dimensions and Social Acceptance Aspects. Social Acceptance Dimensions is referred to different level of Social Acceptance. It's mainly about stakeholders.

Social Acceptance Aspects is related to several terms and factors which have influence on Social Acceptance. These two main parts will be discussed and for this study will be considered.

2.3.1. Social Acceptance Dimensions

All these terms and issues relevant to Renewable Energy Technology which had been discussed in the last part, have an impact on different stakeholder's Social Acceptance. However, these impact are not the same for all of them but could influence Social Acceptance in positive and negative way. For instance, the Energy experts might support a certain Renewable Energy and on the same time the majority of society won't accept it. This could cause problems to reaching the Social Acceptance of Renewable Energy Technologies. Due to clarify and make this more understandable, based on Wustenhagen (2007) (56), the Social Acceptance could be categorized in three different dimensions which are shown in Figure 5 as "The Triangle (Three Dimension) of Social Acceptance of Renewable Energy Innovation":

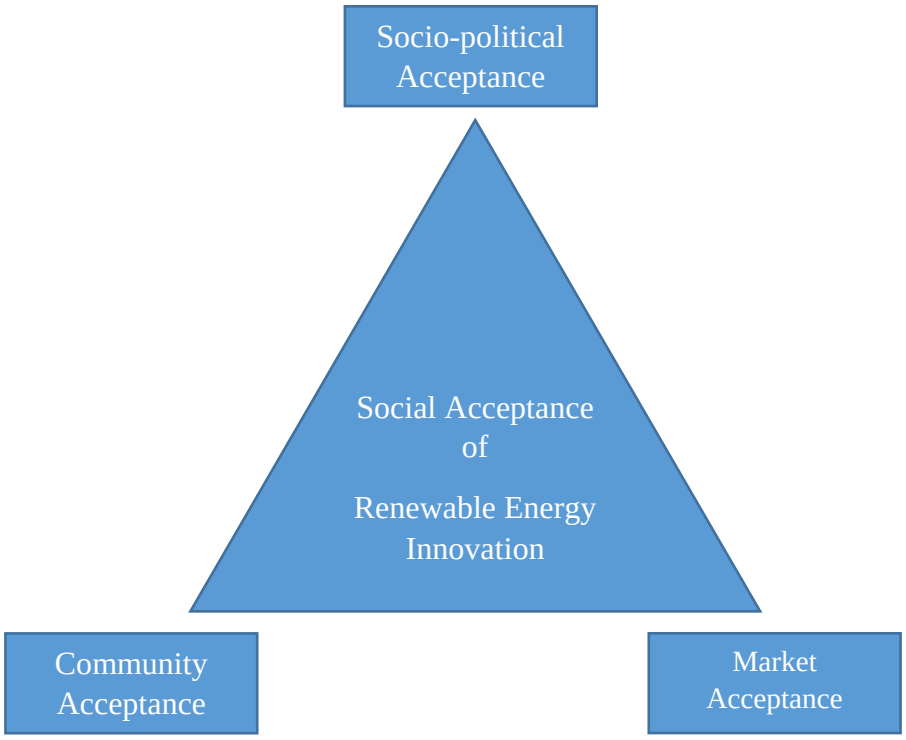

Figure 5: The Triangle of Social Acceptance of Renewable Energy Innovation (56)

1. Socio-Political Acceptance:
   Social-Political Acceptance refers to social and public acceptance on the most extensive and broad level which include both policies (such as tax reform) and technologies (such as new technologies). This acceptance is related to the "key stakeholders" such as "energy experts" and "policy makers".

2. Community Acceptance:
   Community Acceptance is refer to the acceptance of Renewable Energy projects by the local stakeholders particularly the residents who are the potential users. Here is the area which the NIMBY is discussed and barriers for implementation of local Renewable Energy Technology appears. This acceptance related to the "trust" and other criteria between local stakeholders and policy makers.

3. Market Acceptance:
   Market Acceptance refers the Renewable Energy Technology acceptance by the different market players and also, adoption process of new Renewable Energy Technology. One aspect is related to consumers which are needed to get an opportunity to switch to the reliable and affordable Renewable Energy. The other aspect of Market Acceptance is not just focused on the consumers, but also consider the investors who are providing budget for the energy infrastructure developers (41,50,56).

2.3.2. Social Acceptance Aspects

After consideration of Social Acceptance Dimensions, the important part to cover is Social Acceptance Aspects, which refers to different aspect which have influence on Social Acceptance of Renewable Energy Systems, specifically the Solar Thermal Energy. There are several studies which have focused on Social Acceptance Aspects of Renewable Energy. These studies show that apart from Social Acceptance Dimensions, Social Acceptance Aspects are important (4,6,17,18). However, there is no exact boundary and classification for these aspects, but they could be divided in four main groups which are:

1. Social Aspect
   This aspect is focused on the criteria and terms such as "Awareness" and "Quality of Life" which have direct influence on different stakeholder's support for Renewable Energy Technology developments. The main criteria which should be considered in Social Aspect which have influence on "Social Acceptance" and "Adaption" of the "Solar Thermal Energy Systems" and mostly any new Energy Systems are: "Knowledge and Awareness", "Impact on Quality of Life", "Participation of different Stakeholders", "Impact on Landscape and Visual View".

2. Technological Aspect
   The Technological Aspect is mainly related to the design and technological features of Renewable Energy Technologies. Although, technical criteria is mainly important for the energy experts, but usual users and citizens looking for some specific criteria such as "Safety" and "Ease of Use (User-friendliness)". However, other criteria such as "Available Radiation" and "Storage System" are the other important technical aspects which have influence on "Social Acceptance" of "Solar Thermal Energy Systems", but they have not been involved in the survey as an individual criteria. It should be mentioned that in interviews there are more focus on these criteria. The main Technological criteria which

have been considered in this research are: “Safety”, “Ease of Use”, “Efficiency”, “Innovativeness” and “Period of Work”.

3. Economic Aspect
   The Economic Aspect is consist of several criteria such as “Pay Back period”, “Affordability” and “Investment per amount of output energy” which cover different economic criteria such as “Turn Over”. It should be mentioned, however, in different stakeholder’s point of view these criteria could be changed, the criteria which have been mentioned are from the end-user point of view. The main criteria which have been considered are: “Payback Time”, “Budget”, “Influence on Energy Bills”, “Subsidies” and “Economic Development (Job Creation)”.

4. Environmental Aspect
   This aspect is related to general environmental aspect of energy consumption such as “CO2 emission”. This aspect is mainly important for the policy makers and energy experts which care about future. Also, the other criteria from other aspects such as “Awareness” have strong impact on the importance of this aspect. Also, the materials which are using for designing and development of these systems have an impact on Environment after disposal of these systems. The main 2 criteria which have been considered in this group are: “Environmental Impact” and “Use of Recyclable Materials”.

2.4. Technological Aspect

Due to have a reliable Energy System, there are different criteria which should be considered. These criteria have influence on the Energy System Design. The most important criteria which should be considered is “Available Solar Radiation” which have a direct influence on the system design. Because all the system is based on the amount of energy which system can produce. Which this Energy Production is based on the available energy which is Solar Irradiation and Radiation for Solar Systems. As Figure 6 show, the average Solar Radiation in the Netherlands is 1025 kWh/m^2 (10,48,55).

Figure 6: Solar Radiation in the Netherlands (48)

As previously discussed, although, the Solar Radiation in Europe and specifically in the Netherlands is not so high, with a proper system design this available energy could be used for Electricity and Heat production (47,55,56).

The "Solar Radiation" have influence on the "Collector" which is one of the one of the most important part of the Solar Thermal Energy Systems. The "Collector" is the part of the system which transfer the available energy from "Solar Radiation" to the liquid. Collector efficiency and other criteria have a direct impact on the system design. There are different types of Solar Collectors for domestic usage such as: Flat Plate, Vacuum Tubes, Pool Collector and PVT which due to Technical Feasibility and Financial Feasibility the collector should be designed and chosen (10,54,55).

The Storage System is the other important part of the system which have a great influence on the System Design. Due to Energy Demand and Collector Energy Production the Storage System could be designed. Efficiency of all these different parts are important and "Efficiency" of whole system is an important criteria which should be considered. Also, it should be mentioned "Climate" variables such as "Wind Speed" and "Ambient Temperature" should be considered for system design (54,55,57).

2.5. Environment Aspect

Internationally, there has been an urgent of concerns regarding to the environmental issues due to increasing emission of air pollutants. One of the most important aspect of energy consumption is Environmental issues such as acid rain, air pollution, ozone depletion, and climate change, which are the main derivers for switching to the Renewable Energies (18). Based on fossil fuel consumption, one of the output is CO2 which is one of the main causes of the Climate Change. However, energy sector of all nations around the world depends primarily on fossil fuels. Nevertheless, due to Kyoto agreement they have to reduce their CO2 emission and switch to non-polluting energy sources. Despite international agreements, such as the Kyoto agreement, during the last decade, greenhouse gas emissions have increased by about 1% per year (38). To reduce the emission of CO2 in Europe, the European Commission has formulated the target of reducing carbon emissions by between 80% and 95% by 2050 compared with 1990 levels. Also, for the building sector specifically this target is 60% worldwide. Regarding to these goals, the installation of Renewable Energy and Energy Efficient systems have been discussed widely. (14,25,28)

However, the Netherlands with 17 million people is a small country but it's among the 25 countries worldwide with the largest CO2 emission annually. Based on EU targets and regulation for reduce CO2 emission among the member state, Dutch government have made policies to tackle this problem. 30% greenhouse gas emission reduction in 2020 with as base year 1990 is the target that Dutch government want to achieve. (25,38)

One of the main causes for this reduction in CO2 emission is the contribution of Renewable Energy systems. The total net electricity production from renewable energy sources in 2013 in the Netherlands was equal to 11,849 million kWh. When converted, this figure represents the annual electricity consumption of 3.4 million households. The total heat production from renewable energy sources and green gas (such as biogas) in 2013 is equal to the natural gas use of 647,000 households. The avoided annual amount of CO2 emissions is equivalent to the emission of 2.6 million petrol cars (33,34).

Buildings and households play one of the key roles in the European target for CO2 reduction. The household energy consumption contributes to the global greenhouse gas emission. For instance, as it mentioned before the households in the Netherlands are responsible for 30% of total energy consumption and consequently greenhouse gas emission. (35,38)

2.6. Economic Aspect

The Economic aspect of the Renewable Energy Technology, and mostly Solar Thermal Energy is so important for development and installation of these systems. As it mentioned in part 2.3.2. (and also in 2.6. Energy Security), Economic aspect could have several factors which are important for different stakeholders. For instance, on the end-user/ household's point of view the most important financial factor might be the pay-back period. On the other hand, for policy makers the price of Carbon Emissions could be an important criterion which has influence on the policies that support the Renewable Energy Technologies developments. (4,9,11)

In current research, the economic part is not only related to the Renewable Energy investments and costs (End-User/ Household) but also, the other relevant economic terms which have an

influence will be considered. In general, apart from costs, investment and payback period which are more important for end-user, the development of the Renewable Energies depends on four important economic factors which are (6,9,11,15,18,35):

- The trend in prices of Fossil Fuels
- The price of Carbon Emissions
- Reductions in the Renewable Energy Technology's costs
- Cost of other alternative solutions such as Carbon Capture

All these factors are important for the energy experts and they could have an impact on Social Acceptance and development of different Renewable Energy Technologies. For instance, it seems if the Carbon Emission's price will increase, the development of Renewable Energy Technologies will be more cost-effective and attract more attention as an alternative system. Nonetheless, the investment and cost of Renewable Energies are still the main important economic criteria which is considered by people who want to install these systems for their own good. The statistics show that the cost of different Renewable Energy have been fallen, but the Renewable Energy will only become cost-effective in the long term (28,35,45).

Furthermore, it should be considered from societal perspective, the market invests too little on "Energy Saving and "Renewable Energy" Technologies in buildings. The main reasons for this are the limited information that users have, and the 'split incentive' in the rental sector: landlords have too little incentive to invest in "Energy Efficiency" and "Renewable Energy" Technologies if the benefits accrue primarily to the tenant in the form of lower energy bills. (21,45)

2.7. Energy Security

It's simplistic to not count Energy Security as one of the most import factures which have influence on the developments of Renewable Energy sources in the world. However, this factor has important impact on the policy making and governmental level of the energy sector, but also, have a huge influence on the local level and social acceptance of the new technologies. (19)

Energy Security is a complex concept which includes several aspects such as security of supply, security of demand, affordability issues and geopolitical considerations associated with security and defense policy, energy poverty and other economic and political issues. Also, the Acceptance of the Energy Source is another aspect of the Energy Security which should not be forget. Security of supply could be defined as reliable access of customers to the primary energy resources at the reasonable cost. The energy consumer needs energy to be available in the exact time with the certain amount which is needed. On the other hand, from the producer perspective, the most important issue is the maintenance of the energy demand which is Security of Demand. Security of Demand is the major problem for the energy producers and exporters (19,21,26,45).

Due to address all these issues there are several questions which should be answered. The most important questions which should be answered in energy security discussions are:

- Security for whom?
  This question basically related to show that the person, company or country which is

going to be secured are related to which part of the energy sector such as supplier or consumer.

- Security for which values?
  This question is trying to find out about the value which is needed to be protected. For instance, is it the affordability or acceptability of a specific source of energy needed to be scurried.

- From what threats?
  This question is referring to the factor that is threating the value which is needed to be secured. For example, the energy affordability might be insecure because of fluctuations in the Energy Source prices (8).

As it mentioned, answering these questions is related to the position and point of view of the respondent. The Energy Supplier, Energy Consumer and other stakeholders have different benefits and interests which have influence on their point of view about Energy Security. Due to answering these questions which are the most important questions in Energy Security point of view, there is a need to understand different aspect of Energy Security which are known as Four A's:

1. Availability
2. Affordability
3. Accessibility
4. Acceptability

As these main aspect of Energy Security show, the Acceptability (Social Acceptance is one of the terms of Acceptability) and Affordability (Economic Aspect is one of the Affordability) are two important terms of Energy Security (19).

In the EU, since early 2000s because of political and economic crises the Energy Security has gained more credited and importance in political agenda. Besides of global competition for energy resources, Russian and Syria conflicts which cause European countries such as Ukraine to access to the not affordable sources, also energy market issues encourage the EU to focus more on the Energy Security. However, in all EU policy documents the most important energy security aspect which discussed is Security of Supply. This point of view is mainly because of consumption role of EU in Energy sector around the world. But the Netherlands due to natural gas export, have experienced both producer and consumer role in the EU (2,19,26).

The Netherlands has been a major European Natural Gas producer and exporter for many decades. Since the 1950s, Natural Gas exploration and exploitation has been a major focus of the Dutch Energy Policy. However, during last 8 years, this country have faced challenges to deal with the decline of resources. Whiten the next 10-15 years up to 2030, the Netherland will be unable to supply gas demand for national usage and will become a net gas importer. The studies shows that the role of the Netherlands on the European gas market is about to change. There are studies about the transition from gas-exporting role to the gas-transit country. Due to these points an alternative secure Energy Source (Heating Energy Source also) is important for the Netherlands's future. The discussions mostly focus on Renewable Energy Technologies as a suitable alternative (3,17,21,25,44,48).

As it presented, the four A's is the fundamental of Energy Security. The Acceptance of the energy resources for the consumers and energy users is among the four important part of Energy Security. It seems, the most import challenge in energy sector which Dutch government like other nations around the world is going to face is, accessing to affordable, high quality and acceptable energy resources. Although, the fossil fuel have environmental problems, but natural gas still count as a reliable national energy resource for the Netherlands coming years. Based on the Energy Policies of Dutch government and EU commission regulation, discussions about the future of energy in the Netherlands tend to focus either on pro-gas or pro-renewable energy. (25,45)

2.8. Conclusion

As it discussed broadly in the Literature Review, Social Acceptance of Renewable Energy Systems, specifically Solar Thermal Energy Systems, have different aspects related to different stakeholders which makes the subject complicated. Criteria which influence the Social Acceptance and Design of Systems are so divers but its necessary and crucial to consider all different aspects to achieve a reliable conclusion. Figure 7 represent the abstract of several aspects which should be considered.

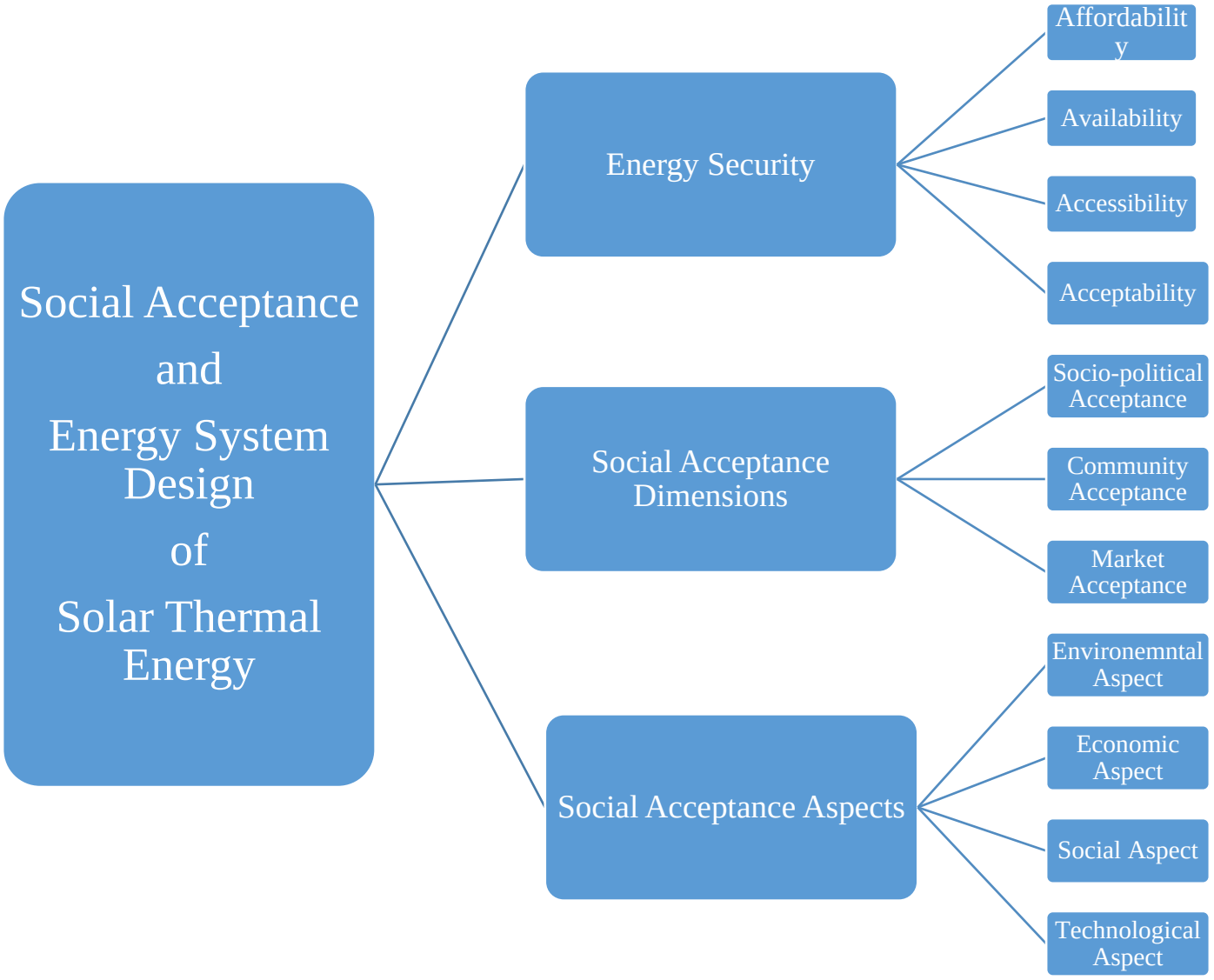

Figure 7: Literature Abstract

Due to all these different aspect which have mentioned, the main criteria and factors which will be considered in these research can be listed as below:

Table 3: Criteria for this Research

Criteria	
Social	Awareness & Knowledge
	Impact on Quality of Life
	Participation of Different Stakeholders
	Impact on Landscape and Visual View
Environmental	Environmental Impact
	Use of Recyclable Materials
Economic	Payback Time
	Budget
	Influence on Energy Bills
	Subsidies
	Economic Development
Technological	Safety
	Efficiency
	Ease of Use
	Innovativeness
	Period of Work
Energy Policy and Energy Security	Governmental Support
	Energy Security
	Independency on Fossil Fuel

Chapter 3: Research Design

Research design is defined as a strategy to answer research question or to test research hypothesis (53). This chapter will describe several activities to answer the research questions.

3.1. Research Framework

Research framework, based on Vershuren and Doorewaard (2010), means schematic presentation of the research objective. It includes step by step activities to achieve research objective. Research framework consists of seven steps as seen as follow:

Step 1: Characterizing briefly the objective of the research project

The aim of this research is study and analyze the main criteria which have strong impact on the Social Acceptance and Energy System Design of Solar Thermal Energy Systems in the Netherlands and also, assess the level of importance of these criteria on Social Acceptance. Last step is to assess the importance of new system design on Social Acceptance in the Netherlands and recommend proper Solar Thermal Energy System Design.

Step 2: Determining the research object

The research object for is the Netherlands in general. The focus will be on the different stakeholders and energy experts such as: Dutch government, policy makers, academic institutes and also, citizens and businesses.

Step 3: Establishing the nature of research perspective

The research aims to consider and monitor different stakeholders who could have a strong influence related to Solar Thermal Systems usage and acceptance in the Netherlands, such as businesses, academic institute, municipalities, Dutch government, civil society and home owners.

Step 4: Determining the sources of the research perspective

The research uses scientific literature, survey and interviews to have a better understanding on the Social Acceptance of Solar Thermal Energy and the factors that could influence it. Furthermore, due to have a better understanding about Energy System Design procedure and process, the Solar Thermal Energy System will be studied and the Social and Technological factors that have impact on it will be considered.

