Air pollution in Bosnia and Herzegovina: Solar energy as an alternative to Coal fired CHP plants

Written By:
Pekaric Ivona

Sustainable Energy Planning
and Management
Aalborg University

AALBORG UNIVERSITY
STUDENT REPORT

Department of Development and Planning
Sustainable Energy Planning and Management
Rendsburggade 14
9000 Aalborg
en.plan.aau.dk

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Author:

Ivona Pekaric

Pekaric Ivona

Supervisor:

Jakob Zinck Thellufsen

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Abstract:

This project investigates the possibility of solving the air pollution problem in Bosnia and Herzegovina by reducing emissions from CHP plant by utilizing solar energy. The case study of the project is Tuzla CHP plant. Institutional analysis has been undertaken in order to understand the political structure of Tuzla CHP plant and role that different actors have in achieving goals of reduced emissions. Second analysis is undertaken to investigate the feasibility of PV technologies as partial alternative to CHP plant. Lastly, questionnaires have been conducted to get an overview of overall citizens opinion on implementing PV technologies on their rooftops. The results of institutional analysis show that the institutional structure constrain Tuzla CHP plant on going towards reaching emission goals. The results of Analysis 2 explains to which extent can solar potential substitute CHP plan in electricity production and the benefits of its implementation from socio-economic perspective. Lastly, questionnaires show that citizens are mostly willing to install PV panels on their rooftops in case of Government subsidies.

Preface

This project is written by Pekaric Ivona to raise awareness of the air pollution problem in the country of Bosnia and Herzegovina. The author is investigating the possibility of utilizing solar energy and the possibility of reduction of electrical energy production in CHP plant in the Municipality of Tuzla.

The project is written in the time of Covid19 pandemic. Hence, interviews about citizens' opinions could not be handled in person.

I would like to thank to citizens who have participated in the on-line questionnaires.

Specially, I would like to thank to my brother Edi for selfless support and help.

List of abbreviations

SDG - Sustainable Development Goals

UN - United Nations

CHP Plant - Combined Heat and Power Plant

DH - District heating

GHG - Greenhouse gasses

PM - Particular matter

BIH - Bosnia and Herzegovina

NERP - National Emission Reduction Plan

RET - Renewable Energy Technologies

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Introduction 1

Bosnia and Herzegovina is among the most polluted countries in Europe in terms of air pollution. Air pollution is causing many health problems to the citizens and thus this problem is responsible for a large number of deaths. Moreover, according to UNEP, this country is accounted to be world's 2nd deadliest country in number of deaths caused by air pollution. Furthermore, the bad economical situation is Bosnia and Herzegovina makes this problem even more difficult to solve. [UNEP, 2018]

Bosnia and Herzegovina is rich in coal ore and consequently the economy is highly dependable on it. Thousands of workers are working in coal mines and the same number of families' existences depend on the coal industry. Meaning that people are surviving because of the coal and at the same time people are dying because of it. The biggest coal consumers are CHP plants which also present one of the biggest air polluters in this country. The other air polluters in country of Bosnia and Herzegovina worth mentioning are industry, transportation and residential heating systems.

This project will look into coal fired CHP plants and their contribution to air pollution problem. Furthermore, the solar potential of Bosnia and Herzegovina will be examined and analyzed to which extend solar energy can replace coal fired CHP plants. However, the society dependency on coal industry will be included in analysis, and obstacles of transition towards renewable energy will be analyzed. Lastly, the measures to outcome defined obstacles will be presented.

Problem Analysis 2

This chapter describes the global air pollution problem, its impact on human health and actions implemented by UN to address mentioned problem.