Step 5: Making a schematic presentation of the research framework:

The Figure 8 present the Research Framework schematic:

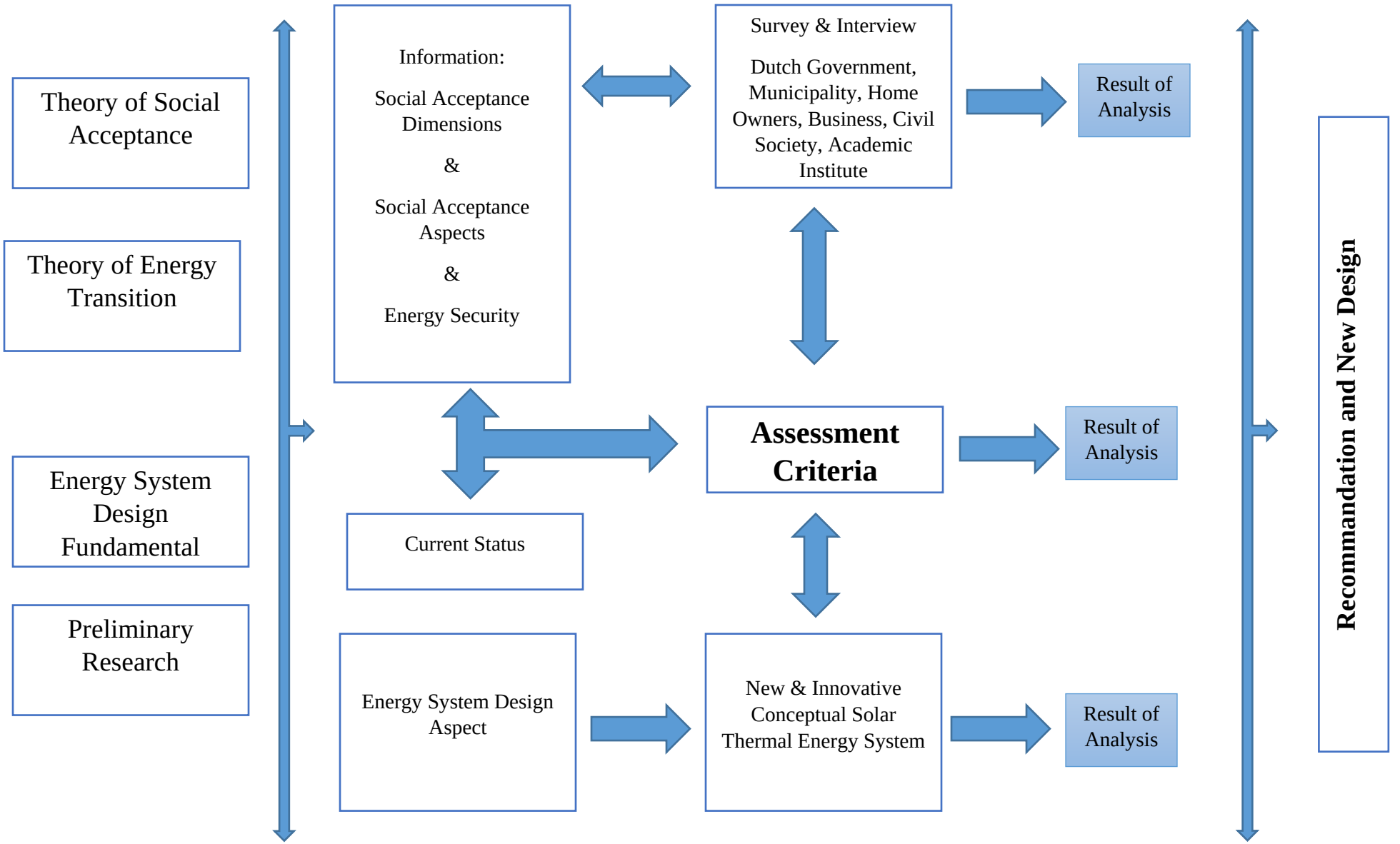

Figure 8: Schematic presentation of the Research Framework

Step 6: Formulating the research framework in the form of arguments which are elaborated:

- Analysis of Theories and Literature of Energy Transition, Social Acceptance and Thermal Design, also, preliminary research about Renewable Energy and promoting acceptance among key actor groups
- Working on the Research Objectives based on the first step
- confronting the result of analysis as the basis of recommendations
- Recommendations with regard to solve the problem

Step 7: Checking whether the model requires any change:

There is no indication at this stage that any change is required.

3.2. Research Questions

Based on research objectives and due to research framework, the following research questions have been defined and during the study will be consider and explore to be answered:

The main Research Question in this study is:

What are the main criteria which have strong influence on the Social Acceptance and Energy System Design of Solar Thermal Energy in the Netherlands for the households?

Due to answer this question, there are several sub question are defined as below:

1. What is the current status of Solar Thermal Energy production and consumption in the Netherlands?
   1.1. What are the main barriers for Solar Thermal Energy System adaption for Households?

2. What are the main criteria which could have an influence on Social Acceptance of Solar Thermal Energy Systems?
   2.1. What is the level of importance of different criteria for influencing Social Acceptance of Solar Thermal Energy in the Netherlands?

3. Does Innovative System Designs could have an influence on Social Acceptance of Solar Thermal Energy systems?
   3.1. With regard to Social Acceptance and consideration of criteria which have strong influence on the Solar Thermal Energy System Design, what System could be designed and recommended?

3.3. Defining Key Concepts

The important and relevant key concept for this study have been presented in this part:

Social Acceptance

As in mention in the literature review part 2.3., for this research the Social Acceptance will be define:

1. There is support for the technology among the expert community and national and local policy-makers;
2. The general public has an informed and largely positive view of the technology;
3. Concrete applications do not meet significant obstacles from local policymakers, residents, the NGO community or other representatives of social interests and
4. When the opportunity arises, ordinary people are willing and prepared to adopt the applications in their own contexts and to support them with positive actions.

In conclusion, "The positive supporting act by different stakeholders due to implementation and adaption of Renewable Energy (Solar Thermal) initiatives" is called Social Acceptance of Renewable Energy Systems.

Energy Transition

Due to the importance of Energy Transition for this research which is the main cause of existing of this research, it should be defined. There are several definition for Energy Transition. Based on Verbong G. & Loorbach D. (2012), two main important definition that fit to this research are presented below:

1. Large-scale transformations within society or important subsystems during which the structure of the societal system fundamentally changes".
2. The shift of the (socio-technical) energy system running on fossil fuels, towards a reorganized (socio-technical) energy system that runs on renewables.

Energy System Design

Energy System Design could be define as an act of defining, calculating, modeling and designing a system which is concluded certain input, output and process (7).

3.4. Research Strategy

The research will be a critical assessment and analysis for the Social Acceptance of Solar Thermal Energy and in the Netherlands. There huge effort to generate data and ….

3.4.1. Research Unit

The Research Units for this study is the Netherlands energy sector, different stakeholders and Renewable Energy systems (specifically Solar Thermal Energy systems).

3.4.2. Research Unit Selection

In this research, the research unit will be the Netherlands Energy Sector, different Stakeholders and Solar thermal Energy systems. All stakeholders which have a strong influence on Social Acceptance of Solar Thermal Energy in all different levels will be considered. For instance, municipalities, citizens, businesses and academic institutes could be important stakeholders which should be considered. As a result, all the criteria which have an impact will be defined and the importance of them will be assessed. The Zwolle, Leeuwarden, Eindhoven and Enschede are the cities which the survey will be done.

3.4.3. Research Boundary

In order to determine and manage the limitations of study, a research boundary is established. In this sense, the objective of the study can be attained within the specified time. The Survey will be done in the Netherlands with emphasis on Friesland Province.

3.5. Research Materials and accessing method

Based on Verschuren G. & Doorewaard D. (2010), Research Materials means "Defining and describing the main key concepts and criteria of Research Questions and Research Objectives". Due to answer the Research Questions and Research Objectives related data and information (materials) are required. In this part, the materials and the way to access them for this study have been discussed.

There are several data and information sources which are going to use and also there are different methods to accessing the information. The most important method is document and media analysis which will be involve the articles, books and literature addressing the Research Objectives and subjects related to the Research Questions. This includes energy reports, EU documents, Dutch government policies, academic articles and technical books. This would help to have reliable information which based on, different criteria and sub subjects would be find out.

Also, the interviews will be held with different position holders. In depth interviews could provide valuable information related to the subject which could not be rich in document analysis. The main position that are going to be interviewed during the research have been listed below:

1. Dutch Government
2. Municipality (the possible one is municipality of Leeuwarden)
3. Companies and Businesses (Ekwadraat)
4. Academic Institute (University of Twente and University of Delft)
5. NGOs

These positions are related to different stakeholders which have influence on the subject and contacting and making appointment with them have been started. For instance, the Municipality of Leeuwarden and Ekwadraat Company show positive reaction. These interviews will provide

information from different expert's point of views which will provide data and information that could not be found in the documents.

Furthermore, for assessing citizen's data, there would be a survey and questionnaire in different cities and provinces of the Netherlands such as Leeuwarden (Friesland), Eindhoven (North Brabant), Zwolle and Enschede (Overijssel). Based on this questionnaires the criteria which are the most important for the people could be found out. It is important to mention all of the participants in Survey and Interviews will be informed properly about the research purpose and how the results will be published.

The required data and the accessing methods in this study due to answer each Research Question and Research Objective have been shown in Table 4:

Table 4: Required data and Accessing Methods

Main Research Question	Sub Research Questions	Required Data/ Information	Sources of Data	Accessing the Data
What are the main criteria which have strong influence on the Social Acceptance and Energy System Design of Solar Thermal Energy in the Netherla	What is the current status of Solar Thermal Energy production and consumption in the Netherlands? What are the main barriers for Solar Thermal Energy Systems adaption for Households?	Information related to the current situation, policies, regulations, plans, stakeholders and history of Solar Thermal Energy developments Barriers, Advantages and Disadvantages of Solar Thermal Energy Development for the Netherlands Energy Production and Consumption	Secondary Data **Documents and Media**	Content Analysis and Research Methods
			Secondary Data **Literature**	Content Analysis and Research Methods
			Primary Data **People: Energy Experts**	Questioning: Face to Face Interview
	What are the main criteria which could have an influence on Social Acceptance?	Finding and Assessing different important criteria	Secondary Data **Documents**	Content Analysis and Research Methods
			Secondary Data **Literature**	Content Analysis and Research Methods
			Primary Data **People: Energy Experts**	Questioning: Face to Face Interview
	What is the level of importance of different criteria on Social Acceptance of Solar Thermal Energy in the Netherlands?	Assessing the level of importance of different Criteria	Primary Data **People: Citizens**	Questioning: Survey/ Questionnaire
			Primary Data **People: Energy Experts**	Questioning: Face to Face Interview
	Does Innovative System Designs could have an influence on Social Acceptance?	Innovative Solar Thermal Energy System Design Criteria that have influence, Barriers and Solutions	Primary Data **People: Citizens**	Questioning: Survey/ Questionnaire
			Primary Data **People: Energy Experts**	Questioning: Face to Face Interview
			Secondary Data **Literature**	Content Analysis and Research Methods
	How New Solar Thermal Energy system design could		Primary Data **People: Energy Experts**	Questioning: Face to Face Interview

nds for the households?	influence the Social Acceptance?	Assessing the importance of Design in public and expert's opinion	Secondary Data **Literature**	Content Analysis and Research Methods
	With regard to Social Acceptance and consideration of criteria which have strong influence on the Energy System Design, what System could be designed and recommended?	Innovative Solar Energy System Design, Solar radiation calculation, Conceptual Thermodynamic Design	Primary Data **People: Energy Experts**	Questioning: Face to Face Interview
			Secondary Data **Literature**	Content Analysis and Research Methods
			Primary Data **Brain Storming and Design**	Thermodynamic Design

Figure 9 will summaries the Research Questions, Research Sources and Accessing Methods.

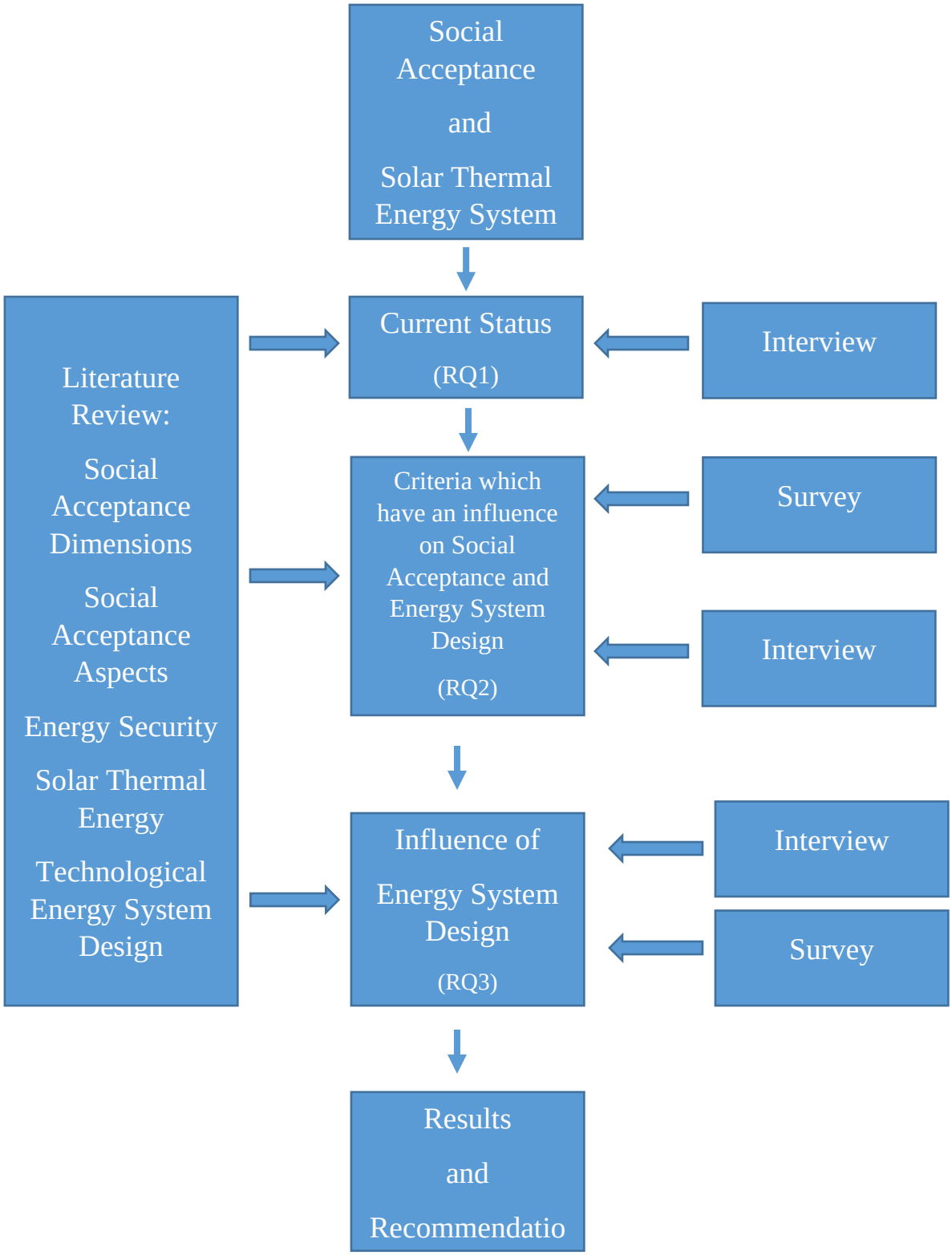

Figure 9: Research Questions, Research Sources and Accessing Methods

3.6. Data Analysis

Data analysis is one of the most important part of any research and study. Based on this analysis the conclusion and recommendation will be provided. Data analysis refers to the data evaluation process due to logical and analytical framework which is presented below:

3.6.1. Methods of Data Analysis

Among different methods of Data Analysis, this study use the Quantitative and Qualitative analysis methods which will develop the better understanding about the subject and research objective. (53)

At first the data collection and analysis of qualitative will be done. Document, Media and Literature analysis due to find the current status and important criteria will be done in this part. Next step is quantitative analysis which is related to find out the level of importance of different criteria on the Social Acceptance and Energy System Design of Solar Thermal Energy Systems in the Netherlands.

Table 5: Methods of Data Analysis

Data/Information Required to Answer the Question	Method of Analysis
Information related to the current situation, policies, regulations, plans, stakeholders and history of Solar Thermal Energy developments Barriers, Advantages and Disadvantages of Solar Thermal Energy Development for the Netherlands Energy Production and Consumption	**Qualitative**: Analyzing the Current Status and Developments of Renewable Energy Systems (specifically the Solar Thermal Energy) in the Netherlands **Qualitative**: Analyzing different Stakeholders related to Renewable Energy Systems (specifically the Solar Thermal Energy) in the Netherlands
Finding and Assessing different important criteria	**Qualitative**: Analyzing the criteria which have strong influence on Social Acceptance and Energy System Design of Renewable Energy Systems (specifically the Solar Thermal Energy) in the Netherlands
Assessing the level of importance of different Criteria	**Quantitative**: Analyzing the level of importance of different criteria
Innovative Solar Thermal Energy System Design Criteria that have influence, Barriers and Solutions	**Qualitative**: Analyzing the Solar Thermal Energy System Design in the Netherlands **Qualitative**: Analyzing the different criteria that have influence, Energy System Design
Assessing the importance of Design in public and expert's opinion	**Quantitative**: Analyzing the level of importance of Energy System Design on Renewable Energy Systems (specifically the Solar Thermal Energy) in the Netherlands
Innovative Solar Energy System Design, Solar radiation calculation, Conceptual Thermodynamic Design	**Qualitative**: Analyzing the Energy System Design and Innovation in Solar Thermal Energy

3.6.2. Validation of Data Analysis

Based on two different ways of Data Analysis for this study, which are Qualitative and Quantitative analysis, there are two way to validate the Data Analysis.

First, due to avoid bias and errors in Qualitative part validation of data analysis, the triangulation technique will be done by comparing the results with the theories and other research findings which have been reviewed during the research. The second part is related to carrying out with using of different methods and sources to find the data of research. Also, accuracy measure instrument will be sued for Quantitative part validation of data analysis.

3.6.3. Analytical Framework

The figure below is a schematic presentation of analytical framework which is going to be done for this research:

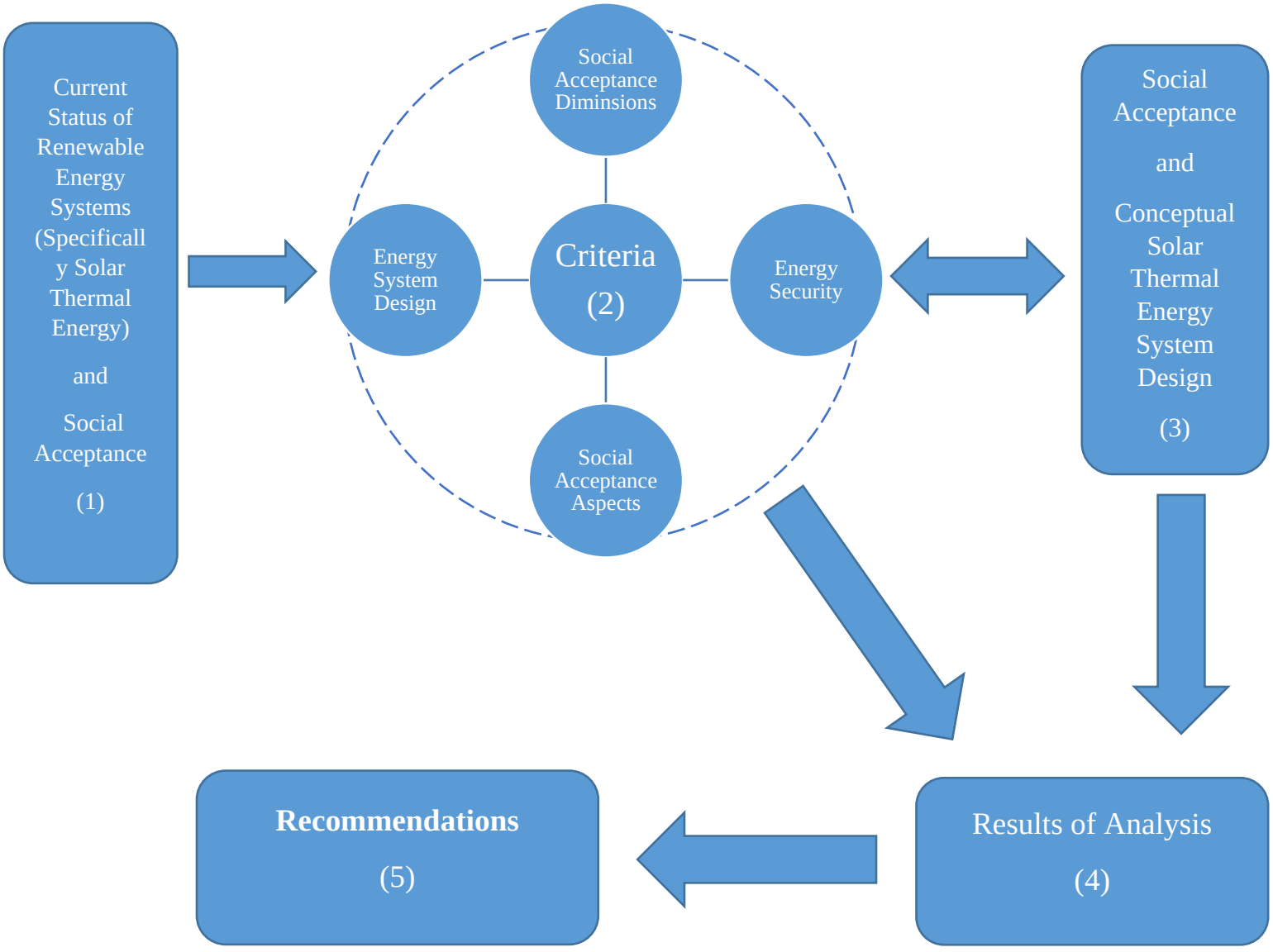

Figure 10: Analytical Framework Schematic

The Data Analysis will be done in following steps:

1. Review the Current Status of Renewable Energy Technologies in the Netherlands with emphasis on Solar Thermal Energy Systems due to answer Research Question 1.

2. Analyses the Social Acceptance Dimension, Social Acceptance Aspects, Energy Security and Energy System Design Criteria, level of importance and their influence due to answer Question 2.

3. The results from previous steps will be applied for this step. Also, the Energy System Design concept will be used due to answer question 3.

4. This step will highlight and analyze the results of Step 2 and 3 and also, provide results of Social Acceptance

5. The results from step 4 will be used for propose the recommendations due to improve Social Acceptance of Solar Thermal Energy in the Netherlands and due to this point improve the Solar Thermal Energy systems Design

Chapter 4: Data Analysis and Results

As one of the aims of this research is to investigate the perception by citizens and also other important stakeholders and/or professionals, two complementary approaches have been used: Survey (Quantitative) and Interview (Qualitative) approaches. In this chapter, the data and analysis based on this two method will be presented.

4.1. Survey Analysis

The quantitative data-collection method took the form of a questionnaire-based survey due to gather information from households and people who live in the Netherlands. There are different kinds of questions which have used in the Survey such as Open Questions, Multiple choice and Scaling (Likert Scale). The survey consist of 5 main different parts. Questions in First part are for gathering "Personal and Basic Information" of participant which have 8 questions. The last question in Part One and questions in Part two are related to understanding the current status of "Energy Consumption and Energy Knowledge" of households which part two have 5 question . Next part, The Third Part of the survey with 7 different questions is to find out the general status and opinion of households about "Solar Thermal Energy Systems. The Part Four which is the main part of this survey is consist of 19 questions which are referring to the criteria that have found in the literature and are going to be studied in this research. These questions and criteria could be rated by using the Likert scale Table 6 shows the relationship between the Survey's questions and Criteria. At last, in Part Five there are two open questions to find out the most important criteria and make sure any information that respondents wanted to add, could indeed be added.