2.1 Global air pollution problem

World, nowadays, is facing some serious major problems, such as climate change, poverty, inequalities, hunger etc. In order to combat the World's major problems, the UN has set 17 Sustainable Development Goals and established targets to achieve which all 193 UN member states are obliged to follow. [UN, 2021]

One of the biggest problems is the air pollution problem. Not only that air pollution has a negative impact on the quality of life of citizens, but it is also aggravating to the problem of the climate change which is responsible on melting glaciers and endangering the existence of numerous plant and animal species. According to UNEP, air pollution presents the biggest environmental risk on population's health. It is estimated that this problem is killing 7 million people every year. Air pollutants are causing different diseases, such as: chronic respiratory disease, heart attacks, strokes and lung cancers. Air pollution is responsible for every fourth death caused by heart attack and about every third death derived from chronic respiratory disease, stroke and lung cancer. [UNEP, 2018]

The main two Sustainable Development Goals set by UN, that are addressing and combating the air pollution problem are Sustainable Development Goal number 7: Affordable and Clean Energy and Sustainable Development Goal number 13: Climate Action. These goals are advocating for the reductions of CO_2 emissions and increase of the renewable energy share in the global energy mix. The target year of achieving these is 2030. [UN, 2021]

Furthermore, UN has undertaken measures to achieve abovementioned goals. The Paris Agreement is one of them. Signed in Paris, in December of 2015 by all 196 UNFCCC parties, the Paris Agreement represents an international legal binding treaty on climate change. The treaty obliges member states to reduce greenhouse gas emissions that adversely affect climate change which is the most significant effect of the air pollution. The biggest source of greenhouse gas emissions are fossil fuels. Member states are, among other directives, expected to reduce fossil fuel usage in order to achieve the goals of The Paris Agreement. Fossil fuels are mostly used in transportation and industry sector, as well as for electricity and heat production. [EPA, 2021] [UN, 2021]

2.2 Air pollution in Bosnia and Herzegovina – Global and Local problem

While most European developed countries have managed to reduce air pollution problem by outcoming fossil fuels and implementation of the renewable energy technologies, there are still countries that are highly dependable on fossil fuels and whose citizens are having serious health consequences due to the air pollution problem. One of them is Bosnia and Herzegovina.

Bosnia and Herzegovina is, according to WHO, a European country with the highest rate of deaths caused by air pollution. [UNICEF, 2021] Furthermore, UNEP has declared this country as the second deadliest in the world in terms of deaths caused by the same problem. [UNEP, 2018] Moreover, according to UNICEF, each year are 44 000 years of life lost due to air pollution. The most polluted areas in this country are bigger cities. The 5 most polluted ones based on UNICEF's report are: Kakanj, Tuzla, Sarajevo, Lukavac and Zenica. The biggest polluters are combined heat and power plants, residential heating system, industry and transportation. [UNICEF, 2021]

Bosnia and Herzegovina is still highly dependable on coal which is used for production of electricity and heat in large combined heat and power plants with the total installed capacity of 2081 MW, as well as in residential heating systems and industry. Furthermore, more than 54% of the electricity produced in Bosnia and Herzegovina is produced in mentioned coal-based power plants. The highly dependency on the coal is deriving from the fact that Bosnia and Herzegovina has plenty of coal mines and that its economy is also highly dependable on it. [Dzemila Agic, 2016]

Not only that fossil fuel combustion in Bosnia and Herzegovina causes a local air pollution problem, but is also aggravating to the global air pollution problem. While global air pollution problem, as mentioned previously, is related to CO_2 emissions, and has direct impact on the climate change, local air pollution is caused by pollutants such as PM, NO_X, SO_2 etc. and has direct impact on citizens health. This project will look both into global polluter – CO_2, as well as major local polluters PM, NO_X and SO_2. [Gabeljic, 2018] [GmbH, 2015]

2.3 Air polluters in Bosnia and Herzegovina

As mentioned before, Bosnia and Herzegovina has a serious problem with air pollution. Polluters that have the major impact on this problem are SO_2, NO_X, CO_2 and fine particular matters $PM_{2.5}$ and PM_{10}. Nonetheless, gasses with the smaller impact should be mentioned as well. Those are H_2S, CO, O_3, NH_3 and black carbon. However, due to lower impact they have on air pollution problem, these are rarely being measured and their emissions are not limited by any law or regulation in this country. [UN, 2019] [UNICEF, 2021]