The Likert scale was implemented as follows:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Table 6: Survey's Questions related to Criteria

Criteria		Related Question in Survey	
		Part	Question Number
Social	Awareness & Knowledge	Part2	3,4
		Part3	1
		Part4	1
	Impact on Quality of Life	Part4	2
	Participation of Different Stakeholders	Part4	3
	Impact on Landscape and Visual View	Part4	15
Environmental	Environmental Impact	Part4	4
	Use of Recyclable Materials	Part4	5
Economic	Payback Time	Part4	6
	Budget	Part4	7
	Influence on Energy Bills	Part4	8
	Subsidies	Part4	18
	Economic Development	Part4	9
Technological	Safety	Part4	10
	Efficiency	Part4	13
	Ease of Use	Part4	11
	Innovativeness	Part4	12
	Period of Work	Part4	14
Energy Policy and Energy Security	Governmental Support	Part4	16
	Energy Security	Part2	5
		Part3	3
		Part4	17
	Independency on Fossil Fuel	Part4	19

As it mentioned there are some criteria such as “Technical Feasibility” which is related to the “Available Radiation (Climate Status)” and “Available Technologies” have not been considered separately in this survey. There are open questions to understand the importance of these criteria which cannot be measured (and also, understand the knowledge of participant about them) such as Question 4 in Part3 or last question which there are some participants who mention these criteria. In the results part these information will be presented.

Also, it should be mentioned the survey have been published online in English through Social Networks which might have influence on the respondents who have been participate in this survey. Because the participants are not only people who has access to social media but also they have to answer in English which some people might not feel confident to do. As it mentioned, this characteristics might limit the sample.

4.1.1. Sample Description

Survey have 48 participant in total of whom 27 were Male (56.25%) and 21 Female (43.75%). The age among participants was so various which is shown in Figure 11. The most participants was between 25 until 34 (17 persons, 35.42%).

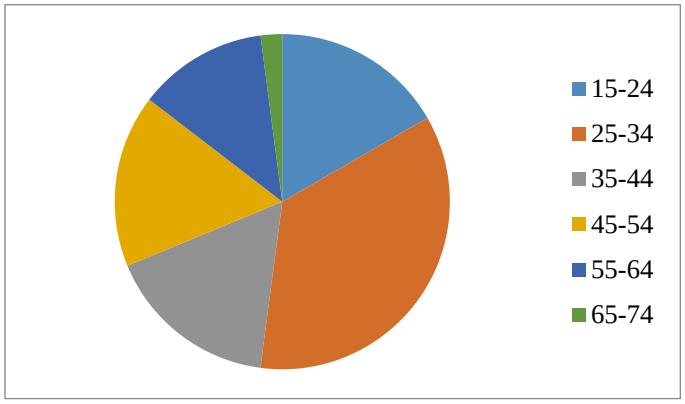

Figure 11: Age of Respondents

Regarding the "Employment Status", 81.25% of participants are employed. Although, participants were from different province in the Netherlands, Friesland with 21 participant (43.75%) has the most. Information regarding to participant from different provinces have been presented in the Figure 12.

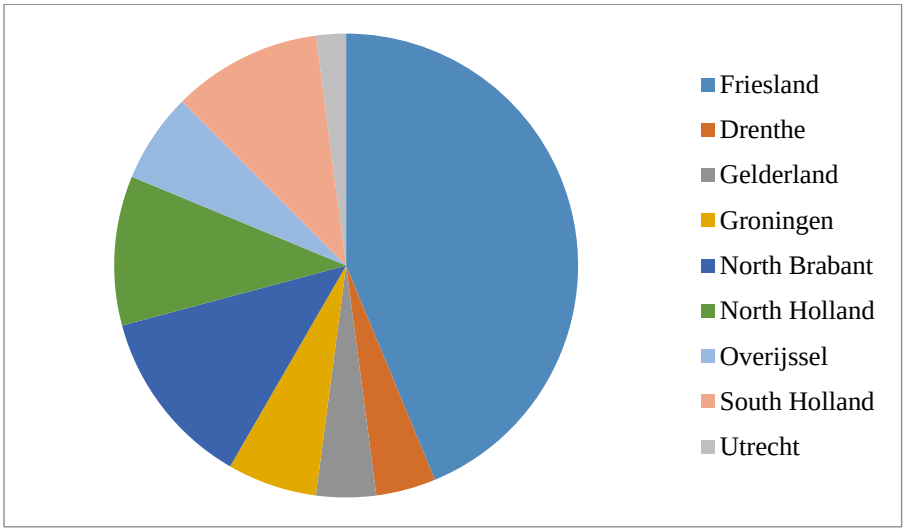

Figure 12: Province of Respondents

The "Type of Accommodation" of most of participants is "Own the House" (64.58%). Next type is "Renting House from Housing Agency" (18.75%) and at last is "Renting House from Private Sector" with 16.67% share of participants. Figure below present these information:

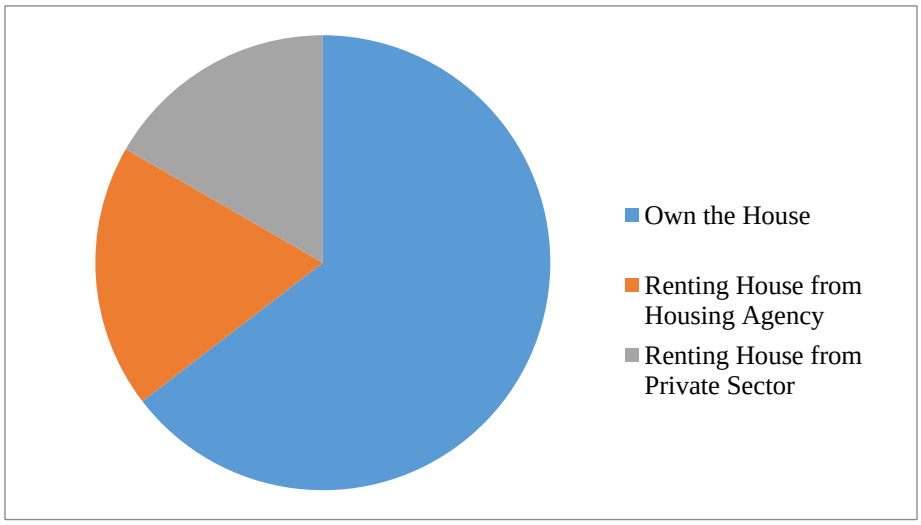

Figure 13: Type of Accommodation

In terms of "Completed Education", the highest percentage is HBO/Bachelor with 45.83% percent. The next biggest part is Master (31.25%). With a considerable difference, PhD with 12.50% share is the third which followed by MBO (8.33%). High School with 2.08% share is the last category. Most of the participants are living "With Family" (58.33%). Living "Alone" and living in a "Share House" with equally 20.83% are following "Status of Living". "Marital Status" of most of the participants are "Single" (54.17%). The information related to the "Marital Status" of the participants have been presented in Figure 14.

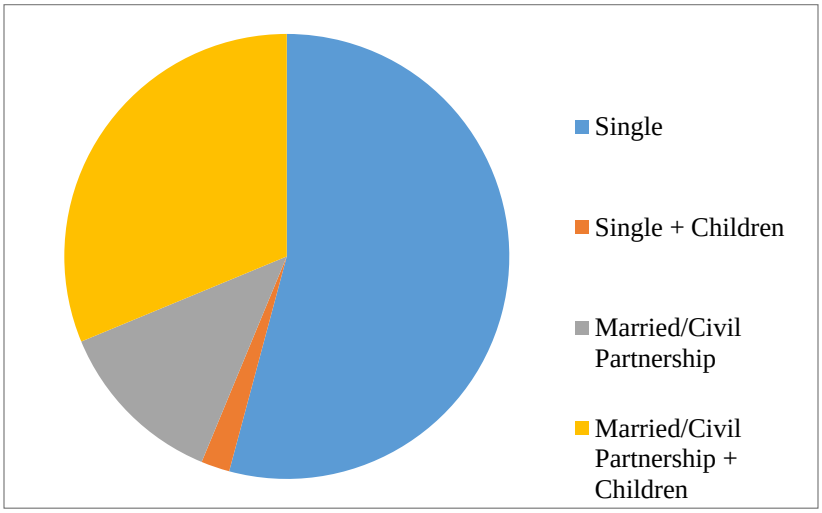

Figure 14: Marital Status of Respondents

4.1.2. Survey Results

As survey divided in 5 different part and due to "Sample Description" which have shown the information from first part of the survey, the Survey Results will be presented in four part.

4.1.2.1. Energy Basics and Knowledge

In this part which is consist of last question of part one and all five questions of part two, general information related to the knowledge about the energy and energy consumption have been asked.

Among participants, 39.58% have been using at least one kind of Renewable Energy Technologies in their house. Table 7 show the information about the each "Renewable Energy Technology" which is using by participants.

Table 7: Usage of Renewable Energy Technologies among Respondents

Do you use any kind of Renewable Energy Technology in your house?	**Number**	**Percentage**	What Kind	Number	Percentage
Yes	19	39.58%	Solar PV	13	59.1%
			Solar Collector	4	18.18%
			Indirect from Supplier	2	9.1%
			Insulation	1	4.5%
			Wind Turbine	1	4.5%
			Heat Pump	1	4.5%
No	29	60.42%			
Total	**48**	**100.00%**		**22**	**100%**

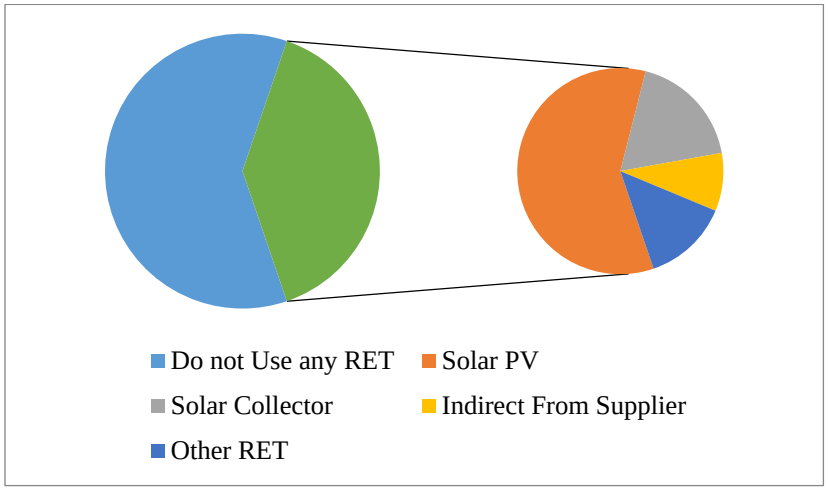

Figure 15: Usage of Any kind of Renewable Energy Technologies

As Table 7 shows, less than 40% of respondent use any kind of Renewable Energy Technologies in their houses. Also, it shows that in general Solar Energy have the most adoption among participants. In specific, Solar PV systems with 59.1% share have the first place among people who have installed any kind of Renewable Energy Technology in their house. Furthermore, it should be mentioned among 19 person who are using RET in their house and there are 22 different RET systems which are being used by them which shows some of them are using more than just one RET system.

Also, the respondent provide information about their awareness about the "Dutch Government National target of 14% Renewable Energy Production share in 2020" and "EU and International targets about CO2 emission reduction". As Figure 16 and Figure 17 present, 81.25% are aware of the "National Targets of RE production" and 91.67% are aware of "CO2 emission reduction targets" which shows "Awareness" about "International Environmental Targets" are more than 10 percent higher than "National Energy Targets".

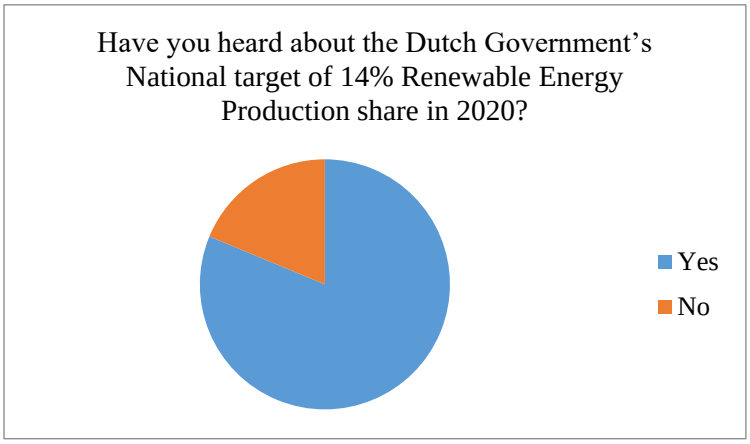

Figure 16: Awareness about Renewable Energy Target

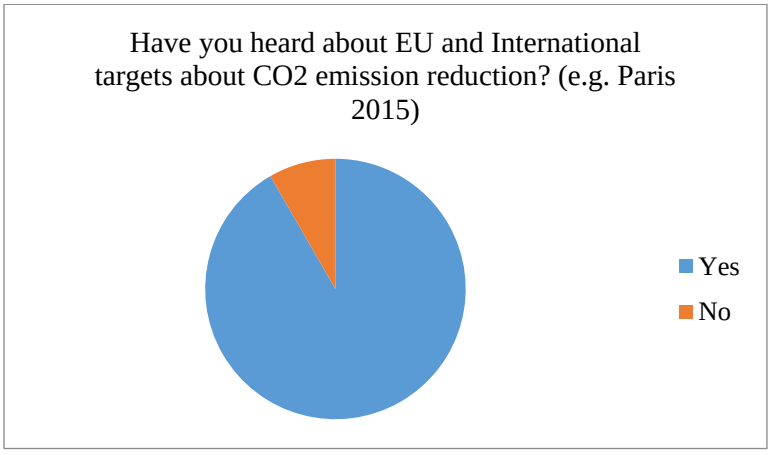

Figure 17: Awareness about CO2 Targets

In the question 3 of part 2, current Energy Source for Heating for house which have been using by participant are indicated. Also, as Table 8 shows, there are more 83.3% who are using only one source of energy and 16.7% are using combination of different sources (for instance, they use both Wood Stove and Natural Gas). Among 48 respondents there are 56 different energy source and systems which are using and among these sources, Natural Gas with 75% is the most common Energy Source for heating the houses. Using Electricity (from Grid) as an Energy Source is the second popular way for Heating the houses and after that Solar Energy (Both PV and Collectors) and Biomass (Wood Stove) are the next. It should be mentioned that there are 3.6% of the participants who are using only electricity as their main Energy Source of Heating in their Houses. "District Heating" is another Heating Energy Source which is using by respondents.

Table 8: Current Heating Energy Source

What is your current Heating Energy Source and System in House?	Gas	RET (Solar)	RET (Wood)	Electricity (from Grid)	District Heating	Total	Percentage
Only one Source	37	0	0	2	1	40	**83.3%**
Combine Source	5	4	3	4	0	8	**16.7%**
Total	**42**	**4**	**3**	**6**	**1**	**56Systems**	**100%**
Percentage	**75%**	**7.14%**	**5.36%**	**10.71%**	**1.79%**	**100%**	

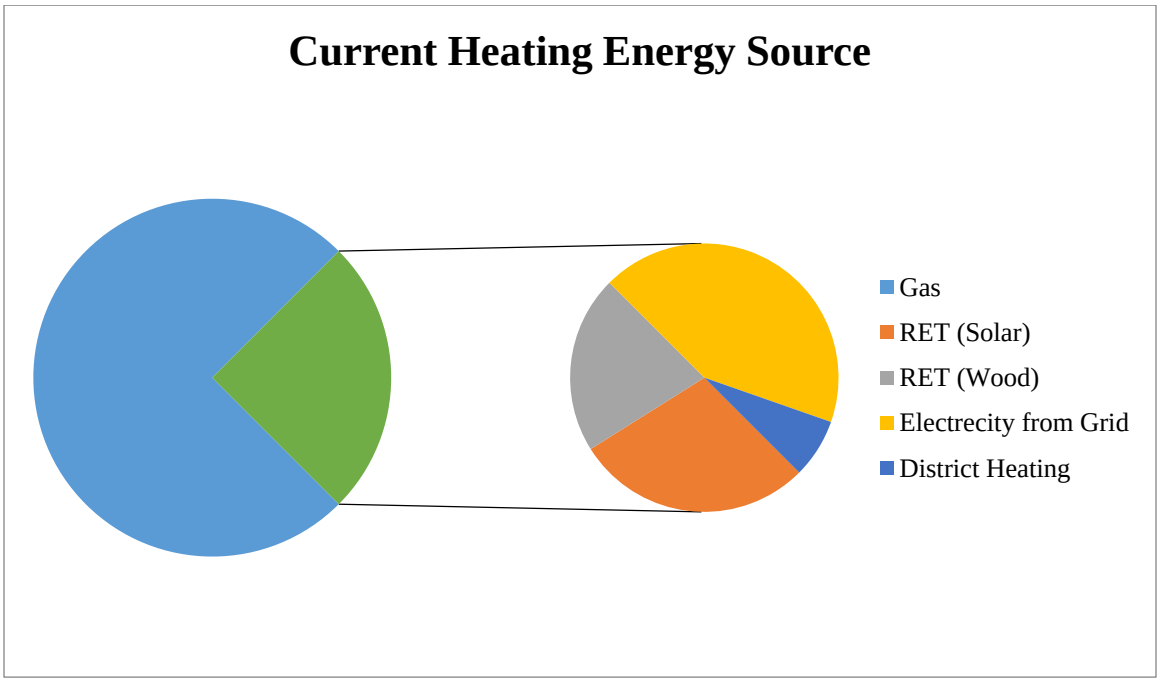

Figure 18: Current Heating Energy Source

Furthermore, in this part participants indicate their overall Natural Gas usage during the year. As Table 9 shows, 64.58% of participants know how much gas they use during the year which includes

8.32% of respondent who do not use any gas in their house. These 8.32% are people who are living without any Gas Consumption in their house and their Heating Energy Source is Electricity, District Heating and RET sources (For instance Wood Stove and Solar PV). On the other hand, there are 35.43% who do not know how much gas do they use in their house (including 2.1% who have not answered the question). The average Gas consumption of people who have Gas usage in their house is 1556.5 m3/year which is due to average consumption of 1500 m3/year is reasonable.

Table 9: Current Gas Consumption

How much gas (m3/year) do you use in your house per year approximately?			**Number**	**Percentage**	**Average**
Respond	Know about the amount	Gas Usage	27	56.25%	Average Consumption of people who use Gas: 1556.5
		No Gas Usage	4	8.32%	
	Do not Know about the amount		16	33.33%	
No Respond			1	2.1%	
Total			**48**	**100%**	

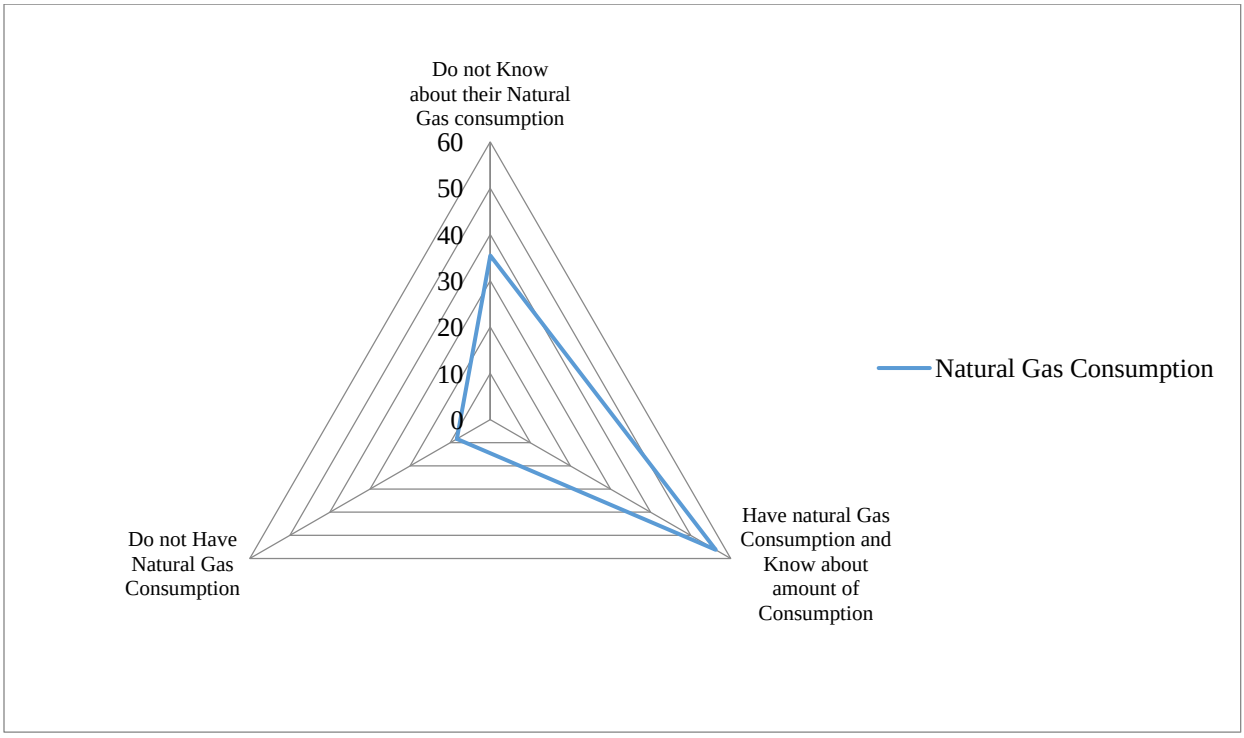

Figure 19: "Awareness" about Current Gas Consumption Aggregation

The last information in part 2 is related to the question with three different parts which ask people about three important aspect of the their energy source: Affordability, Availability and Fossil Fuel base. This question have been designed based on Likert scale and the maximum score which each of these criteria could achieve is 240 point (due to 48 participants). Table 10 present information about regarding for these three criteria.

Table 10: Aspects of Current Energy Source

Level of Agreement	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agreement (4)	Strongly Agree (5)	Value	Average Value
Energy is always affordable	1	3	12	19	13	**184**	**3.83**
Energy is always available	1	4	5	13	25	**201**	**4.19**
Energy is mostly from Fossil Fuels sources.	4	7	13	17	7	**160**	**3.33**

Participants are mostly agree on the availability of the current energy source with average score of 4.19. People scored affordability 3.83 in average which is slightly lower than availability criteria. Also, people ranked Energy Source based on Fossil Fuels 3.33 which is lightly higher than being Neutral in average. Figure 20 shows the information separately for each criteria based on scale in total value.

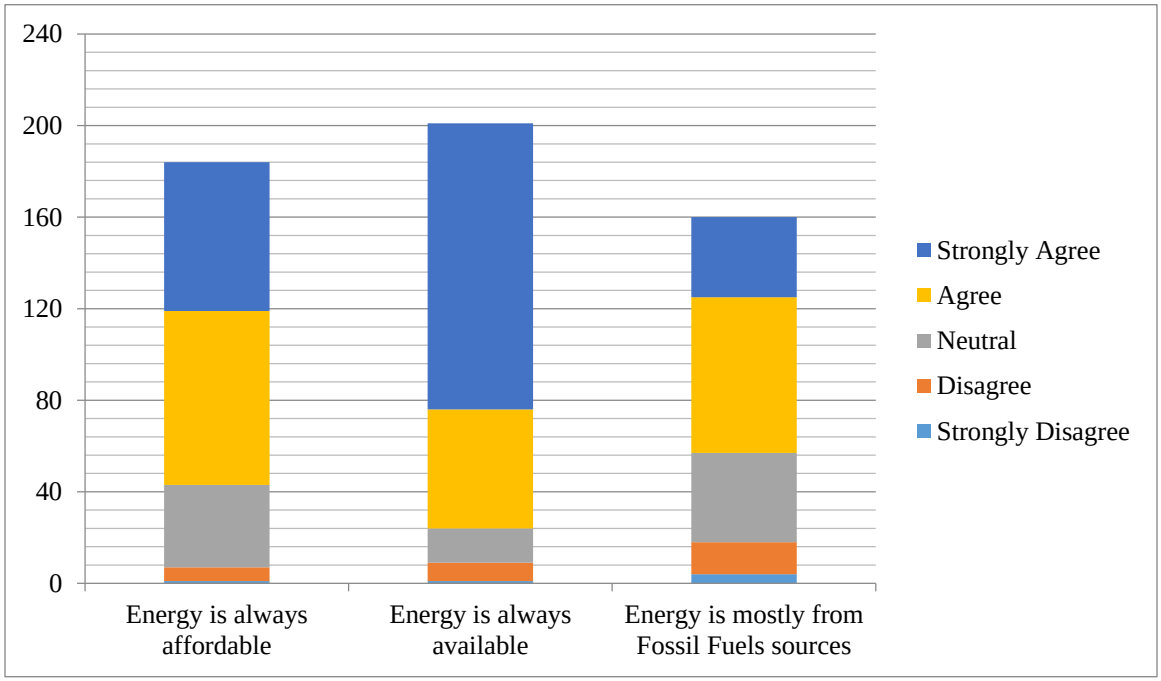

Figure 20:Energy Security of Current Energy Source

The criteria which most of the participants (52.1%) are Strongly Agree with is Availability of the Energy Source. However, for only 15,56% of participants are Strongly Agree that their Energy Source is based on Fossil Fuels.

4.1.2.2. Solar Thermal Energy

In this part the questions are related to the awareness, willingness and general information about "Solar Thermal Energy Systems". 72.92% of participant are familiar with "Domestic Solar Thermal Energy Systems" and 16.67% of respondents are already using these systems in their houses. Figure 21 and Figure 22 show these information:

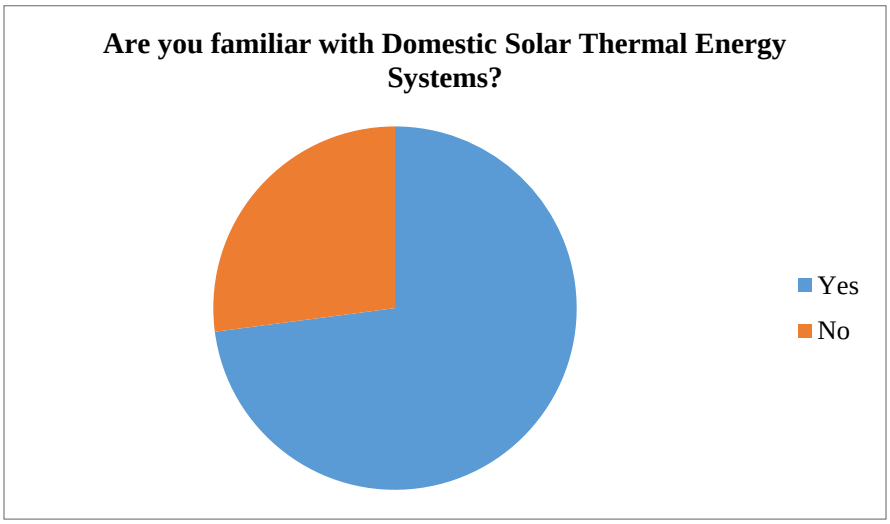

Figure 21: Familiarity with "Domestic Solar Thermal Energy Systems"

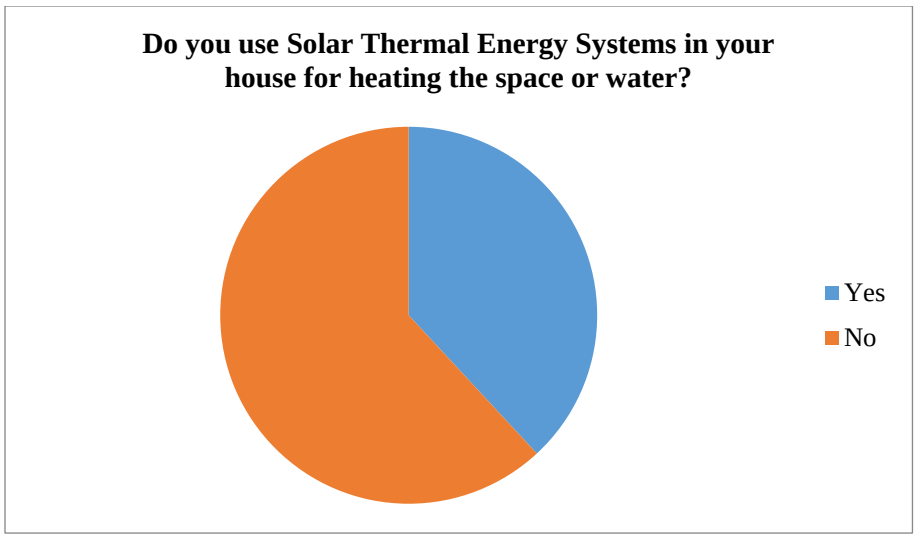

Figure 22: Usage of "Solar Thermal Energy Systems"

General idea (89.58%) among participants about Solar Thermal Energy Systems is they believe it can be a suitable alternative energy source for heating houses in the Netherlands. On the other hand, only 10.42% of respondent do not believe that Solar Thermal Energy Systems could not be a suitable alternative for reduction of Fossil Fuels which is using for heating the houses.

As it mentioned in in the Literature Review, Solar Thermal Energy production have only 1% share of RET energy production in the Netherlands. The most important individual barriers can be ranked:

1. System is so expensive. (26.5%)
2. There is no knowledge among Families and Companies (who are energy advisers of households for their energy systems). (20.5%)
3. Due to the Netherlands's climate and geography, the Radiation is Low for using these systems. (14.5 %)

These three barriers together consist more than 60 percent (61.5%) of the barriers which have been mentioned in this part of Survey. In more detail the barriers could be divided in four main categories: Financial, Technical, Social and Political. Participants indicated the most important category for this low usage of these systems is firstly Financial Barriers. Table 11 present the information for this part:

Table 11: Causes for Low usage of "Solar Thermal Energy Systems"

Why do you think that Solar Thermal Energy has not adopted by Households in the Netherlands?	Number	Barrier	Number	Percentage
It's Expensive	22	Financial Barriers	**33**	**39.76%**
Gas is Cheap	7			
General Financial issues	4			
Low Radiation	12	Technical Barriers	**23**	**27.71%**
Other Technical Issues	2			
Complexity	4			
Peak days	1			
Place to implant the system (Collector and Storage)	4			
Knowledge and awareness in companies and Families	17	Social Barriers	**20**	**24.10%**
no feeling of urgency	1			
not attractive	2			
Due to old houses, it's not good for the Netherlands	1	Political Barriers	**6**	**7.23%**
No attention of media and government	2			
it's not compulsory	1			

Fossil Fuels are more interesting for Government	1			
No offer form other side (companies, municipalities and etc.)	1			
In general, other RETs are better	1	Other Barriers	**1**	**1.2%**
Total		**83**		**100.00%**

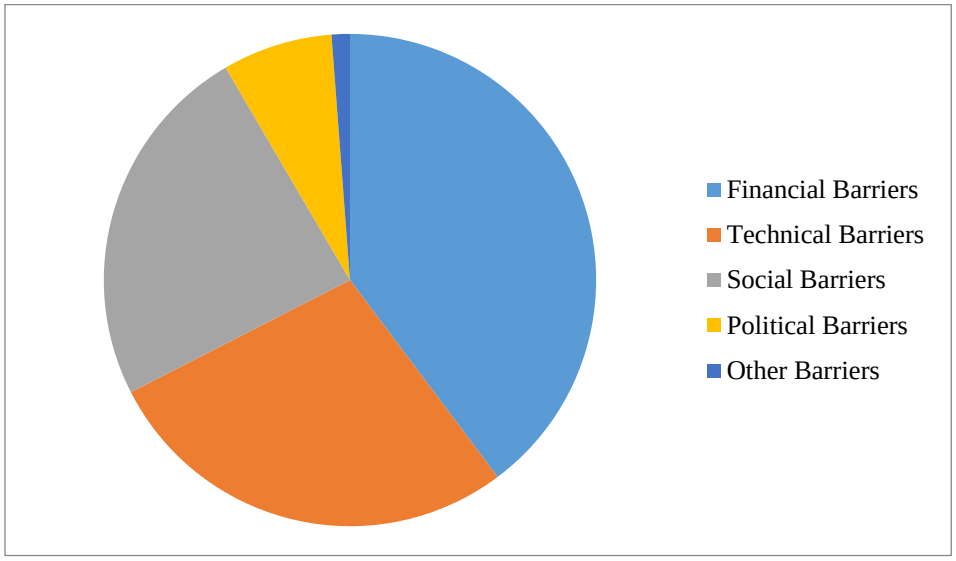

Figure 23: Causes for Low Usage of "Solar Thermal Energy Systems"

Most of these barriers which have mentioned by respondents in this part, will be discussed further in "Criteria" part in more detail. The most important point which should be mentioned is all these barriers and issues are related to each other and have a connection together.

Based on first part of the survey, which asked about the "Type of the Accommodation" and due to have a better understanding about the "Solar Thermal Energy Systems" situation, motivation and barriers, there are focus and questions which are addressing "House Owners" and "Tenants" separately.

Among House owners, 64.86% wish to invest on the Solar Thermal Energy Systems in their houses and their main motivation is Environmental Issues. On the other hand, 35.14% of house owners due to several barriers such as “Problems with their house (age, space & etc.)” do not wish to install these systems in their houses. Table 12 present these information in more detail:

Table 12: House Owner’s opinion about "Solar Thermal Energy Systems"

Do you wish to invest and install the “Solar Thermal Energy Systems” in your house?	Number	Percentage	Motivation	Number	Percentage	Barriers	Number	Percentage
Yes	24	64.86%	Financial Benefits	4	15.38%			
			National Responsibility	3	11.54%			
			Fun and Life style	1	3.85%			
			Environmental Issues	18	69.23%			
No	13	35.14%				Lack of Knowledge	3	18.75%
						Problems with House	5	31.25%
						Prefer to invest in other RETs	3	18.75%
						Financial Issues	4	25%
						General Feasibility	1	6.25%
Total	**37**	**100%**	**26**			**16**		

As the Motivation for the House Owners who wish to install the system is mainly one Motivation, “Environmental Issues” (69.23%), the barriers among House Owners to do not install these systems are various which shows that the problem is complex and depends on different criteria and issues.

Among Tenants the results are totally different. Only 4.76% of Tenants live in a house which have these systems and only 16.67% of Landlord wish to install these systems in their rented houses. The important point from analyzing the House Owners information is their interest in investment on these systems, however, when they are renting their house, they lose their motivation to install Solar Thermal Systems. The table below shows the information:

Table 13: Landlord's opinion about "Solar Thermal Energy Systems"

If your landlord has not installed or indicated an intention to install "Solar Thermal Energy Systems" have you approached him/her?	Number	Percentage	If YES, please indicate the respond after asking your landlord	Number	Percentage
Yes	6	28.57%	Positive	1	16.67%
			Not Interested	5	83.33%
			Prepared to Install Solar Thermal Energy Systems	0	0%
No	15	71.43%			
Total	**21**	**100%**			

The other critical point which have been considered in this research is the difference of installation of "Solar Thermal Energy Systems" in renting houses. 71.43% of participants demonstrate that installation of these systems is counting as an advantage for the house which they wish to rent. Figure 24 present this information.

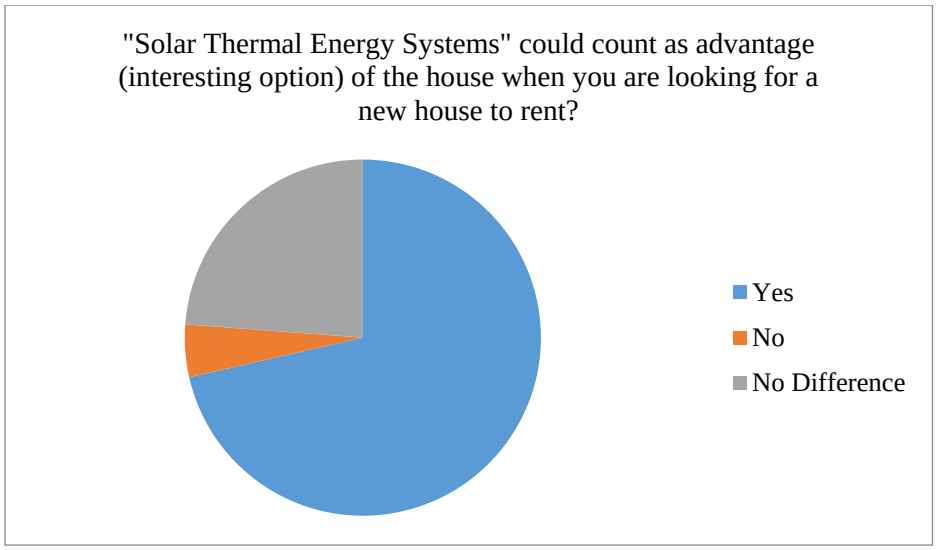

Figure 24: Tenant's opinion about "Solar Thermal Energy Systems"

4.1.2.3. Criteria

As it mentioned in chapter 3, this part of the survey is the most important part of the survey which is developed for indication of the "Level of Importance" of different criteria which have influence on the acceptance and adoption of "Solar Thermal Energy Systems" by Households. Table 14, shows all the criteria and their Likert Score. This Likert score is a measure of how important the respondents find the criteria in question. The table shows that on average the respondents are agree with the importance level of criteria derived from literature no less than 3. Respondents score the criteria "Impact on Landscape and Visual View" of these systems lowest and on the other hand, score criteria "Environmental Impact" and "Independency of Fossil Fuels" highest.

Table 14: Overview of all the Criteria due to correspondent's Likert Scores

Criteria		Likert Score
Social	Awareness & Knowledge	4.04
	Impact on Quality of Life	3.81
	Participation of Different Stakeholders	3.33
	Impact on Landscape and Visual View	3.08
Environmental	Environmental Impact	4.27
	Use of Recyclable Materials	3.73
Economic	Payback Time	4.17
	Budget	4.21
	Influence on Energy Bills	4.13
	Subsidies	3.85
	Economic Development (Job Creation)	3.42
Technological	Safety	3.69
	Efficiency	4.17
	Ease of Use	3.92
	Innovativeness	3.29
	Period of Work	4.02
Energy Policy and Energy Security	Governmental Support	3.73
	Energy Security	4.1
	Independency on Fossil Fuel	4.23

Although, there are some Criteria which score as Neutral (Three in Likert Score), but in average all nineteen criteria Likert score is 3.85 which shows that in general respondent are "Agree" with the Importance of these "Criteria" and their influence on "Social Acceptance" of "Solar Thermal Energy Systems". Among five category which criteria have been divided to and studied based on them, the "Energy Policy and Energy Security" and "Environmental" categories score highest. (4.02 and 4.00). Figures 25,26,27,28 & 29 show each category score:

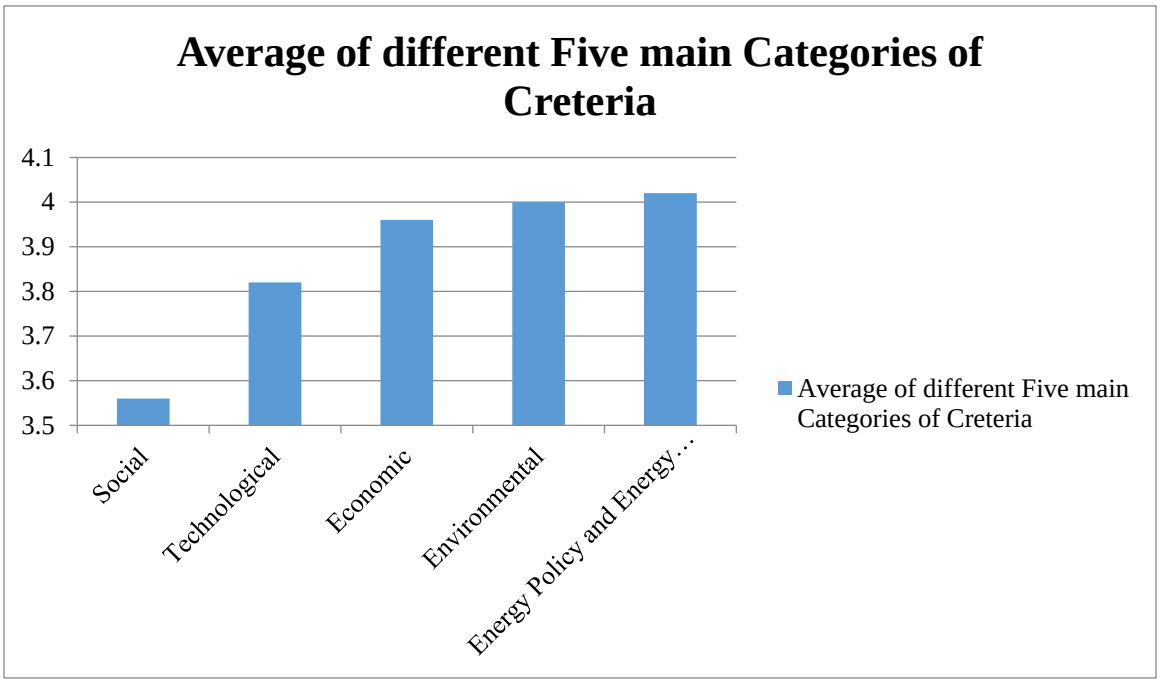

Figure 25: Average of Different Categories

As this Figure show, the Social category with average 3.56 score is on fifth place. However, in this category the "Awareness and Knowledge" criteria is scored 4.04. Due to go in more detail, the graphs below show the different Likert Scores for five categories, "Social", "Economic", "Technological", "Environmental" and "Policy and Security". For "Social" the most important criteria is "Awareness and Knowledge" (4.04) which is generally is among ten most important criteria too. Furthermore, "Impact on Landscape and Visual View" is scored as least important social criteria (and also among all criteria).

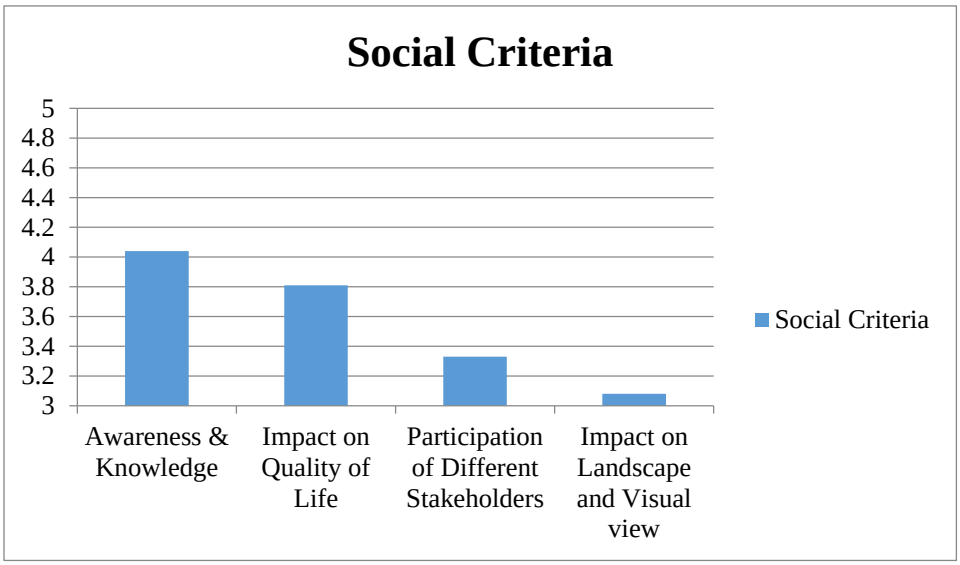

Figure 26: Survey Results for Social Criteria

For "Environmental" criteria, the "Environmental Impact" is scored as the most important criteria among all criteria (4.27). The other "Environmental" criteria, "Use of Recyclable Materials" is ranked as thirteenth.

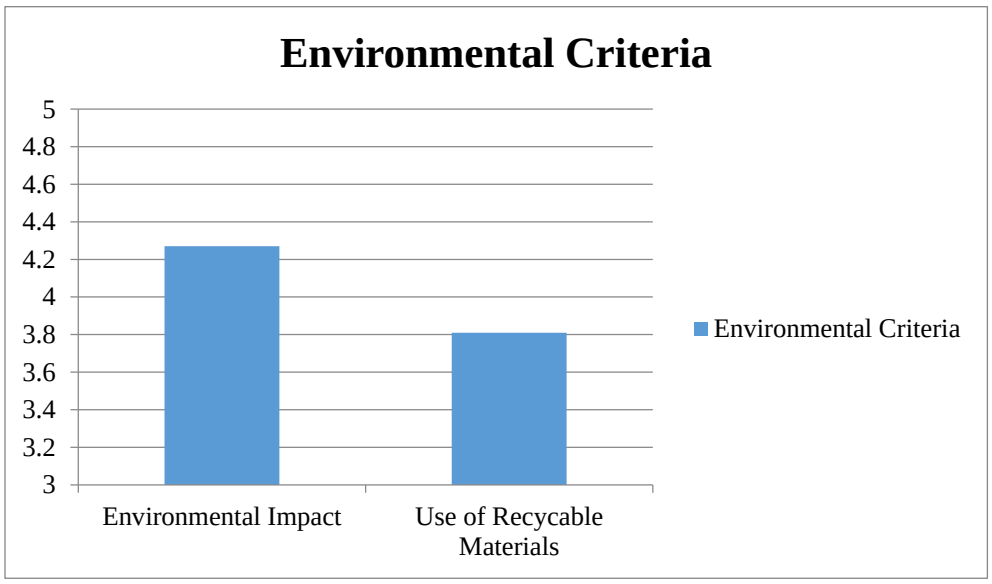

Figure 27: Survey Results for Environmental Criteria

The results for "Economic" criteria have a deviation in how participants score the "Level of Importance" in different criteria, where "Budget" and "Payback Time" are in top of 4 most important criteria and "Economic Development (Job Creation)" is among 4 least important.