2.3.1 SO_2

Usually, SO_2 emissions in other parts of Europe are not having a big share in air pollutants emissions. This is mainly due to laws and regulations which do not allow high concentration of sulfur dioxide in fossil fuels. However, Bosnia and Herzegovina does not have as strict laws and policies regarding concentration of sulfur in fossil fuels. This makes SO_2 emissions one of the biggest treats to citizens and environment of this country. [centar za ekologiju i energiju, 2018] Compared to the EU legislation of maximum 10 ppm of sulfur concentration in diesel and gasoline, in Bosnia and Herzegovina this limit is many times higher. For gasoline, the maximum amount of sulfur is 150 ppm and highly 350 ppm for diesel. Furthermore, the quality of coal used in residential heating systems is bad. It has sometimes up to 5% of sulfur. If it is compared to an EU country such as Ireland, which has limit of 0.7%, it is noticeable how much also residential heating systems are aggravating to this problem. However, biggest emitters of sulfur dioxide are CHP plants. Even though, CHP plants' SO_2 emissions are limited in National emission reduction plan approved by Secretariat of the Energy Community, they have been in total exceeding SO_2 limit values for more than 9 times. [centar za ekologiju i energiju, 2018] SO_2 is affecting the respiratory system by causing pulmonary dysfunction and exacerbation of asthma and chronic bronchitis, it makes people susceptible to respiratory tract infections, creates eye irritation and deterioration of the heart problems, as well as increasing the risk of ischemic strikes. [CEE, 2013]

2.3.2 PM

Next to the SO_2 emission, one of the biggest threats for residents' health are fine particular matters: $PM_{2.5}$ and PM_{10}. Numbers 2.5 and 10 are presenting their diameters in micrometers. Because of its smaller size, $PM_{2.5}$ is more dangerous because it is easily accessing humans' lungs and blood system and causing multiple health problems and diseases. The report from October 2019 called Air Pollution Management in BIH stated that more than 3300 citizens die every year prematurely due to the exposure of $PM_{2.5}$ in this country. Fine particular matters emissions in EU are limited with value of $10g/m^3$. Reason for its high concentration in Bosnia and Herzegovina is that their limit values are set to be two times higher than in the EU, which is $20g/m^3$. Moreover, these limit values are being often multiple times exceeded. Biggest sources of this polluters are CHP plants and residential sector, and the reason is the combustion of the solid fuels. The fact that makes situation with the PM concentration in this country even worse is that mainly $PM_{2.5}$ are not being monitored at all. Usually, the one that is monitored is PM_{10}, and as mentioned

before, PM_{10} is way less harmful than $PM_{2.5}$. [UN, 2019] PM negatively affects the respiratory system (asthma, worsening of asthma, chronic obstructive pulmonary diseases, development of stunted lungs, lung cancer), cardiovascular system (cardiac arrhythmia, acute myocardial infarction, congestive heart failure) and nervous system (ischemic stroke). [CEE, 2013]

2.3.3 NO_X

Beside sulfur dioxide and fine particular matters, nitrogen oxides are also representing one of the major air polluters in country of BIH. Similar as other polluters, these gasses are also mainly produced throughout the coal combustion in CHP plants. In the year of 2014, each CHP plant has emitted more than 2000 tons of NO_X. The reduction of NO_X emissions of BIH are included in this country's emission reduction plan, which aims to limit NO_X emissions to 200 tons per year per each CHP plant in the year of 2026. There is no available data on how much CHP plants have reduced NO_X emissions in the meantime and how likely they are to follow the national plan. [Ioana Ciuta, 2019] NO_X affects the occurrence of asthma, exacerbation of asthma, chronic obstructive pulmonary disease, development of stunted lungs; cardiac arrhythmia and ischemic stroke. [CEE, 2013]