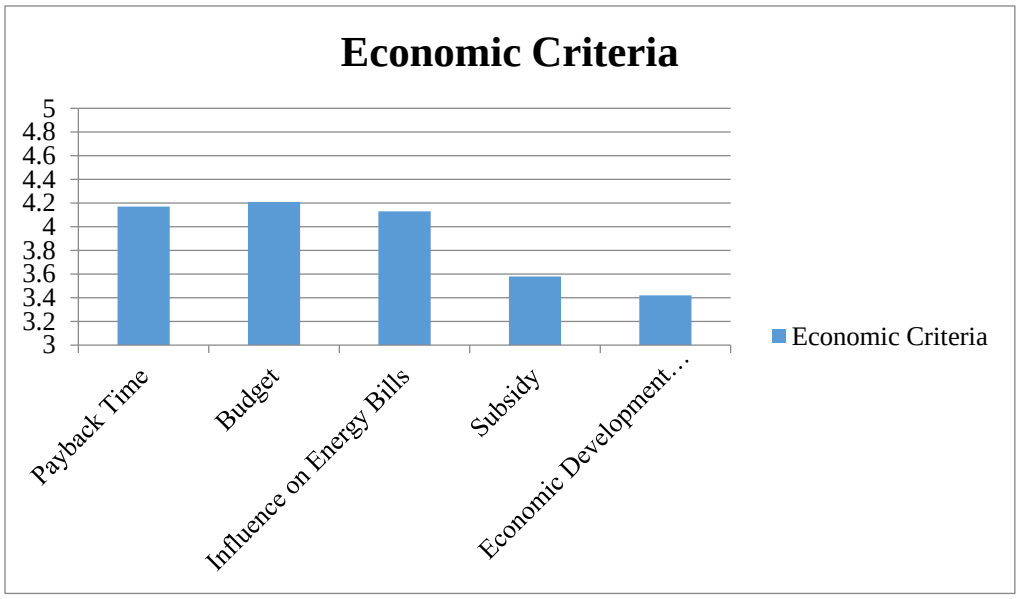

Figure 28: Survey Results for Economic Criteria

"Technological" criteria scored very various, where "Efficiency" of the system is the among 4 most important criteria (4.17) and "Innovativeness" with 3.29 score is the second least important criteria in general.

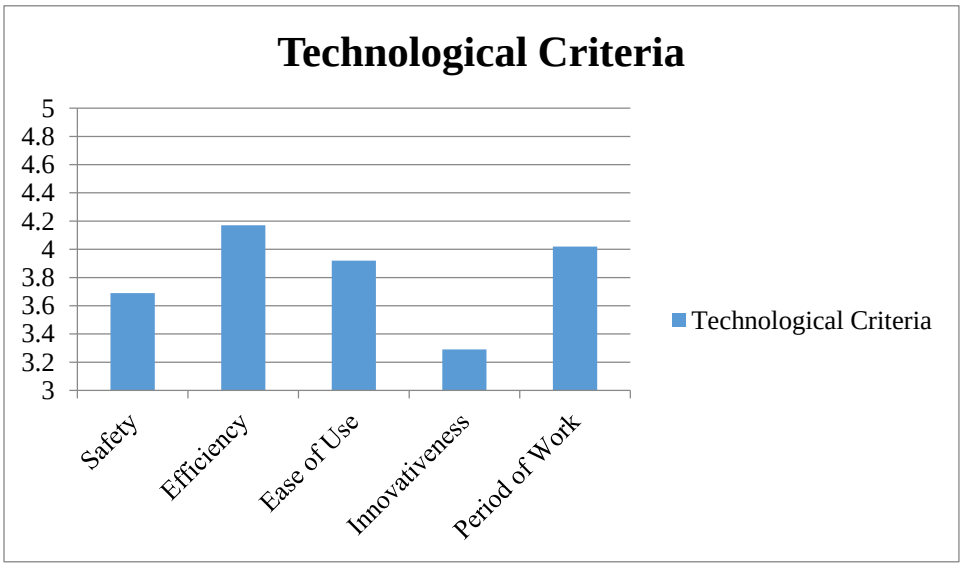

Figure 29: Survey Results for Technological Criteria

For "Energy Policy & Energy Security" criteria, the scores are diverse. For instance, "Independency on Fossil Fuel with 4.23 score, is the second most important criteria which shows

the high importance of this criteria among participants, however, "Governmental Support" scored 3.73 (Thirteenth).

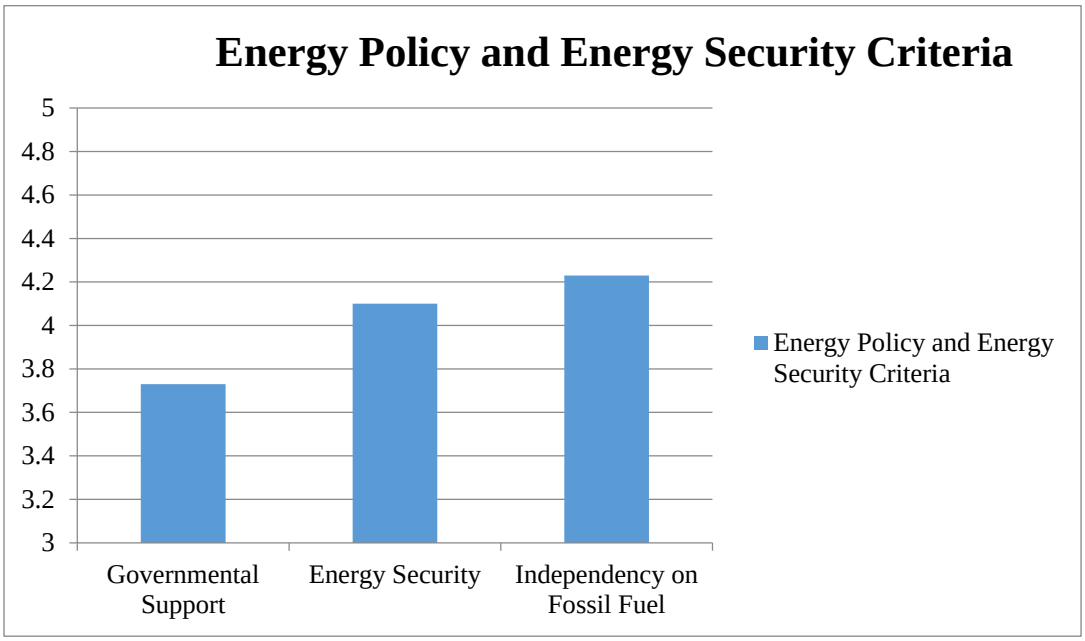

Figure 30: Survey Results for Energy Policy and Energy Security Criteria

According to Table 14 and Figures 26,27,28,29 & 30, the five most important criteria in general which have been scored by participants are:

1. Environmental Impact (4.27)
2. Independency on Fossil Fuel (4.23)
3. Budget (4.21)
4. Efficiency (4.17)
5. Payback Time (4.17)

However, these are the most important criteria, but there are other criteria such as "Impact on Energy Bills" (4.13), which are following these five criteria with small difference. This might be based on the sample's size which cause the not enough discrimination between some criteria. Due to having a better understanding about these criteria and their level of importance for Households, Table 15 and Figure 31 show the information about each criteria in more detail:

Table 15: Correspondent's Likert Scores in detail for all Criteria

Aspect/ Factor "SunThermal" = "Solar Thermal Energy Systems"	Not Important at all (1)	Not Important (2)	Neutral (3)	Important (4)	Very Important (5)	Total	Average	Level of Importance
1. Increased Awareness about Energy Consumption	1	3	8	17	19	**194**	**4.04**	**8**
2. Positive impact on User's Quality of Life	2	5	7	20	14	**183**	**3.81**	**12**
3. Participation of Different Stakeholders from different levels in implementation (e.g. Companies, Municipalities)	3	6	17	14	8	**160**	**3.33**	**17**
4. Positive Environmental impact (e.g. Reduction of CO2 Emission)	2	1	3	18	24	**205**	**4.27**	**1**
5. Recyclable materials usage in design and production	1	5	14	14	14	**179**	**3.73**	**13**
6. Payback Time (Investment Return)	1	2	6	18	21	**200**	**4.17**	**4**
7. The Investment (Initial Budget) for installation	1		5	25	17	**202**	**4.21**	**3**
8. Influence on Energy Bills Reduction	2	2	6	16	22	**198**	**4.13**	**6**
9. Job creation (on both Local and National Level)	3	6	11	22	6	**164**	**3.42**	**16**
10. Safety of "SunThermal" for users and facilities	4	4	8	19	13	**177**	**3.69**	**15**
11. Understandability of the system for households and people	2	3	9	18	16	**188**	**3.92**	**10**
12. Innovation and use of advanced technology in the system	2	8	19	12	7	**158**	**3.29**	**18**
13. Efficiency of the system	0	2	5	24	17	**200**	**4.17**	**4**
14. Period which system works (e.g. whole of the year or only in summer)	1	3	8	18	18	**193**	**4.02**	**9**
15. Negative impact on Landscape and visual view	10	7	9	14	8	**148**	**3.08**	**19**
16. Availability of Facilities for implementation of "SunThermal" for any households in the Netherlands	4	0	13	19	12	**179**	**3.73**	**13**
17. Overall Affordability for the Households who wish to implant "SunThermal"	1	1	9	18	19	**197**	**4.1**	**7**
18. Availability of Governmental Subsidies	1	2	14	17	14	**185**	**3.85**	**11**
19. Reduction of Fossil Fuels Consumption	0	1	8	18	21	**203**	**4.23**	**2**

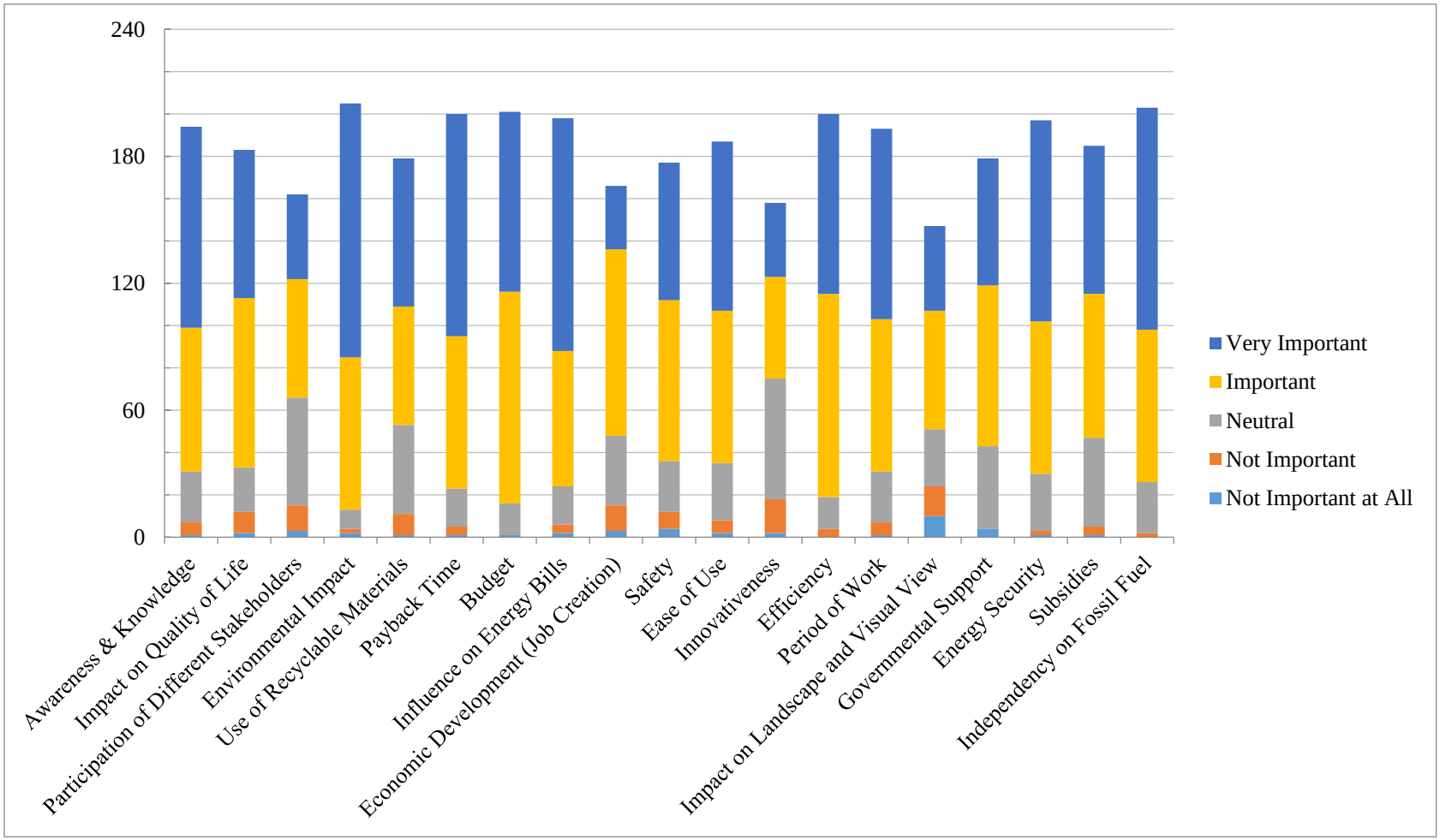

Figure 31: Correspondent's Likert Scores in detail for all Criteria

As Table 15 and Figure 31 show, “Importance Level” of criteria are various. The common opinion on the “Importance Level” of criteria is important because it show that how people really think about a certain criteria. For instance, 25 of participants (52.08%) scored “Budget” as “Important”. Also, other 17 participants (35.42%) choose “Very Important” for “Budget”. In sum 87.50% (42 people) have scored “Budget” as important criteria which show that most of participants have aggregation and same idea about this criteria. Table 16 show that which criteria have got more score in 5 scoop of scoring in the survey:

Table 16: Aggregation of Participant about Criteria

Scope					
“Not Important at all” and “Not Important”		**“Neutral”**		**“Very Important” and “Important”**	
Criteria	Percentage	Criteria	Percentage	Criteria	Percentage
Impact on Landscape and Visual view	35.42%	Innovativeness	39.58%	Environmental Impact	87.50%
Innovativeness	20.83%	Participation of Different Stakeholders	35.42%	Budget	87.50%
Participants of Different Stakeholders	18.75%	Use of Recyclable Materials	29.17%	Efficiency	85.42%
Economic Development (Job Creation)	18.75%	Subsidies	29.17%	Payback Time	81.25%
Safety	16.67%	Governmental Support	27.08	Independency on Fossil Fuel	81.25%

This information is important for have a general over view about the aggregation of respondent idea and how much they have same idea about a certain criteria. Also, it should be mentioned that in the “Not Important at All” scope, the “Impact on Landscape and Visual View” criteria with 20.83% is the criteria which have highest aggregation on this scope. There is a considerable difference (12.53%) with this criteria and next two which are: “Safety” and “Governmental Support”.

4.1.2.4. Additional Criteria

In this part, there are two main information:

1. Participants choose the most important criteria. This is a direct question about the criteria and give the opportunity to the respondents to consider all criteria together and choose between them.
2. Participants add any other criteria which they believe it's important have an influence on Social Acceptance and Adaption of "Solar Thermal Energy Systems" among Households.

The tables below show the information related to the most important criteria:

Table 17: Most Important Criteria choose by Survey's Respondents

From the Criteria in the table, which do you consider the most important one? (You can choose more than one criteria)	Number of times which have been chosen	Percentage	Level of Importance
1. Increased Awareness about Energy Consumption	10	6.80%	**5**
2. Positive impact on User's Quality of Life	8	5.44%	**9**
3. Participation of Different Stakeholders from different levels in implementation (e.g. Companies, Municipalities)	5	3.40%	**13**
4. Positive Environmental impact (e.g. Reduction of CO2 Emission)	22	14.97%	**1**
5. Recyclable materials usage in design and production	1	0.68%	**17**
6. Payback Time (Investment Return)	21	14.29%	**2**
7. The Investment (Initial Budget) for installation	9	6.12%	**6**
8. Influence on Energy Bills Reduction	17	11.56%	**3**
9. Job creation (on both Local and National Level)	2	1.36%	**17**
10. Safety of "SunThermal" for users and facilities	4	2.72%	**10**
11. Understandability of the system for households and people	4	2.72%	**10**
12. Innovation and use of advanced technology in the system	0	0.00%	**19**
13. Efficiency of the system	3	2.04%	**14**
14. Period which system works (e.g. whole of the year or only in summer)	6	4.08%	**12**
15. Negative impact on Landscape and visual view	2	1.36%	**16**
16. Availability of Facilities for implementation of "SunThermal" for any households in the Netherlands	3	2.04%	**14**
17. Overall Affordability for the Households who wish to implant "SunThermal"	9	6.12%	**6**
18. Availability of Governmental Subsidies	9	6.12%	**6**
19. Reduction of Fossil Fuels Consumption	12	8.16%	**4**
Total	**147**	**100**	

It should be mentioned there is a possibility in the survey to make multiple choices which is cause of 147 of total choices among 48 participants. In this question, the 5 criteria which have been chosen the most are:

1. Environmental Empact (14.97%)
2. Payback Time (14.29%)
3. Influence on Energy Bills (11.56)
4. Independency on Fossil Fuel (8.16%)
5. Awareness and Knowledge (6.8%)

The “Environmental Impact” criteria is the most important criteria which is the same criteria that score as the important criteria in the previous question. However, there are difference between other criteria from this question and last question. The most important which worth to mention is the absence of “Efficiency” and “Budget” criteria and presence of “Awareness and Knowledge” and “Influence on Energy Bills” in this new list which is in contrast with the output from the previous question. This might be because this current question is directly asking for the most important criteria however, the previous question is about scoring different criteria. Although, the most important point is that in both questions with two different methodology (Scoring (passive) and direct question) the most important criteria is “Environmental Impact” which show the really high “Level of Importance” of this criteria.

However, the majority of respondents have not add any criteria (81.25%), the added criteria which have been mentioned are important and will be discussed more in the next chapter (discussion). For instance, the "Level and Duration of Installation" is a criteria which have influence on the "Social Acceptance" of these systems. As Table 18 and Figure 32 show:

Table 18: Added Criteria by Survey's Respondents

Are there any other Criteria not included in the list above that you think are important?	Number	Percentage	What is the Criteria	Number	General Category	Total Number	Percentage
Answered	9	18.75%	Level of difficulty in installation	2	Technical	5	45.5%
			Ease of use	1			
			Duration of Installation	1			
			Surface and Indoor space which is needed	1			
			Positive price impact for future house-sale (better energy label)	1	Financial	2	18.2%
			Simplifying the Investment and Funding Procedure	1			
			Test and insurance of the Influence on people's Health	1	Health	1	9.1%
			Existence of neighborhood / city plans and strategies	2	Policy	2	18.2%
			Available and reliable technical Expert	1	Social	1	9.1%
No answer	39	81.25%			**12**		**100%**
Total	**48**	**100%**					

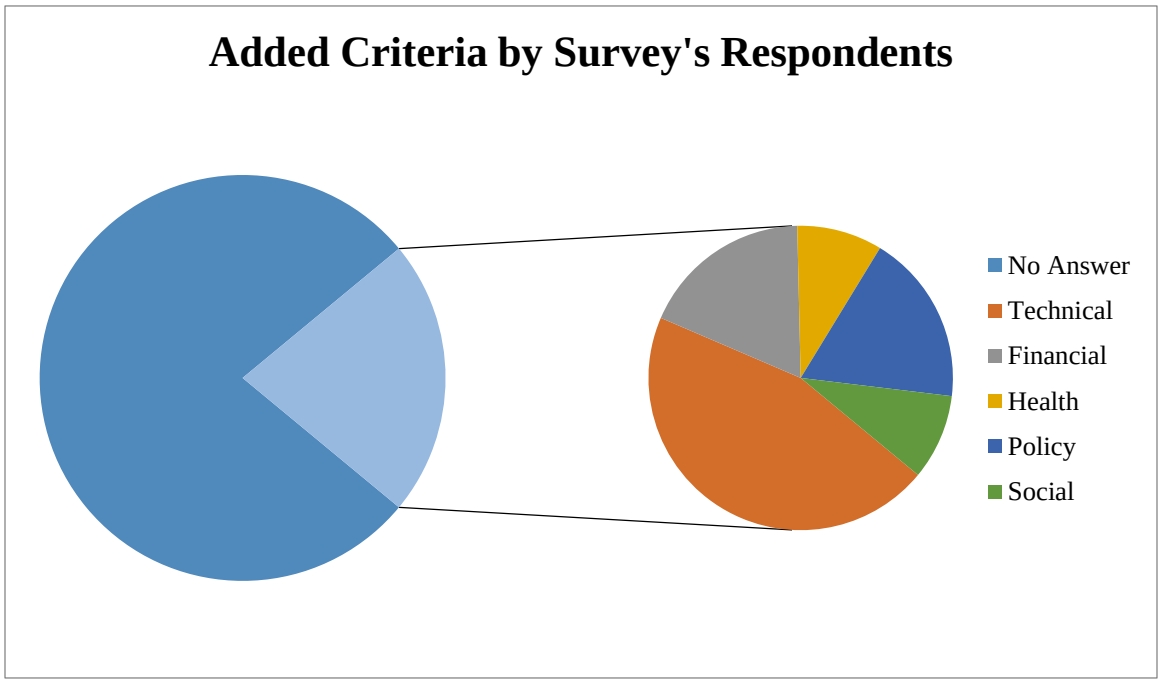

Figure 32: Added Criteria by Survey's Respondents

As Table 18 show, the most additional criteria are related to “Technological” criteria which show the importance of these category among participants. Also, it might be because of lack of “Knowledge and Awareness” about these systems. Furthermore, there is an additional criteria related to the “Health” which is interesting because it present the household’s concern about the effect of these systems on their health. It should be remind that all these data and analysis are based on the information which have been provided by participants of the survey. The influence of the sample should be considered in this study and also future studies.