2.3.4 CO_2 footprint

Even though CO_2 is not considered as a threat for humans' health it is considered as an air pollutant in terms of climate change, and it will be discussed in this project. The majority of CO_2 emissions, which is almost 74%, are emitted through the coal combustion processes. This number is 2.4 times higher than the European average. This fact proves again how highly dependable this country is on coal. Moreover, according to Worldometer, this country is taking 25th place in terms of coal reservation in the world, 28th place in terms of coal production and 40th place in terms of coal consumption. [Worldometer, 2021] The rest of the CO_2 emissions are coming from gasoline and diesel (22.15%) and the same 1.93% share come as from natural gas as well as from other sources. [Worldometer, 2021] The positive fact is that the CO_2 emissions per capita in the year of 2016 were slightly below the European average and were accounted to be 6.45 tons. [Worlddata.info, 2021]

2.4 Electrical sector and CHP plants

2.4.1 Electrical sector and renewable energy potential

Dominated by 5 large coal-based CHP plants, where 54% of electrical energy is produced, electrical sector is one of the biggest sources of the air pollution problem in Bosnia and Herzegovina. The rest of the electricity is being generated in hydropower plants, wind power plant, solar power plants and mini hydropower plants. Among the renewables, hydropower plants are dominating. 98% of renewable energy is generated in 15 hydropower plants that has 1958.15 of MW installed energy. The rest 2% of renewable energy is produced in mini hydropower plants (159 MW), wind power plant (50MW) and solar power plants (18.15MW). [Gabeljic, 2018] However, according to UNDP, the potential of the renewable energy in country of Bosnia and Herzegovina is huge. Furthermore, the solar photovoltaic energy in particular has the biggest energy potential according to the same source. [UNDP, 2014] Furthermore, the wind, biomass and water potential should not be forgotten either. As previously mentioned, currently the most utilized renewable energy technologies are hydropower plant. However, it is estimated that only 40% of the hydro potential has been used. Deriving from that fact, there is still room for expanding this technology. Considering the fact, that 50% of this country's territory is covered by forests, there is a big biomass potential as well. Wind energy has recently started to being explored and develop as well, when the first and so far, only wind power plant Mesihovina is built in 2018 with installed capacity of 50 MW. [INOGENALLIANCE, 2019]

2.4.2 CHP plants and NERP

As previously mentioned, CHP plants are biggest electricity producers while also being biggest air polluters in Bosnia and Herzegovina. There are 5 CHP plants with total installed capacity of 2081 MW. The biggest CHP plant is situated in Tuzla with 723 MW installed capacity. The second biggest is in located in the city of Kakanj with 466 MW of installed capacity. Each of the other three CHP plants have 300 MW installed capacity and are located in cities: Gacko, Ugljevik and Doboj. All five CHP plants are located nearby the mines that are mojority owned by the same state-owned company. Tuzla CHP plant is accounted to be a biggest polluter among all CHP plants in Bosnia and Herzegovina. [Ioana Ciuta, 2019] The main reason why these CHP plants are declared as some of the biggest polluters is bad quality coal that is being combusted in them. All 5 CHP plants are combusting lignite which is the lowest quality coal in this country. With share of moister up to 70% and relatively big share of ash and sulfur compared to other types of coal, lignite cannot be transported or sold on the market due to economical unprofitability. Furthermore, this is the main reason of building all 5 CHP plants near lignite coal mines. Furthermore, their low energy efficiency, which is around 30%, required even higher coal consumption. CHP plants are obliged to follow The Paris Agreement as well as National Emission Reduction Plan that got approval from the Secretariat of the Energy Community in the year of 2016. NERP has set emission reduction plan for each CHP Plant for the period from 2018 to 2027. However, in year of 2018, all CHP plants have significantly exceeded the maximum values set by the NERP. Sulfur Dioxide (SO_2) presented the biggest problem since its emissions from these facilities have been even up to 9 times higher than the maximum allowed values. [Ioana Ciuta, 2019] [EIA, 2015] Even though, CHP plants