4.1.3. Survey Final Discussion and Findings

In general all the criteria score more than three (Neutral) which show the criteria which have been find based on literature are important for people. The Likert Score on average for all nineteen criteria is 3.85. Also, due to all information and data which have presented in these parts, the "Environmental Impact" criteria is the most important criteria which have scored by participants which in all different analysis (Likert Score, Aggregation, Direct Question) is ranked as the first place. This criteria score is 4.27 on Likert score and it have been chosen as the most important criteria among all criteria. It should be mentioned the 87.5% of respondents score this criteria as "Very Important" or "Important".

Beside "Environmental Impact" criteria, other criteria show different results in several analysis. For instance, "Independency on Fossil Fuel" which score 4.23 on Likert score (2^{nd} place among Nineteen criteria), on the Aggregation Analysis and Direct Question Analysis is in 4^{th} place which still show the importance of this criteria. The analysis show "Financial" criteria, mostly "Budget", "Payback Time" and "Influence on Energy Bills" are important for respondents. All these three criteria are among t6 most scored criteria on Likert score. "Budget" and "Payback Time" are among five criteria with highest Aggregation on "Very Important" and "Important" level. "Payback Time" is on 2^{nd} place and "Influence on Energy Bills" is on 3^{rd} place in Direct Question analysis.

Although, among "Technological" criteria "Efficiency" is among 5 highest results in both Likert score and Aggregation Analysis, in "Direct Question" Analysis none of "Technological" criteria have been ranked highly. The most important criteria among "Social" criteria is "Awareness and Knowledge" which with 4.04 Likert score is in 8^{th} place and is among 5 criteria which have the highest share in Likert score.

On the other hand, "Impact on the Landscape and Visual View" is score as 19^{th} criteria which is the least important one in this study (3.08 score). "Aggregation Analysis" is also show that more than 35% of participants ranked this criteria as "Not Important at all" and "Not Important". (1^{st} place). Due to Municipality and Local Communities point of view this point will discuss further in next parts. The "Innovativeness" "Participation of Different Stakeholders" are the next least important criteria in this study.

At last it should mention that the nine different criteria which have added by participants in this research might have influence on these results which should be considered in the next studies.

4.2. Interview Analysis

As it mentioned in Research Methodology, due to consider different stakeholders which have influence on Social Acceptance of "Solar Thermal Energy Systems", a survey and different interviews have been developed and organized. The survey's results which the purpose was to gather information from households have been presented in previous part. In this chapter the Interview results will be presented.

4.2.1. Interview Results

The interviews have been held with other four main stakeholders (excluding Households): Policy Makers and Government, Business Companies and Market Players, Local Communities and Academic Researchers. All the interviewees have been contacted by the researcher and individually have been interviewed in English. The stakeholders which have been interviewed are:

1. Policy Makers and Government: Municipality of Leeuwarden, Province of Friesland
2. Business Companies and Market Players: Ekwadraat, Wilms and Alius Energy
3. Local Communities: Ameland Energy Cooperative, Elkein Housing Agency
4. Universities, Researchers and Academic Institutes: TU Delft, TU Eindhoven, Utrecht University, Nordwin Collage

The interviews were semi-structured with the main focus on the Research Questions and Research Objectives. The main topics which have been discussed during interviews can be divided in seven main categories:

1. Current Status of Energy Consumption, Renewable Energy Production and Consumption by households and Current Status of "Solar Thermal Energy Systems"
2. Plans and Programs for future of Energy, Plans for Renewable Energy Technologies based on "Solar Thermal Energy Systems"
3. The Barriers for developments and adoption of "Solar Thermal Energy Systems" in the Netherlands
4. Proper Solutions for overcoming these barriers
5. Nexus and relation between "System Design", "Social Acceptance", "Energy Management" and "Energy Policy and Energy Security" of the "Solar Thermal Energy Systems"
6. Stakeholders and their motivations
7. Suggestions for improving this research

Due to the interviewee position, field of work, background and interests questions could be different for each interviewee. During the interview itself, additional questions could be asked when they were in line with the interview and of importance to the research. All interviews were recorded and additional notes were made by researcher and also the minutes or reports of the interview. Analysis of the interviews was based on the summaries as suggested by Jansen (2007). The processing of the interviews was done by summarizing the answer to each question for each interviewee. The main points of the interviews have been presented in the Tables due to their category in next parts. It should be mentioned, all the interviewees were agree about the current Energy Consumption and Energy Sources, Rate of Renewable Energy Production and also, plans

and programs for increasing Renewable Energy production. The other result which is worth to mention is, in general all the interviewees believe that the "Solar Thermal Energy System" would be a suitable alternative for "Heat Energy Production" in the Netherlands which have three main barriers to be feasible and acceptable:

1. Financial Barriers
2. Lack of Knowledge
3. System Design (Low Available Radiation and Energy during peak time and winter if there is no storage system)

4.2.1.1. Policy Makers and Government

For this information there have been two different interviews with "Municipality of Leeuwarden" and "Province of Friesland". Based on these two interviews (1person from Municipality and 2person from Province), there is no any specific plan for supporting "Solar Thermal Energy Systems". There are general plans for supporting reduction of Natural Gas consumption and "RET" production such as SDE+ subsidy program or other special programs for Leeuwarden and Friesland such as Friese Energiepremie. Although, all three interviews mentioned some technological barriers for acceptance of these systems such as "Low Efficiency" and "Low Available Energy in Winter", they believe that "Solar Thermal Energy Systems" would be a suitable alternative energy source for heating houses. Table 19 describe these interview's summery and results.

Table 19: Brief Data from "Policy Makers and Government"

Topic & Question	Organization	
	Municipality of Leeuwarden- Energy Coordinator	**Province of Friesland- Project Leader Sustainable Innovations & Local Energy Innovation- Solar Energy**
Current Energy Consumption Source, Renewable Energy Technology projects, Solar Thermal Energy status	The main current Energy Source for Heating Houses is Gas with the average 1500 $m^3/year$ for normal houses. There are different plans and programs for supporting Renewable Energy adoption and production but there is nothing special for "Solar Thermal Energy Systems". Dutch Government, Province and Municipality trying to reduce the Gas consumption and increase the Renewable Energy production	
General Idea about the Solar Thermal Energy Systems	In General, there is "Lack of Knowledge" in all different organization. Due to high acceptability of PV systems, there is less motivation about these systems. However, only 20% of Energy Consumption in the houses is Electricity, due to high price of the bills, people focus on reduction of the Electricity. If there are available results which prove these systems are suitable, they would be more supported	
Main Barriers for Acceptance and Adaption of "Solar Thermal Energy Systems" by Households	❖ There is no indicator to show that how much energy these systems are producing ❖ There is "Lack of Knowledge" among households ❖ People cannot easy talk about these systems and communicate about its output ❖ There are no company with proper business case for these systems ❖ These systems are expensive ❖ Due to cheap price of Gas, people are not financially motivated ❖ Lack of proper coordination between different stakeholders	❖ System is complex for households and it's hard to be installed. ❖ Gas is cheap and people do not wish to invest in other systems ❖ They are not interesting for people ❖ There is "Lack of Knowledge" among household's energy advisers (companies and advisors who are in charge of Energy systems in houses) ❖ There is no proper system design which prove how much Gas will be saved ❖ It's ugly
Solution for Barriers	❖ Collaboration between companies and municipality to advertise and improve the awareness and also develop a proper business plan ❖ More Governmental Support	❖ Improving knowledge among companies and Teaching the "Energy Advisers" about these systems ❖ Develop a proper system design with a pilot ❖ More study on these systems in Universities to make them more cheap
Main Stakeholders	Households, Municipality and Government, Companies, Energy cooperative	Households, Government, Energy Advisers, Companies, Universities, Institutes who teach Energy Advisors for companies
Main Motivation	Environmental Improvements & Financial Benefits,	

4.2.1.2. Business Companies and Market Players

Business Companies and Market Players have an important influence on "Social Acceptance" of these systems. Due to gather these information, there have been held three meeting with three companies which are working with these systems: Ekwadraat, Wilms, Aluis. In general all three interviewees believe that however, the market for these systems are still small, it will grow in coming years. In all interviews "Technological Barriers", "Lack of Knowledge" and "Financial Barriers (Investment, Payback Time and Cheap Gas)" are the main reasons for current small market and low "Social Acceptance" of these systems.

Table 20: Brief Data from "Business Companies and Market Players/ Alius Energy"

Topic & Question	Organization
	Alius Energy
Current Energy Consumption Source, Renewable Energy Technology Sources and Solar Thermal Energy status	The main Source is Gas, but people are using RET in their house which the main systems are: Solar PV, Wood Stove, Geothermal (in some part) and Heat Pump There are people who use and install "Solar Thermal Energy Systems" in their house but not as much as other RET.
General Idea about the Solar Thermal Energy Systems	There is a small market for these systems which is growing slowly now, but in future it will be more popular. It will be a suitable alternative for reduction of Fossil Fuel consumption.
Main Barriers for Acceptance and Adaption of "Solar Thermal Energy Systems" by Households	❖ There is no specific plan and support from Government ❖ People and also companies do not know about these systems and they are more into other RET ❖ Although the price of these systems have been decreased, they are still expensive
Solution For Barriers	❖ Practical Results with a real prototype ❖ Combine these systems with Heat Pumps ❖ More research on these systems to make them more cheap ❖ Using PCM (Phase Changing Material) for Heat Storage ❖ If Industry and Companies use these systems, people will accept them more easy.
Main Stakeholders	Government, Households, Companies, Industry, Universities and Academic Institutes
Main Motivation	**For Companies:** Being the front runner in this market which will grow fast in future **For Other Stakeholders:** Environmental Improvements, Reduction of Fossil Fuels consumption and Financial Benefits (Financial Benefits should not be the main motivation)

Table 21: Brief Data from "Business Companies and Market Players/ Wilms"

Topic & Question	Organization
	Wilms
Current Energy Consumption Source, Renewable Energy Technology Sources and Solar Thermal Energy status	Natural Gas is the main Energy Source in the Netherlands. Households are one of the main Energy Consumers in the Netherlands who their main need is for Heat Energy. The first main important point for reduction of Energy consumption in the houses is Insulation. Solar PV, Wood Stoves and Heat Pumps are current popular Energy Sources in the houses. However, in coming years, Geothermal and CHPs will become important too. Government support RET systems. Solar Thermal Energy Systems is not so popular among people and companies.
General Idea about the Solar Thermal Energy Systems	Solar Thermal Energy is a suitable alternative for Heat Production for Heating Houses in the Netherlands. Their efficiency are good and they do not have negative environmental impact. Furthermore, they can be used easily. The main issue which need to be solved is about the "Heat Storage".
Main Barriers for Acceptance and Adaption of "Solar Thermal Energy Systems" by Households	❖ It's unknown for people and companies, ❖ There is no proper Business Plan for these systems, ❖ Technical Issues mainly "Heat Storage" as it mentioned, ❖ Financial Issues ❖ Support from Policy Makers
Solution For Barriers	❖ Proper support from Government and Policy Makers with Tax and Subsidy ❖ More cheap systems (Collaboration between Academic Institute and Companies) ❖ More practical System with a proper storage system
Main Stakeholders	Government, Households, Companies, Industry, Universities and Academic Institutes
Main Motivation	Financial Benefits and Environmental issues

Table 22: Brief Data from "Business Companies and Market Players/ Ekwadraat"

Topic & Question	Organization
	Ekwadraat
Current Energy Consumption Source, Renewable Energy Technology Sources and Solar Thermal Energy status	Gas is the major Energy Source for Heating Houses now. Also, people are using RET in their house mainly Solar PV, Wood Stove and Heat Pumps. Government support these systems with subsidy. Solar PV and Wood Stove are cheap and popular among people. Due to CO2 emission of Wood Stove, in future they will not be this much popular. Also, government put lots of effort on development of Wind Farms. Solar Thermal Energy Systems are available and becoming popular slowly.
General Idea about the Solar Thermal Energy Systems	Solar Thermal Energy is the right way to produce Thermal Energy for Houses. There is a small market for these systems which is growing slowly now, but in future (5 to 10 years) it will be more popular. These systems need to developed

	more and also become more cheap but they are the most sustainable technology for heating.
Main Barriers for Acceptance and Adaption of "Solar Thermal Energy Systems" by Households	❖ Financial Issues are the most important Barrier. ❖ People and companies do not have information about these systems. ❖ These systems are not attractive (Negative Impact on Landscape)
Solution For Barriers	❖ More cheap systems (Collaboration between Academic Institute and Companies) ❖ More support from Government ❖ Proper System Design (more attractive, more efficient) ❖ There is a need for more Technical/Innovative solutions.
Main Stakeholders	Government, Households, Companies, Industry, Universities and Academic Institutes, Energy Deliverer Company (Grid), Construction Companies
Main Motivation	Financial Benefits and Environmental issues

4.2.1.3. Local Communities

Due to literature review, Housing Agencies have great share of houses which are available for rent in the market. Also, Survey results show 18.75% of participants have contract with these agencies which is a considerable share market. Elkien is one of the largest Housing Agencies in the Friesland and Leeuwarden which have participate in this research. Furthermore, the local energy communities, Energy Cooperative have energy information and influence on local people. Due to the Interview with Municipality of Leeuwarden, there was an information about "Ameland Energy Cooperative" which have been trying to make RET more acceptable, mostly "Solar Thermal Energy Systems". The Table 21 present information for these two important interview:

Table 23: Brief Data from "Local Communities/ Ameland Energy Cooperative"

Topic & Question	**Organization**
	Ameland Energy Cooperative
Current Energy Consumption Source, Renewable Energy Technology Sources and Solar Thermal Energy status	There are different RET which are using in Ameland: Solar PV, Biomass, Wind, Heat Pump and Solar Thermal. Heat Pump are becoming more and more popular. Also, there are studies for Geothermal Feasibility. There is a motivation for making Ameland more sustainable.
General Idea about the Solar Thermal Energy Systems	There is a need for new energy systems due to "Climate Change" and "Energy Transition" which due to high consumption of Heat Energy, Solar Thermal Energy Systems might be suitable alternative. There are people who are using these systems in Ameland. It seems due to "Low Radiation" the efficiency is not high and there would be problem in winter if it's the only Heating Source in the house.
Main Barriers for Acceptance and Adaption of "Solar Thermal Energy Systems" by Households	❖ Economic Feasibility ❖ There are not enough information among households and companies about these systems ❖ They are ugly and have negative impact on visual view

	❖ They are not interesting because people cannot communicate about them ❖ It's hard to change the available infrastructures and people's way of living
Solution For Barriers	❖ People should get involved ❖ Combine these systems with Solar PV and Heat Pump ❖ More research and study on these systems
Main Stakeholders	Municipality, Energy Companies (in future Shell), Local Community, Households, Universities and Academic Institutes
Main Motivation	Environmental Improvements (Paris Agreement), Financial Benefits (More Tourists in the Island, saving money for Households)

Table 24: Brief Data from "Local Communities/ Elkien Housing Agency"

Topic & Question	**Organization**
	Elkien Housing Agency
General Information about "ELKIEN" and Housing market	Elkien is among three largest Social Housing Agencies in Friesland Elkien have 20 000 accommodation in total Elkien is trying to make all their houses energy neutral until 2030
Current Energy Consumption and Plan's for Future	Most of Elkien's properties are using "Natural Gas" as the main Energy Source Among RET, Solar PV have most usage among Elkien's Tenants Elkien's plans for Energy Source in the future is based on Electricity which is providing by Solar PV Elkien do not need Governmental Support (Subsidy). They have cooperation with several municipalities, province and other Housing Agencies to develop their projects. Their tenants and "energy adviser companies" have important role in achieving their goals
General Idea about the Solar Thermal Energy Systems and Barriers for Adaption	It is one of the possible solutions which is related to the each situation and accommodation The "Energy Adviser Companies" will give advice for this and these systems should be accepted by these companies first Elkien looking for a "efficient" and "user-friendly" which have financial benefits
Main Stakeholders	Housing Agencies, Households, Energy Adviser Companies, Municipality
Main Motivation	All the stakeholders should be informed about the benefits of these systems: "Environmental Impact", "Energy Production and Consumption" and "Financial Benefits".

4.2.1.4. Universities, Researchers and Academic Institutes

Du to get more information about the academic projects and researches and also having a better understanding about the Academic point of view about "Solar Thermal Energy Systems" there are several interviews with this important category of stakeholders. There are interviews with different institutes: TU Delft, TU Eindhoven, Utrecht University, Van Hall University of Applied Science and Nordwin College. In general, all interviews emphasis on "Technological Problems such as "Complexity of System", "Lack of Knowledge" and "Investment budget".

Table 25: Brief Data from "Universities, Researchers and Academic Institutes/ Nordwin College"

Topic & Question	**Organization**	
	Nordwin College	
	Sustainable Energy Coordinator	**Internship with focus on Energy and Climate**
Current Energy Consumption Source, Renewable Energy Technology projects, Solar Thermal Energy status	The main Energy Source is Gas. There are programs in different levels to change the Energy Consumption pattern. The focus is mostly on Solar PV and Biomass (Wood Stove). Due to cheap gas and way of living, changing in Heat Sources is not interesting for Households.	
General Idea about the Solar Thermal Energy Systems	These systems would be suitable alternative for the Heat Source in the Netherlands (at least for the summer time and partial need of winter)	
Main Barriers for Acceptance and Adaption of "Solar Thermal Energy Systems" by Households	❖ Lack of Knowledge ❖ Financial Costs (Investment) ❖ There is no plan for future scenarios ❖ Storage system	❖ House Owners do not wish to install these systems for their tenants ❖ There is no emphasis on these systems in University Level of Teaching
Solution for Barriers	❖ Hard facts which prove these systems will provide certain amount of Energy ❖ More focus on these systems in Universities ❖ Make people understand about the urgent need for Energy Transition	
Main Stakeholders	Government, Households, Companies, Universities	
Main Motivation	Environmental Impacts, Developing knowledge	

Table 26: Brief Data from "Universities, Researchers and Academic Institutes/ TU Delft"

Topic & Question	Organization
	TU Delft/ Built Environment
Current Energy Consumption Source, Renewable Energy Technology Sources and Solar Thermal Energy status	Gas is the current source. The main focus is on Insulation for available houses. In big cities the "waste heat" from industry is an alternative system. Solar PV with combination of Heat Pump is popular. "Solar Thermal Energy Systems" are not accepted well among people.
General Idea about the Solar Thermal Energy Systems	These systems need a storage system and also a backup system for instance Heat Pump and all these make them more expensive.
Main Barriers for Acceptance and Adaption of "Solar Thermal Energy Systems" by Households	❖ There is no available proper storage system for single houses ❖ They are expensive ❖ The main focus is about other RET ❖ There is no enough space on the roof for both Solar PV and Solar Collector ❖ Due to complexity of these systems, the education system do not focus on them during the Bachelor and Master programs. Most focus is on Solar PV.
Solution For Barriers	❖ Working on "Technological" and "Financial" aspects of Solar PVT and "Storage Systems" ❖ Expand the Market for these systems ❖ Increase awareness about these systems among people ❖ Design a combine systems with: Solar Thermal Collector, Solar PV and Heat Pump ❖ Make these systems more understandable
Main Stakeholders	Universities, Government, Municipalities, Households, Companies
Main Motivation	Environmental Impact and Financial Benefits

Table 27: Brief Data from "Universities, Researchers and Academic Institutes/ TU Eindhoven"

Topic & Question	Organization
	TU Eindhoven/ Built Environment
Current Energy Consumption Source, Renewable Energy Technology Sources and Solar Thermal Energy status	The current source is Gas. There are discussions about two main way for "Energy Transition": 1. All Heating based on Electricity 2. Combination of Heat and Electricity based on RET (also, there are debates about "Fabricant Gas"). Political issues are a great motivation. All possibilities should be open and their feasibility should be studied
General Idea about the Solar Thermal Energy Systems	In general these systems are suitable alternative. They are Environmentally friendly. The main problem is Storage System and also investment.
Main Barriers for Acceptance and Adaption of	❖ Proper Storage System (also, problem with PCM) ❖ Financial Barriers Investment ❖ Lack of Knowledge and awareness

"Solar Thermal Energy Systems" by Households	❖ Space of the whole system ❖ Lack of motivation among Companies ❖ Availability of huge and expensive infrastructure ❖ No feeling about need for urgent "Energy Transition" among people
Solution For Barriers	❖ Cheaper system (without no subsidy) ❖ More Researches on PCMs ❖ Increase Awareness among people ❖ Suitable Plan from Government
Main Stakeholders	Government, Universities, Households, Companies,
Main Motivation	The main and most important one should be Environmental Impact

Table 28: Brief Data from "Universities, Researchers and Academic Institutes/ Utrecht University"

Topic & Question	**Organization**
	Utrecht University/ Sustainable Development/Energy Department (Geoscience)
Current Energy Consumption Source, Renewable Energy Technology Sources and Solar Thermal Energy status	People use Natural Gas mostly for their heat source. However, they are some people who use RET in their house, such as Solar PV, Bio Energy and Solar Thermal Energy. The most important point is about the coldest days of the year (20-30 days/year). The first priority is about insulation of the house. There are some ambitious targets in the Netherlands such as "Utrecht Gas Free city" which motivate the development of RE systems.
General Idea about the Solar Thermal Energy Systems	Solar Thermal Energy is suitable solution for heating tap water and it's relatively popular in this way. This source is hard to be used for Heating the space.
Main Barriers for Acceptance and Adaption of "Solar Thermal Energy Systems" by Households	❖ There is a low radiation in the winter, which makes these systems useless in that period without Storage Systems ❖ People do not know about the system, risks, advantages and disadvantages of these systems ❖ The Financial Feasibility (investment and payback time) ❖ People prefer to invest on Solar PV ❖ People do not want to face troubles and change their current energy systems ❖ There is no proper system design for Single Houses ❖ There is no enough space in most of the houses to put the storage system ❖ There is no motivation among Housing Agencies to install these systems for their tenants
Solution For Barriers	❖ Universities should work more on the design of these systems and make them more cheap ❖ Energy Companies should develop a proper Business Plan for these systems ❖ Proper plan from government to support these systems
Main Stakeholders	Households, Universities, Energy Companies (System Producers, Installers and Advisors), Government and Municipalities
Main Motivation	Reduction of Fossil Fuel consumption and Environmental Impact

Table 29: Brief Data from "Universities, Researchers and Academic Institutes/ TU Delft"

Topic & Question	Organization
	TU Delft/ Urbanism Department
Current Energy Consumption Source, Renewable Energy Technology Sources and Solar Thermal Energy status	The main Energy Source for heating house is Natural Gas in the Netherlands. However, there are some actions about the installation of RET. Among RET, main focus is on Wind Energy (for electricity production). Unfortunately, if the deployment of RET will be slow, the Nuclear Energy would be an strong alternative due to reduce CO_2emotion. The main important point is about the scale of the Energy source and project which is going to be installed.
General Idea about the Solar Thermal Energy Systems	Solar Thermal Energy is a suitable alternative energy source for heating houses. The scale of the project and the way of adjustment of these system to the current system is so important
Main Barriers for Acceptance and Adaption of "Solar Thermal Energy Systems" by Households	❖ Natural Gas stakeholders ❖ Social Aspect: Knowledge and Acceptance of these Systems Lack of motivation among stakeholders ❖ Financial Barriers ❖ Scale of the project
Solution For Barriers	❖ Motivate Natural Gas Stakeholders ❖ More research on these systems due to have a better and cheap design ❖ Integrated System with Heat Pump and Storage System ❖ Identify the benefits of these systems
Main Stakeholders	Government, Universities, Households, Companies
Main Motivation	The main and most important is RET targets and Positive Environmental Impact

As all the interviewees mention, the main Heating Source in houses is Natural Gas. However, there are plans and programs for "Energy Transition" which support Renewable Energy Technologies developments in general among people. The main RET which have been developed fast among people are: Solar PV, Heat Pump and Biomass (Wood Stove). Also, due to location of the house and availability of proper infrastructure "District Heating" is another choice. It should be mentioned there is no specific plan for developments of "Solar Thermal Energy Systems" among people.