are accounted for some of the biggest polluters in Bosnia and Herzegovina, this country is still planning on building new CHP plants. Furthermore, at the moment, new block of Tuzla's CHP plant is being built. Tuzla CHP plant is the biggest polluter among the aforementioned CHP plants. [UN, 2018] However, Bosnia is being the only Balkan country that is exporting energy. Concluded from everything mentioned above, the Government is rather earning money through the energy export than protecting it citizens. [Euronews, 2019]

Problem Formulation 3

This chapter outlines the problem that is under this project's investigation.

Derived from the problem analysis, it is noticeable that the country of Bosnia and Herzegovina has among all European countries, one of the biggest problems with the local air pollution while at the same time exacerbating the problem of global air pollution. In this country, air pollution has become a deadly treat to the citizens as well as a major danger for the environment and one of the biggest reasons is coal dependency.

Many gases are responsible for the air pollution problem, such as SO_2, NO_X, $PM_{2.5}$, PM_{10} and CO_2. There are many different sources of this emissions, but most common are CHP plants. Moreover, they are accounted to be the biggest emitters for majority of air pollutants. Most of the emissions' limits stated in National Reduction Emission Plan, are being exceeded by CHP plants.

Nonetheless, the country of Bosnia and Herzegovina still has a big renewable energy potential, especially in solar energy.

However, due to CHPs profitability and coal dependable economy, the Government of Bosnia and Herzegovina is not doing much to fight this problem and improve it. Therefore, there is an urgent need of addressing this problem. This project will investigate:

1. *To which extent can solar energy be utilized for production of electrical energy in order to reduce emissions produced by coal-based CHP plants in Bosnia and Herzegovina?*
2. *Which will be barriers to this transition and which measures could be implemented in order to outcome them?*

Delimitations

- Only four most concentrated air pollutants have been analyzed: CO_2, SO_2, NO_X and PM.
- Since Tuzla CHP plant currently has excess heat that is being wasted, only the substitution of electricity production will be looked into in this project. [Centralno grijanje Tuzla, d.o.o., 2009a] [Centralno grijanje Tuzla, d.o.o., 2009b]
- Citizens opinion will be collected from 100 questionnaires. Hence overall citizens' opinion will be concluded from those 100 questionnaires from people from 100 different households in Tuzla Municipality.

Research Design 4

This chapter is describing the overall research design, as well as applied methods and theories and the overall project's structure.

4.1 Applied Theories

This section will outline and describe the applied theories that have been used in order to answer research questions.

4.1.1 Choice Awareness theory

When an old, fossil fuel dependent, energy system needs radical changes, the theory of choice awareness can be applied. Choice awareness theory finds, presents and analyzes the technical alternatives of a current system. Actors in power will always advocate for technologies that they can benefit from, which in this case are coal-based CHP plants. CHP plants are favored by the government because country's economy is dependable on them and government is earning a lot of money by producing electricity and heat in them through coal combustion process. As mentioned before, coal used in these plants cannot be sold and transported internationally due to its low quality. Hence, it is affordable only to use it locally in local CHP plants. Moreover, not only that this fossil fuel energy is being produced for Bosnian and Herzegovinian market, but also being exported and sold to neighbor countries. To sum the previously mentioned, the reason why the government will always favor coal-based energy production is due to its large profit. In this project, this theory is needed to present alternatives which in this case will be solar energy. The choice awareness theory will be applied in the Analysis 2. [Lund, 2014]

4.1.2 Institutional theory

Institutional theory is an approach which can be applied when an investigation or/and understanding of a topic or a problem related to institution are needed. Institutional theory aims to understand how companies respond to external pressure from institutions and organizations. In order to better understand the behavior of CHP plant, and the Government influence on them and their mutual relationship as well as the way and reasons that the Government favors CHP plants, institutional theory have been combined together with an institutional analysis in the Analysis 1 chapter. Analysis 1 will partially give an answer to the research question 2. [Geels, 2004]