4.2.2. Final Interview Discussion and Findings

As most of the interviews mentioned the main Heating Energy Source is “Natural Gas”. Which there are plans to decrease these share and participate more RET for Energy Production. Also, the main RET which Households are using now is “Solar PV”, “Biomass” and “Heat Pump”. Furthermore, interviewees accept that the “Solar Thermal Energy Systems” are a suitable Energy Alternative for Heating Houses in the Netherlands which is facing several barriers in different levels. These barriers can be categorized as following:

1. Awareness and Knowledge:
   The Knowledge among Policy Makers about these systems,
   The Knowledge among Companies who are “Energy Consultant” for households and also companies who produce energy systems,
   The Awareness among Households about Energy Consumption and also Solar Thermal Energy Systems.
2. System Design:
   There is no specific indicator and system for monitoring the system and have information, about Energy Production, which is one of the main cause that make these systems less understandable for Households
   System is complex and hard to install,
   There is a need for proper storage system (mostly for single houses),
   Space for installation of different parts (collector, Storage Systems, Pump, etc.)of these systems.
3. Financial:
   Gas is Cheap which is a reason that people are not motivated to change their current system,
   These system is expensive.
4. Governmental:
   There is no proper collaboration and cooperation between companies, government and municipality (Different Stakeholders),
   There is no specific plan and future scenarios for these systems,
   There is a focus from Government and other stakeholders on other RET,
   Changing people life-style from Natural Gas to these systems is hard.
5. Other:
   There is no company with feasible business case for these systems,
   These systems are ugly which have Negative Impact on Landscape and Visual View,
   Due to different issues such as complexity of these systems, in the University level there is no emphasis on these systems (System Design).

Furthermore, understanding the different stakeholders who are involved in the deployment of Solar Thermal Energy Systems is important. Universities, Households, Government and businesses are some of the most important stakeholders. It should be mentioned, interviewees believe that the fossil fuels companies would have important influence on development of RET.

There are some solutions which have mentioned due to overcome to these barriers and solve these issues which are mentioned previously in the tables. The last point which is worth to mention is some interviewees have emphasized on that the Governmental "Subsidy" for a less than 10 years period would not be a help for developing these systems, because companies need time to develop a suitable product for market and also it takes time for people to accept new product. Also, due to some opinions, the "Negative Impact on Landscape and Visual View" will not a huge problem in future. Three interviewees mentioned at first people did not accept "Solar PV" because of they are ugly. But during the time, people get use to them and also, due to market developments and more researches, "Solar PV Systems" become more proper. These experts believe these process will be the same for "Solar Thermal Energy Systems". However, some other interviewees do not agree on this point due to other barriers which have mentioned before in the research.

The last point which is important to mention here is about the less development and being back in the RET production in general in comparison with other European Countries. Although, this situation have problems and issues, but there is a great advantage for the Netherlands which can use other countries experience. Two interviewees believe, this could be a great help for development of any kind of RET, specially technologies like "Solar Thermal Energy Systems" which Dutch Government do not have present any specific "Development Plan" yet.

Chapter Five: Findings, Discussion, Recommendation and Conclusion

In this chapter answers to the research questions are provided. Research findings will be discussed and as a result the proper Recommendations will be presented. Furthermore, Conclusion have been made.

The background of the research is to understand the social factors which contribute to decreasing energy demand due to implementation of "Renewable Energy Technology (RET)" on a small scale, in response to European regulations and national targets in the Netherlands. In respect of solar energy, although, the improvements in development and energy production share of "Solar PV Systems" is notable in the Netherlands, "Solar Thermal Energy Systems" have only 1% of RET energy production. The research focus on factors which influence the "Social Acceptance" of particular energy system, Solar Thermal Energy Systems, in the Netherlands amongst households.

5.1. Findings

As Literature Review indicate and Survey and Interviews have proved the main Energy Source for Heating Houses in the Netherlands is Natural Gas. Furthermore, less than 40% of participants use any kind of Renewable Energy Systems in their houses which in Heating and Thermal Sector this status is 25%. The interesting point is 33% of respondents do not have knowledge about amount of their Gas Consumption.

5.1.1. General Opinion about "Solar Thermal Energy Systems"

In general, opinion about "Solar Thermal Energy Systems" is so positive. As a matter of fact, 90% of participants and also interviewees believe "Solar Thermal Energy Systems" are suitable alternative for heating houses in the Netherlands. Although, 72.9% of participants are familiar with "Domestic Solar Thermal Energy Systems", only 16.7% of them have installed these systems in their houses. On the other hand, 64.8% of participants are willing to invest in these systems in their houses which could be interesting for other stakeholders such as Policy Makers, Municipalities and Companies. Moreover, for 71.4% of tenants and people who are looking for an accommodation, these systems are count as an advantage.

An in-depth literature study identified nineteen important influencing criteria which have been divided in to five main categories:

1. **Social Criteria**

Awareness & Knowledge, Impact on Quality of Life, Participant of Different Stakeholders, Impact on the Landscape and Visual View

2. **Technological Criteria**

Safety, Efficiency, Ease of Use, Innovativeness, Period of Work

3. **Financial Criteria**

Payback Time, Budget, Influence on Energy Bills, Availability of Subsidies, Economic Development

4. **Environmental Criteria**

Environmental Impact, Use of Recyclable Materials

5. **Energy Policy and Energy Security**

Governmental Support, Energy Security, Independency on Fossil Fuels

5.1.2. Most Important Criteria

Data analysis from Surveys and Interviews indicate "Environmental Impact" as the most important criteria which have influence on "Social Acceptance" of Solar Thermal Energy Systems among households in the Netherlands. "Independency from Fossil Fuels", "Budget" and Efficiency are found to be the next most important criteria positively influencing adaption of "Solar Thermal Energy Systems". Energy Experts have emphasized strongly on importance of the "Energy Policy" criteria such as "Independency of Fossil Fuels".

5.1.3. Most Important Barriers

"Lack of Knowledge", "Being Expensive" and "Low Solar Radiation" are the main barriers for installation of Solar Thermal Energy Systems which have been mentioned by participants in survey. Although, survey's results indicate the "Financial Barriers" and "Technical Barriers" as the main categories which are blocking implementation of Solar Thermal Energy Systems, based on the information from interviewees the most important barriers are related to "Technical" aspect (System Design) and "Energy Policy" aspect which shows a contrast. However, "Financial" and "Social" aspects (mainly the Budget and Lack of Knowledge) are other important barriers which have been mentioned by interviewees.

5.1.4. Least Important Criteria and Barriers

Surprisingly, the "Negative Impact on the Landscape and Visual View" was not identified as one of the important criteria and barriers in the Survey. Actually, this criteria, "Innovativeness of the energy system" and "Participation of different Stakeholders" are the criteria which have minimum impact on the "Social Acceptant" of "Solar Thermal Energy Systems". This appears to be in conflict with one of the main reasons advanced by municipalities and academicians for rejection of such schemes. However, some interviewees determined that "Negative Impact on the Landscape and Visual View" is not the most important criteria and they believe the adaption of Solar PV systems among households is a proof for this.

5.2. Discussion

As it discussed in Chapter 2, the research's subject is a multi-dimension topic. Social Acceptance of the Renewable Energy Systems is a new and complex subject which have different aspects and get influenced from several criteria. The findings and discussions which have been presented in 4.1.3, 4.2.2 and 5.1. are based on the literature review, surveys, interviews and modeling. The research have provided deep literature review which have direct influence on the data gathering

and analysis. Also, it tries to understand different point of view of all stakeholders. The survey's sample would be a good representative of the Netherlands. Interviewees are from several background.

Although, the research have tried to consider different aspects which have influence on the Social Acceptance of Solar Thermal Energy Systems, there are some criteria such as the ones that have been mentioned by participants of the survey and interviewees which could be important and have influence on the results. Also, impact of other socio-tech fields of Energy is critical. Furthermore, due to have a reliable output, consideration of all stakeholders and their point of view and understanding the drivers for the Solar Thermal Energy Systems deployment is crucial. Nexus of technical and social aspects are one of the most crucial subjects which the research tries to address and consider their interaction. Energy Policy and Energy Security are essential subjects which have great influence on the several aspects of development of RET and specially Social Acceptance of these systems.

5.3. Recommendation

Based on the criteria and barriers which have been identified in the study, the recommendations for more participation and development for "Solar Thermal Energy Systems" for heating houses in the Netherlands have been presented.

5.3.1. Awareness Creation

To address the barrier "Lack of Knowledge" about "Solar Thermal Energy Systems" there is a need to increase awareness and educate different stakeholders about these systems. For instance, the "Households" do not have enough information about these systems and "Energy Technician" do not have knowledge about installation and energy production of these systems. Moreover, due to "Lack of Knowledge", Policy Makers focus on other Energy Technologies. Understanding and awareness about the different benefits of installation of "Solar Thermal Energy Systems" would have a great influence on development of them. The availability of information and education about "Solar Thermal Energy Systems" could have a great influence on the development of these systems.

5.3.2. Provision of Financial Solutions

Financial issues is an important barrier which have direct influence on the participation of stakeholders. The "Budget" and "Pay Back time" are important criteria for households which have impact on their decision about installation of "Solar Thermal Energy Systems". "New Business Plans", "Availability of Governmental Subsidies" and "Cheap Solar Thermal Energy System Design" are some practical solutions.

5.3.3. New System Design

Due to addressing the "Technical" aspect and "System Design", there is a concept for development of Solar Thermal Energy Systems. The system is combination of three main parts: "Solar Collector", "Heat Storage System" and "Heat Pump". At first, water will be heated in the Solar Collectors and will flow through a Heat Exchanger. The heated water from Heat Exchanger will be stored in Heat Storage System and at the time which the thermal Energy is needed it would flow

though the Heating System. The Heat Pump will act as an auxiliary system when there is no enough available thermal energy in the Heat Storage System.

Due to the Leeuwarden climate and location, the average Irradiation which have been modeled is $226.8 {}^{W}/_{m^2}$. More detail information about the modeling and assumptions are Appendix: C. Technical. Due to available Irradiation and Radiation and based on 50 c needed temperature for heating the space, eight Flat Plate Collector (24 m^2 surface) in series should be installed. However, it should be mentioned, the Heat Storage System efficiency and the Heat Pump COP have influence on the system design.

5.3.4. New Innovative Coordinated Plan for different stakeholders

There is a great need for creation of innovative coordinated plans for different stakeholders due to development of Solar Thermal Energy Systems. On one hand, availability of companies which are producing the system with close collaboration of Energy Experts who can advise households and install systems in their houses is important. On the other hand, possibility for financial and political support is another critical aspect. All these are addressing to Energy Issues on the local and national level and it influence on the deployment of the Solar Thermal Energy Systems and in general all Renewable Energy Technologies. The Municipalities or local Energy Cooperative could be the coordinators for this coordinated plans.

5.3.5. Energy Policy and Energy Security Ambitions

Due to important barriers which have influence on the development of "Solar Thermal Energy Systems", there is a need for more supportive Energy Policies for Renewable Energy Systems. From the survey results, "Environmental Impact" and "Independency of Fossil Fuels" are the most important motivation for the participants which would get influence from Energy Policy. On the other hand the interviewees indicated the Energy Policy as one of the most important criteria (and Policy Makers as one of the most important stakeholders) which should be considered. Due to deployment of Renewable Energy Technologies, especially Solar Thermal Energy Systems, understanding the political drivers and barriers is so important. Availability of more information and education related to Renewable Energy Technologies (mostly Solar Thermal Energy Systems) for policy makers is important and would have influence on the Renewable Energy Policies. Furthermore, one of the most crucial subjects which should be considered is Energy Security in all dimensions which would have great influence on the deployment of all Renewable Energy Systems. Acceptability of Energy Source is one of the most important aspect of the Energy Security.

5.4. Conclusion

As a conclusion, Solar Thermal Energy Systems could count as a feasible and suitable Renewable Energy Technology and Source for Heating Houses in the Netherlands. It could help the country to reduce the Fossil Fuel consumption in the domestic area and as a result reduce the CO_2 emission. Deployment of these systems would support national Energy and Environmental targets.

"Environmental Impact" and "Independency of Fossil Fuels" are the most important criteria and motivation for people to install Solar Thermal Energy Systems in their houses. Although, "Financial aspect", "Lack of Knowledge" and "Technical aspect" are the most important barriers

for deployment of these energy systems, there are suitable solutions are mentioned in part 5.3. Recommendations. More public education and knowledge about these systems, Financial Solutions and better system design are main solutions for overcome the low participation. However, all these are addressing to the Renewable Energy Policy as the main solution for deployment of any Renewable Energy Technology.

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Appendix

A. Survey

The survey have been developed in the www.suveyplanet.com and have been published throw Social Networks such as Facebook and Linkedin.

Questionnaire Form

The purpose of this survey is gathering information related to "**Solar Thermal Energy Systems in the Netherlands**", which is going to be used for Javanshir Fouladvand's **Master Thesis** at "University of Twente". Your participation will be anonymous and the information will be used for the purpose of this study only. The different parts of survey and the results will be stored separated safely.
If you wish to have access to the final Thesis report please write your email here:……...

Part 1- Personal Information:

1. Please select your **gender**:
   a. Male
   b. Female
   c. I prefer to don't answer this question
2. How **old** are you?
   a. 15-24 d. 45-54 g. 75-84
   b. 25-34 e. 55-64 h. 85-94
   c. 35-44 f. 65-74 i. Older than 95
3. Are you **employed**? a. Yes b. No
4. Which **Province** do you live? ……
5. What tipe of **Accomodation** do you live in?
   a. Rented House from Private Sector b. Rented House from Housing Associations c. Own House
6. What is the highest level of **Education** you have completed?
   a. High School b. MBO c. HBO/Bachelor d. Master e. PhD
7. What is your "**Living Status**"?
   a. Alone b. Share House (e.g. Student House, with Friends) c. With Family
8. What is your "**Marital Status**"?
   a. Single b. Single + Children c. Married/Civil Partnership d. Married/Civil Partnership + Children
9. Do you use any kind of **Renewable Energy Technology** in your house? a. Yes b. No
   If YES, please indicate:……..

Part 2 - Energy Basics and Consumption:

1. Have you heared about the Dutch Government's National target of 14% Renewable Energy Production share in 2020?
   a. Yes b. No
2. Have you heared about EU and International targets about CO2 emission reduction? (e.g. Paris 2015) a. Yes b. No
3. What is your current Heating Energy Source and System in House? …….
4. How much Natural Gas (m^3) do you use in your house per year approximately? ……
5. Please indicate the level of your agreement with these statements in relation to the current E**nergy** use for "S**pace Heating"** in your home.
   (1:**Not Important at all**, 2: **Not Important**, 3:**Neutral**, 4: **Important**, 5: **Very Important**)

Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Energy is always affordable.					

Energy is always available.					
Energy is mostly from Fossil Fuel sources.					

Part 3 - Solar Thermal Energy:

1. Are you familiar with Domestic Solar Thermal Energy Systems? a. Yes b. No
2. Do you use Solar Thermal Energy Systems in your house for heating the space or water? a. Yes b. No
3. Do you think the **Solar Thermal Energy** could be a suitable alternative to reduce the dependency on Fossil Fuels for heating homes in the Netherlands? a. Yes b. No
4. Solar Thermal energy has only 1% share among the Renewable Energy production. Why do you think that Solar Thermal Energy has not adopted by Households in the Netherlands?……
5. **For House Owners**: Do you wish to invest and install the "Solar Thermal Energy Systems" in your house?
   a. Yes b. No If YES, please indicate your motivation:
   a. Financial Benefits b. National Responsibility c. Fun and Life Style d. Environmental Issues
   If NO, please indicate the barriers: ……...
6. **For Tenants**: Does your landlord voluntarily wish to install Solar Thermal Energy Systems in your home?
   a. Yes b. No
7. If your landlord has not installed or indicated an intention to install Solar Thermal Energy Systems have you approached him/her? a. Yes b. No
   If YES please indicate the respond after asking your landlord:
   a. Positive b. Not Interested c. Prepared to Install Solar Thermal Energy Systems
8. **For Tenants**: "Solar Thermal Energy Systems" could count as advantage (interesting option) of the house when you are looking for a new house to rent? a. Yes b. No c. No Difference

Part 4 – Criteria:

In this part you will be asked to give your opinion about "**Importance Level**" of different aspects and factors related to the "**Solar Thermal Energy Systems in the Netherlands**". This information will be used by researcher to understand the importance of different criteria and their influence on the adoption of New System Design and Implementation of Solar Thermal Energy System for Heating Houses in the Netherlands. For making the survey short and easy, the **"SunThermal"** which is used in the following table, means: **New Solar Thermal Energy System for Heating Houses**. When you have completed this section you will be asked to state which of these factors you consider to be most important. Please keep that in mind while completing the table.

(1:**Not Important at all**, 2: **Not Important**, 3:**Neutral**, 4: **Important**, 5: **Very Important**)

Aspect/ Factor	Not Important at all (1)	Not Important (2)	Neutral (3)	Important (4)	Very Important (5)
20. Increased Awareness about Energy Consumption					
21. Positive impact on User's Quality of Life					
22. Participation of Different Stakeholders from different levels in implementation (e.g. Companies, Municipalities)					
23. Positive Environmental impact (e.g. Reduction of CO2 Emission)					
24. Recyclable materials usage in design and production					
25. Payback Time (Investment Return)					
26. The Investment (Initial Budget) for installation					
27. Influence on Energy Bills Reduction					
28. Job creation (on both Local and National Level)					
29. Safety of "SunThermal" for users and facilities					
30. Understandability of the system for households and people					
31. Innovation and use of advanced technology in the system					
32. Efficiency of the system					
33. Period which system works (e.g. whole of the year or only in summer)					
34. Negative impact on Landscape and visual view					
35. Availability of Facilities for implementation of "SunThermal" for any households in the Netherlands					
36. Overall Affordability for the Households who wish to implant "SunThermal"					
37. Availability of Governmental Subsidies					
38. Reduction of Fossil Fuels Consumption					

Part 5 - Additional Criteria:

1. From the Criteria above, which do you consider the most important one? …….....
2. Are there any other Criteria not included in the list above that you think are important? ……...

Statistical Survey Results

Personal Information:

Population analysis among total 48 participants who have been considered. Tables below show the exact and share of the participants with respect to each question in the Survey.

Gender	Number	Percentage
Male	27	56.25%
Female	21	43.75%
Total	**48**	**100.00%**

Age	Number	Percentage
15-24	8	16.67%
25-34	17	35.42%
35-44	8	16.67%
45-54	8	16.67%
55-64	6	12.50%
65-74	1	2.08%
Total	**48**	**100.00%**

Employment	Number	Percentage
Yes	39	81.25%
No	9	18.75%
Total	**48**	**100.00%**

Province	Number	Percentage
Friesland	21	43.75%
Drenthe	2	4.17%
Gelderland	2	4.17%
Groningen	3	6.25%
North Brabant	6	12.50%
North Holland	5	10.42%
Overijssel	3	6.25%
South Holland	5	10.42%
Utrecht	1	2.08%
Total	**48**	**100.00%**

Type of Accommodation	Number	Percentage
R.H from Private Sector	8	16.67%
R.H from Housing Agency	9	18.75%
Own House	31	64.58%
Total	**48**	**100.00%**

Education	Number	Percentage
High School	1	2.08%
MBO	4	8.33%
HBO/Bachelor	22	45.83%
Master	15	31.25%
PhD	6	12.50%
Total	**48**	**100.00%**

Living Status	Number	Percentage
Alone	10	20.83%
Share House	10	20.83%
with Family	28	58.33%
Total	**48**	**100.00%**

Marital Status	Number	Percentage
Single	26	54.17%
Single + Children	1	2.08%
Married	6	12.50%
Married + Children	15	31.25%
Total	**48**	**100.00%**

Energy Basics and Consumption:

In this part, the information related to each question about the “Energy Basics and Consumption” part have been presented.