4.1.3 Regulatory Policy Measures

In the discussion part of this project, some measures will be proposed that could outcome the obstacles of the transition from CHP plants to solar energy technologies. In order to do so, the understanding and usage of regulatory policy measures theory is needed. Two types of regulatory policy proposals exist, and they are indirect and direct policy measures proposals. On the one hand, traditional laws and rules set by the Government belong to direct policy measures. On the other hand, informational (media, webpages, community meetings) and economic (taxes, subsidies) measures that only indirectly influence some sector represent indirect policy measures. [B. Arts and P. Leroy, 2006] [Glen Hepburn, 2021]

4.2 Research Development

A figure called Research Onion, shown on Figure 4.1., is used in this project to illustrate the research design of the project. It contains six step that define different aspects of the research design, as well as methods used in the project. It starts with the outer layers. First layer is called philosophy, after which approach, strategy, choice, time horizon and techniques and procedures have been presented. [Thesismind, 2019]

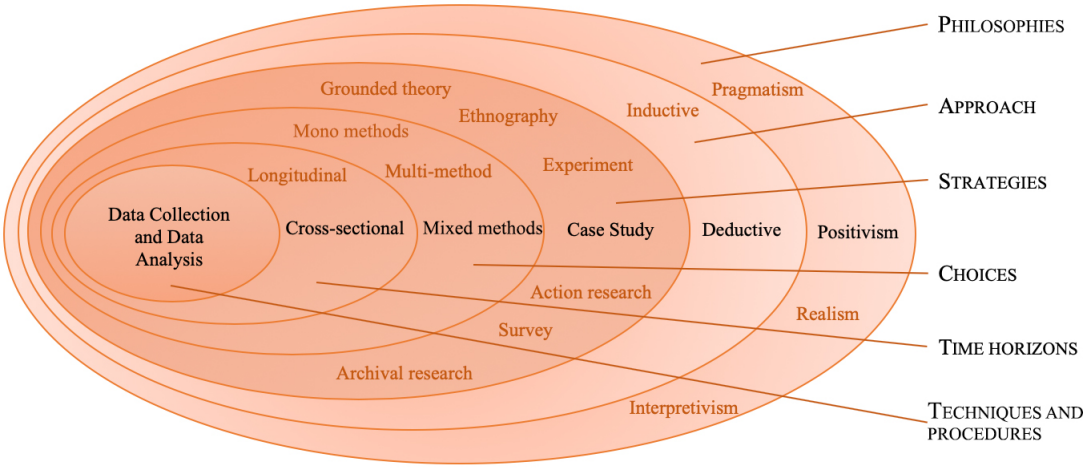

Figure 4.1. Research Onion illustrates the research design of the project. It contains 6 layers. In each layer, different options are presented, but once that are in the middle in lack letters present the option used in this project. [Thesismind, 2019]

4.2.1 Philosopy

Philosophy used in this project is Positivism philosophy. Positivism philosophy is based on the fact that scientific knowledge is true and acceptable. Furthermore, positivism advocates that a hypothesis is able to be tested and derived from the scientific knowledge. This project's hypothesis is that the electricity production from the CHP plant can be substitute with the electricity production from PV panels. Moreover, knowledge that will be obtained through this project is usable and can be replicated for projects with similar quantifiable results. [Thesismind, 2019]

4.2.2 Approach

The approach this project is based on is called inductive approach. This approach is starting with an observation. The observation of this project is that CHP plants are highly impacting on worsening the air pollution situation in Bosnia and Herzegovina. After the observation, a pattern is found: all 5 CHP plants are combusting low quality coal and are in charge of more than 50% of electricity production. Furthermore, this coal is not being able to be sold and there is a huge dependency of the economy on it. Afterwards, a hypothesis is developed: solar energy has big potential and is barely used, therefore it can substitute one part of energy derived from fossil fuels. At the end of the project, based on the further analysis of the hypothesis a theory will be developed. [Research Methodology, 2021]