Do you use any kind of Renewable Energy Technology in your house?	Number	Percentage	What Kind	Number	Percentage
Yes			Solar PV	13	59.1%
			Solar Collector	4	18.18%
			Indirect from Supplier	2	9.1%
			Isolation	1	4.5%
			Wind Turbine	1	4.5%
	19	39.58%	Heat Pump	1	4.5%
No	29	60.42%			
Total	**48**	**100.00%**		**22**	**100%**

Have you heard about the Dutch Government's National target of 14% Renewable Energy Production share in 2020?	Number	Percentage
Yes	39	81.25%
No	9	18.75%
Total	**48**	**100.00%**

Have you heard about EU and International targets about CO2 emission reduction? (e.g. Paris 2015)	Number	Percentage
Yes	44	91.67%
No	4	8.33%
Total	**48**	**100.00%**

What is your current Heating Energy Source and System in House?	Gas	RET (Solar)	RET (Wood)	Electricity	District Heating	Total	Percentage
As Only Source	37	0	0	2	1	40	**83.3%**
Combine Source	5	4	3	4	0	8	**16.7%**
Total	**42**	**4**	**3**	**6**	**1**	**56Systems**	**100%**
Percentage	**75 %**	**7.14%**	**5.36%**	**10.71%**	**1.79%**	**100%**	

How much gas (m3/year) do you use in your house per year approximately?			Number	Percentage	Average
Respond	Know about the amount	Gas Usage	27	56.25%	Average Consumption of people who use Gas: 1556.5
		No Gas Usage	4	8.33%	
	Do not Know about the amount		16	33.33%	
No Respond			1	2.1%	
Total			**48**	**100%**	

Level of Agreement	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agreement (4)	Strongly Agree (5)	Value	Average Value
Energy is always affordable	1	3	12	19	13	**184**	**3.83**
Energy is always available	1	4	5	13	25	**201**	**4.1875**
Energy is mostly from Fossil Fuels sources.	4	7	13	17	7	**160**	**3.33**

Solar Thermal Energy:

Regarding to the questions in the third part of the questioner about the "Solar Thermal Energy", the tables show the information:

Are you familiar with Domestic Solar Thermal Energy Systems?	Number	Percentage
Yes	35	72.92%
No	13	27.08%
Total	**48**	**100.00%**

Do you use Solar Thermal Energy Systems in your house for heating the space or water?	Number	Percentage
Yes	8	16.67%
No	40	83.33%
Total	**48**	**100.00%**

Do you think the Solar Thermal Energy could be a suitable alternative to reduce the dependency on Fossil Fuels for heating homes in the Netherlands?	Number	Percentage
Yes	43	89.58%
No	5	10.42%
Total	**48**	**100.00%**

Why do you think that Solar Thermal Energy has not adopted by Households in the Netherlands?	Number	Barrier	Number	Percentage
Expensive	22	Financial Barriers	**33**	**39.76%**
Gas is Cheap	7			
General Financial issues	4			
Radiation (technical)	12	Technical Barriers	**23**	**27.71%**
Other Technical Issues	2			
Complexity	4			
Peak days	1			
Place to implant the system	4			
Knowledge in companies	1	Social Barriers	**20**	**24.10%**
Knowledge and awareness in Families	16			
no feeling of urgency	1			
not attractive	2			
It's not good for the Netherlands (houses)	1	Political Barriers	**6**	**7.23%**
No attention of media and government	2			
it's not compulsory	1			
Political (fossil fuels)	1			
No offer form other side	1			
Other RETs are better	1	Other Barriers	**1**	**1.2%**
Total	**83**			**100.00%**

Do you wish to invest and install the "Solar Thermal Energy Systems" in your house?	Number	Percentage	Motivation	Number	Percentage	Barriers	Number	Percentage
Yes	24	64.86%	Financial Benefits	4	15.38%			
			National Responsibility	3	11.54%			
			Fun and Life style	1	3.85%			
			Environmental Issues	18	69.23%			
No	13	35.14%				Lack of Knowledge	3	18.75%
						Problem with House	5	31.25%
						Prefer to invest in other RETs	3	18.75%
						Financial Issues	4	0.25%
						General Feasibility	1	6.25%
Total	37	100%	26			16		

Does your landlord voluntarily wish to install "Solar Thermal Energy Systems" in your home?	Number	Percentage
Yes	1	4.76%
No	20	95.24%
Total	**21**	**100%**

If your landlord has not installed or indicated an intention to install “Solar Thermal Energy Systems” have you approached him/her?	Number	Percentage	If YES, please indicate the respond after asking your landlord	Number	Percentage
Yes	6	28.57%	Positive	1	16.67%
			Not Interested	5	83.33%
			Prepared to Install Solar Thermal Energy Systems	0	0%
No	15	71.43%			
Total	**21**	**100%**			

Solar Thermal Energy Systems” could count as advantage (interesting option) of the house when you are looking for a new house to rent?	Number	Percentage
Yes	15	71.43%
No	1	4.76%
No Difference	5	23.81%
Total	**21**	**100%**

Criteria:

Aspect/ Factor	Not Important at all (1)	Not Important (2)	Neutral (3)	Important (4)	Very Important (5)	Total	Average	Level of Importance
39. Increased Awareness about Energy Consumption	1	3	8	17	19	**194**	**4.04**	**8**
40. Positive impact on User's Quality of Life	2	5	7	20	14	**183**	**3.81**	**12**
41. Participation of Different Stakeholders from different levels in implementation (e.g. Companies, Municipalities)	3	6	17	14	8	**160**	**3.33**	**17**
42. Positive Environmental impact (e.g. Reduction of CO2 Emission)	2	1	3	18	24	**205**	**4.27**	**1**
43. Recyclable materials usage in design and production	1	5	14	14	14	**179**	**3.73**	**13**
44. Payback Time (Investment Return)	1	2	6	18	21	**200**	**4.17**	**4**
45. The Investment (Initial Budget) for installation	1	0	5	25	17	**202**	**4.21**	**3**
46. Influence on Energy Bills Reduction	2	2	6	16	22	**198**	**4.13**	**6**
47. Job creation (on both Local and National Level)	3	6	11	22	6	**164**	**3.42**	**16**
48. Safety of "SunThermal" for users and facilities	4	4	8	19	13	**177**	**3.69**	**15**
49. Understandability of the system for households and people	2	3	9	18	16	**188**	**3.92**	**10**
50. Innovation and use of advanced technology in the system	2	8	19	12	7	**158**	**3.29**	**18**
51. Efficiency of the system	0	2	5	24	17	**200**	**4.17**	**4**
52. Period which system works (e.g. whole of the year or only in summer)	1	3	8	18	18	**193**	**4.02**	**9**
53. Negative impact on Landscape and visual view	10	7	9	14	8	**148**	**3.08**	**19**
54. Availability of Facilities for implementation of "SunThermal" for any households in the Netherlands	4	0	13	19	12	**179**	**3.73**	**13**
55. Overall Affordability for the Households who wish to implant "SunThermal"	1	1	9	18	19	**197**	**4.1**	**7**
56. Availability of Governmental Subsidies	1	2	14	17	14	**185**	**3.85**	**11**
57. Reduction of Fossil Fuels Consumption	0	1	8	18	21	**203**	**4.23**	**2**

From the Criteria in the table, which do you consider the most important one? (You can choose more than one criteria)	Number of times which have been chosen	Percentage	Level of Importance
20. Increased Awareness about Energy Consumption	10	6.80%	**5**
21. Positive impact on User's Quality of Life	8	5.44%	**9**
22. Participation of Different Stakeholders from different levels in implementation (e.g. Companies, Municipalities)	5	3.40%	**13**
23. Positive Environmental impact (e.g. Reduction of CO2 Emission)	22	14.97%	**1**
24. Recyclable materials usage in design and production	1	0.68%	**17**
25. Payback Time (Investment Return)	21	14.29%	**2**
26. The Investment (Initial Budget) for installation	9	6.12%	**6**
27. Influence on Energy Bills Reduction	17	11.56%	**3**
28. Job creation (on both Local and National Level)	2	1.36%	**17**
29. Safety of "SunThermal" for users and facilities	4	2.72%	**10**
30. Understandability of the system for households and people	4	2.72%	**10**
31. Innovation and use of advanced technology in the system	0	0.00%	**19**
32. Efficiency of the system	3	2.04%	**14**
33. Period which system works (e.g. whole of the year or only in summer)	6	4.08%	**12**
34. Negative impact on Landscape and visual view	2	1.36%	**16**
35. Availability of Facilities for implementation of "SunThermal" for any households in the Netherlands	3	2.04%	**14**
36. Overall Affordability for the Households who wish to implant "SunThermal"	9	6.12%	**6**
37. Availability of Governmental Subsidies	9	6.12%	**6**
38. Reduction of Fossil Fuels Consumption	12	8.16%	**4**
Total	**147**	**100**	

Are there any other Criteria not included in the list above that you think are important?	Number	Percentage	What is the Criteria	Number	General Category	Total Number	Percentage
Answered	9	18.75%	Level of difficulty in installation	2	Technical	5	45.5%
			Ease of use	1			
			Duration of Installation	1			
			Surface and Indoor space which is needed	1			
			Positive price impact for future house-sale (better energy label)	1	Financial	2	18.2%
			Simplifying the Investment Procedure	1			
			Test and insurance of the Influence on people's Health	1	Health	1	9.1%
			Existence of neighborhood / city plans and strategies	2	Policy	2	18.2%
			Available and reliable technical Expert	1	Social	1	9.1%
No answer	39	81.25%			**12**		**100%**
Total	**48**	**100%**					

B. Interview

As it mentioned in 3.5. part, the Interviews have been held as face to face. The list interview have been presented in this part:

Interview contact page

	Name	Organization	Position	Email	Date
1.	**Bouwe de Boer**	Municipality of Leeuwarden	Energy Coordinator at the Department of Economic Affairs	bouwe.deboer@leeuwarden.nl	12.08.2016
2.	**Barend Leest**	Province of Friesland	Project Leader Sustainable Innovations	b.b.leest@fryslan.frl	22.09.2016
3.	**Richtsje van Berkum**	Province of Friesland	Energy Advisor, Local Energy Initiative, Solar Energy	r.vanberkum@fryslan.frl	22.09.2016
4.	**Heleentje Swart**	Nordwin College	Sustainability Coordinator	H.Swart@nordwincollege.nl	13.09.2016
5.	**Madelon van Kempen**	Nordwin College	Internship with focus on Energy and Climate VHL University of Applied Science	madelon.vankempen@hvhl.nl	13.09.2016
6.	**Bert de Vries**	Utrecht University	Professor/Institute for Sustainable Development Geoscience Department	B.J.M.deVries@uu.nl	17.10.2016
7.	**Bauke de Vries**	TU Eindhoven	Professor/ Urban Systems Department of Built Environment	b.d.vries@tue.nl	29.09.2016
8.	**Regina Bokel**	TU Delft	Assistant Professor/ Building Physics Architecture and Building Technology	R.M.J.Bokel@tudelft.nl	26.09.2016
9.	**Johan Kiewiet**	Ameland Energy Cooperation	Member of Board	johan@kooperaasje.nl	19.09.2016
10.	**Jan Klien Hesselink**	Ekwadraat	Senior Advisor	jkleinhesselink@ekwadraat.com	14.07.2016 02.10.2016
11.	**Pieter-Jan Duineveld**	Wilms	Senior Technical Advisor	pjd@wilms.nl	30.10.2016
12.	**Ton van de Ven**	Alius Energy	Sales Departement	ton.vandevan@aliusenergy.nl	22.09.2016
13.	**Aafke Postma**	Elkien Housing Agency	Strategic Relationship Manager	Aafke.Postma@elkien.nl	04.10.2016
14.	**Arjan van Timmeren**	TU Delft	Professor/ Environmental Technology & Design Department of Urbanism	A.vanTimmeren@tudelft.nl	18.11.2016

Interview guidelines

As in part 3.5. mentioned, the interviews were semi-structured based . There are several main questions which have been discussed with all interviewees and also, there are some important questions which due to the position and background of the interviewee have been discussed. The main questions which have been discussed in all the interviews:

1. What is the main ”Energy Source” for heating the Houses in the Netherlands and what are the future plans for this sector to become more independent from “Fossil Fuels”? What is the status of Renewable Energy Technology usage in houses?
2. What do you think about the “International Environmental Targets (for instance Paris Agreement)” and also “National Energy Targets (14% Renewable Energy production and Consumption by 2020 in the Netherlands)”? Do you believe they are reachable for the Netherlands and EU countries?
3. How do you see the current status and future of the Solar Thermal Energy Systems in the Netherlands? (mostly in the Houses and Domestic usage)
4. Is there any running project about “Solar Thermal Energy Systems” in the Netherlands?
5. Do you believe the “Solar Thermal Energy” could be a suitable alternative Energy Source for Heating Houses in the Netherlands?
6. What are the main barriers (in different aspects such as economic, social and technical) for adaption and developments of “Solar Thermal Energy Systems” by Households in the Netherlands?
7. What is the proper solution for these barriers? How can overcome these problems?
8. What are the main problems in different technical part (Radiation, Collector, Storage, Pump, Pipe, Auxiliary system) of the “Solar Thermal Energy Systems” in General? (for instance in comparison with Middle East the Radiation is lower in the Netherlands, also seasonal heat storage is harder than electricity storage)
9. What is the “Level of Importance” problems (such as efficiency and price) on the adaption of “Solar Thermal Energy Systems” by Households?
10. Are there any available proper design for “Solar Thermal Energy Systems for Heating Houses” in the Netherlands which is proved by government/province? I have been designing a model and system if you are interested I can show you and discuss it with you.
11. How can the proper “System Design” influence the Acceptance and Adoption of “Solar Thermal Energy Systems” by Households in the Netherlands?
12. What is the “Level of Importance” problems (such as efficiency and price) on the adaption of “Solar Thermal Energy Systems” by Households?
13. Who are the different Stakeholders which are involved in adaption and developments of “Solar Thermal Energy Systems” by Households?
14. How can these different stakeholders could be motivated for “Solar Thermal Energy Systems” adaption by Households?
15. Is there any point and suggestion that you want to add to this research

C. Technical

The Proper Technical Design is one of the main criteria which have mentioned in surveys and interviews and also, in have been identified in literature. In this part, the model and design which have been developed will be presented.

An in-depth literature study identified necessary formulas/equations and information which is needed to develop a proper model for Solar Thermal Energy Systems. Furthermore, due to available information the study contain "Demand Side and Auxiliary System Modeling" (9,12). For achieving a proper model and reliable results there are various steps which should take place:

- Irradiation: which could be define as available energy in the atmosphere (this is the information which Climate Offices will provide).

- Radiation: which could be define as available energy on the surface. It's based on different criteria such as Irradiation and Climate (Radiation is actually using for system modeling, For roughly calculation, due to the Netherlands information Radiation can be assumed as 0.8 Irradiation).

- Collector Design: Designing a collector is a complex subject regarding to different parameters which have important roles. The system will work based on this. The last output of this part will be the available energy which system is able to produce.

As it mentioned the calculation will start based on the Irradiation. Due to different days of a month have approximately same Irradiation and also, with respect to importance of the average irradiation for each month, the Irradiation will be calculated for the nominated day of the month only. These nominated days have been chosen based on the most similar "Hourly Distribution of Irradiation" for the whole of the month. Table 1 show this information:

Table 30: Nominated days for Irradiation/Radiation Calculations

Month	For Average Day of Month		
	Date	n	δ
January	17	17	-20.9
February	16	47	-13
March	16	75	-2.4
April	15	105	9.4
May	15	135	18.8
June	11	162	23.1
July	17	198	21.2
August	16	228	13.5
September	5	258	2.2
October	15	288	-9.6
November	14	318	-18.9
December	10	344	-23

The Irradiation Flux out of the atmosphere is 1367 watt per square meter which is not constant for the whole of days of the year, due to Earth distance fluctuations with Sun and other climate factures. The Equation 2 shows Solar Irradiation Flux for each days of the year.

$$G_{sc} = 1367\ {}^{W}/_{m^2} \qquad (Eq.1)$$

$$G_{on} = G_{sc}(1 + 0.033\cos\left(\frac{360n}{365}\right) \qquad (Eq.2)$$

Due to calculation of Irradiation in different hours of the day, the Equation 3 will be used. In this equation,

$$I_0 = \frac{12 \times 3600}{\pi} G_{sc}\left(1 + 0.33\cos\frac{360n}{365}\right) \times \left[\cos\phi\cos\delta\,(\sin\omega_2 - \sin\omega_1) + \frac{\pi(\omega_2 - \omega_1)}{180}\sin\phi\sin\delta\right] \quad (Eq.3)$$

Now, the atmosphere influence should be considered which is based on $k_T$factur:

$$k_T = \frac{I}{I_0} \qquad (Eq.4)$$

Due to available information, the practical measurements show that k_T is equal to 0.4 for the Netherlands. The importance of k_T is for calculation of beam and defuse radiation. Equation 5 show the how to calculate Defuse Irradiation based on k_T.

$$\frac{I_d}{I} = \begin{cases} 1.0 - 0.09k_T & for\ k_T \le 0.22 \\ 0.9511 - 0.1604k_T + 4.388{k_T}^2 & for\ 0.22 < k_T \le 0.8 \\ -16.638{k_T}^3 + 12.336{k_T}^4 & \\ 0.165 & for\ k_T > 0.8 \end{cases} \qquad (Eq.5)$$

Now do to outputs from Equation 3 and 5 which show the Irradiation, in respect to Equation 6, the Radiation can be calculated.

$$S = I_b R_b(\tau\alpha)_b + I_d(\tau\alpha)_d\left(1 + \frac{\cos\beta}{2}\right) + \rho_g I(\tau\alpha)_g\left(1 - \frac{\cos\beta}{2}\right) \qquad (Eq.6)$$

It should be mentioned in all the calculations, the Collector's Angel have been considered as Location's Altitude which for this specific project is 53. (all the angels in this calculations are Radian). In Equation 6, the $R_b$can be calculated based on the Equation 7:

$$R_b = \frac{\cos(\phi - \beta)\cos\delta\ \cos\omega + \sin(\phi - \beta)\sin\beta}{\cos\phi\cos\delta\cos\omega + \sin\phi\sin\delta} \qquad (Eq.7)$$

In Equation 6 and 7, β represent the Altitude angel, ϕ represent the Collector's angel (which as it mentioned is the same as β), δ is the angel based on monthly position of the Earth with Sun and

ω present the hourly angel of the Earth. The information regarding to δ have been shown in Table 1 and for Table 2 present information for ω :

Table 31: Omega for different hours

Time (Hour)	ω
6-7 AM	82.5
7-8 AM	67.5
8-9 AM	52.5
9-10 AM	37.5
10-11 AM	22.5
11-12 AM	7.5

Due to calculation of S in Equation 6, there is a need to $(\tau\alpha)_b$, $(\tau\alpha)_d$ and $(\tau\alpha)_g$be calculated which their equation have been shown below:

$$\tau_r = \frac{1}{2}\left(\frac{1-r_{\parallel}}{1+r_{\parallel}} + \frac{1-r_{\perp}}{1+r_{\perp}}\right) \qquad (Eq.8)$$

$$r_{\perp} = \frac{\sin^2(\theta_2-\theta_1)}{\sin^2(\theta_2+\theta_1)} \qquad (Eq.9)$$

$$r_{\parallel} = \frac{\tan^2(\theta_2-\theta_1)}{\tan^2(\theta_2+\theta_1)} \qquad (Eq.10)$$

$$\tau_a = \exp(-\frac{KL}{Cos\theta_2}) \qquad (Eq.11)$$

$$\tau = \tau_a \times \tau_r \qquad (Eq.12)$$

$$cos\theta_1 = sin\delta sin\varphi cos\beta - sin\delta cos\varphi cos\gamma + cos\delta cos\varphi cos\beta cos\omega + cos\delta sin\varphi sin\beta cos\gamma cos\omega + cos\delta sin\beta sin\omega \qquad (Eq.13)$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad (Eq.14)$$

$$n_1 = 1\,, n_2 = 1.5 \qquad (Eq.15)$$

$$\theta_{e,d} = 59.7 - 0.1288\beta + 0.001497\beta^2 \qquad (Eq.16)$$

$$\theta_{e,g} = 90 - 0.5788\beta + 0.002693\beta^2 \qquad (Eq.17)$$

$$\alpha\tau = 1.01\alpha\tau \qquad (Eq.18)$$

In all these calculations one of the most important criteria which have influence on all the equations is the absorber. Here we assumed that the absorber is a normal one which use is most Flat Plate collectors with the $\alpha = 0.97$. Due to all these equations and calculations the Irridation and Radiation have been modeled. Just for a sample the information about the Irradiation model have been presented below:

Table 32: Irradiation for different Months

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I (W/m^2)	79.4	136.4	218.5	300.9	355	375.5	365	322.7	249.4	160.2	93.2	66.4

For Collector Design, the main goal is to calculate the output temperature and efficiency of the collector with respect to Heat Transfer, Thermodynamic and Fluid Mechanic Laws. The equation below show the principals and the main way to calculate and model the Collector behavior.

$$Q_u = A_c\left[S - U_L\left(T_{pm} - T_a\right)\right] \qquad (Eq.19)$$

Equation 19 represent the output Energy from the Collector. A_c is collector's surface and U_L is the Insulation Factor (coefficient) which have 3 main parts for the losses from back, front and sides.

$$U_L = U_t + U_b + U_e \qquad (Eq.20)$$

Due to very low losses from sides (because the surface of the sides are so small) the energy losses from sides have been considered as zero. Equation 21 present the way to calculation U_t:

$$U_t = \left(\frac{N}{\frac{C}{T_{pm}}\left[\frac{(T_{pm}-T_a)}{(N+f)}\right]^e} + \frac{1}{h_w}\right)^{-1} + \frac{\sigma\left(T_{pm}+T_a\right)\left(T_{pm}^2+T_a^2\right)}{\frac{1}{\varepsilon_p + 0.00591Nh_w} + \frac{2N+f-1+0.133\varepsilon_p}{\varepsilon_g} - N}$$

$$f = \left(1 + 0.089h_w - 0.1166h_w\varepsilon_p\right)(1 + 0.07866N) \qquad (Eq.22)$$

$$C = 520(1 - 0.000051\beta^2)\ for\ 0^\circ < \beta < 70^\circ;\ for\ 70^\circ < \beta < 90^\circ\ use\ \beta = 70^\circ \qquad (Eq.23)$$

$$e = 0.430\left(1 - \frac{100}{T_{pm}}\right) \qquad (Eq.24)$$

AfterU_t, Equation 25 is for U_b calculation:

$$U_b = \frac{k}{L} \qquad (Eq.25)$$

Due to Equation 21 and 25 which the outputs are Insulation Factor (coefficient) and also with respect to $U_e = 0$, the U_L can be calculated.

The next step is modeling the Average Plate Temperature which will start with an assumption and after calculations and testing this assumption. This procedure will go on until the results become converged for the collector. Equations below show the way to this modeling

$$T_{pm} = T_{fi} + \frac{Q_u/A_c}{F_R U_L}(1 - F_R) \quad (Eq.26)$$

$$F_R = \frac{\dot{m}C_p}{A_c U_L}\left[1 - \exp\left(-\frac{A_c U_L F'}{\dot{m}C_p}\right)\right] \quad (Eq.27)$$

$$F' = \frac{1/U_L}{W\left[\frac{1}{U_L[D + (W - D)F]} + \frac{1}{C_b} + \frac{1}{\pi D_i h_{fi}}\right]} \quad (Eq.28)$$

$$C_b = \frac{K_b b}{\gamma} \quad (Eq.29)$$

$$F = \frac{\tanh[m(W - D)/2]}{m(W - D)/2} \quad (Eq.30)$$

$$m = \sqrt{\frac{U_L}{k\delta}} \quad (Eq.31)$$

For the modeling in this specific project, due to available information about the available Flat plat and PVT collectors in the market, there have been some assumption which presented below:

$$A_c = 3\ m^2$$

Diameter collector pipes, D = 1 in

$$m = 0.04\ {}^{kg}/_{s}$$

And also, other assumption about the Insolation which are available in the model and also can be changed for other projects. Table 4 shows the information of 8 collector in on row as an series of collectors.

Table 33: Collector's Information

No. of Series Collectors	$U_L(W/m^2K)$	$T_{fo}(K)$	η
1	1.9	293.5	0.88
2	2.11	298.7	0.81
3	2.22	303.4	0.74
4	2.28	307.7	0.68
5	2.34	311.7	0.62
6	2.38	315.2	0.56
7	2.42	318.5	0.51
8	2.45	321.5	0.47

The final delta T after eight collectors would be 33.5 c which means the output water would be 48.5 c with average efficiency of 65.9%. Several inputs such as input water temperature and velocity of water have influence on the re