4.2.3 Strategies

This project's strategy is case study strategy. It is also considered as a method of this project. The case study is the CHP plant in Tuzla. This case study is chosen because of the fact that this area is the most polluted one in the whole country. Deriving from that fact, and from the fact that case study findings can be also generalized to similar cases, the idea is if the air pollution problem in the most pollutes area can be partially solved with solar energy, then the other CHP plans could follow the same strategy. Moreover, Tuzla area is one with the less solar irradiance, which means that in the other areas, energy production could be even bigger than in the area of Tuzla. Based on the findings for this case study in the analysis 1 and 2 and the possibility of generalization, the policy measures proposals for the whole country will be presented in the discussion chapter. [Stakes, 1995]

4.2.4 Choices

Fourth layer of the research onion is called choices. There are three different choice that a project can be based on. Which choice is used in the project, depends on the type/types of data used in the same project. There are 2 data types: qualitative (descriptive) data and quantitative (numerical) data. This project will use both type of data, and in that case the choice is mixed methods. Furthermore, both type of data will be obtained through literature review method. [Thesismind, 2019]

4.2.5 Time Horizons

In the fifth layer of the research onion, time horizon is determined. Cross-sectional time horizon is used in this project. In the cross-sectional time horizon, relevant data is data from the past which is collected at one point of time and used in the project. On the other hand, longitudinal time horizon represents the idea of data collection and observation for the longer period. [Thesismind, 2019]

4.2.6 Techniques and Procedures

Techniques and procedures represent the sixth layer of the research onion figure. In this layer, the processes of data collection and data analysis have been explained.

Data collection

Literature review

A method called literature review is used to gather needed data for this project. There are two different types of data: qualitative and quantitative, and they can be obtained from primary and secondary sources. Data gathered from primary sources is often called first-hand data, whereas data obtained from secondary sources is called second-hand data. First-hand data is gathered through observations, personal interviews, surveys etc. Second-hand data is data made and analyzed by other organisations and researchers. In this project, both qualitative and quantitative data will be gathered from both primary and secondary sources. [Benedictine University, 2021]

Questionnaires

A hundred of citizens were asked to take online questionnaires to gather data regarding their awareness of the air pollution problem and their willingness to implement PV projects on their roofs. The targeted group were those who co-own or own houses. The overall citizens opinion is concluded based on these hundred undertaken questionnaires. Data obtained through questionnaires is later used in discussion chapter for answering the reasearch question 2 about the barriers of implementation of solar technologies. Furthermore, some measures to overcome mentioned barriers have been proposed based on this data.

Data analysis

In this chapter, methods used for data analysis will be explained.

Analysis 1

The institutional analysis will be conducted in order to answer the research question 2: "Which will be barriers to this transition and which measures could be implemented in order to outcome them?". In this case institutional analysis is needed to understand actors and political structure, which actors are involved in this decision and how they are related to each other as well as actors possible behavior towards the transition. It is conducted through 4 steps. The first step is underlining energy goals in terms of the air pollution reduction. Second step is the actor analysis. The actor interaction analysis is the third step. And the final step is the discussion of outcome of previous two analysis.

Analysis 2

In order to answer the research question 1: "To which extent can solar energy be utilized for production of electrical energy and heat in order to reduce emissions produced by coal-based CHP plants in Bosnia and Herzegovina?" Analysis 2 will be undertaken. It is starting with solar potential technology analysis and benefits in terms of reduced air polluters' emissions that it would cause. Furthermore the analysis of those benefits from

socio-economic point is made. The analysis finish with the social impact and awareness assessment.

4.3 Visualised Project Structure

The project's overall structure is visualised on figure 4.2.

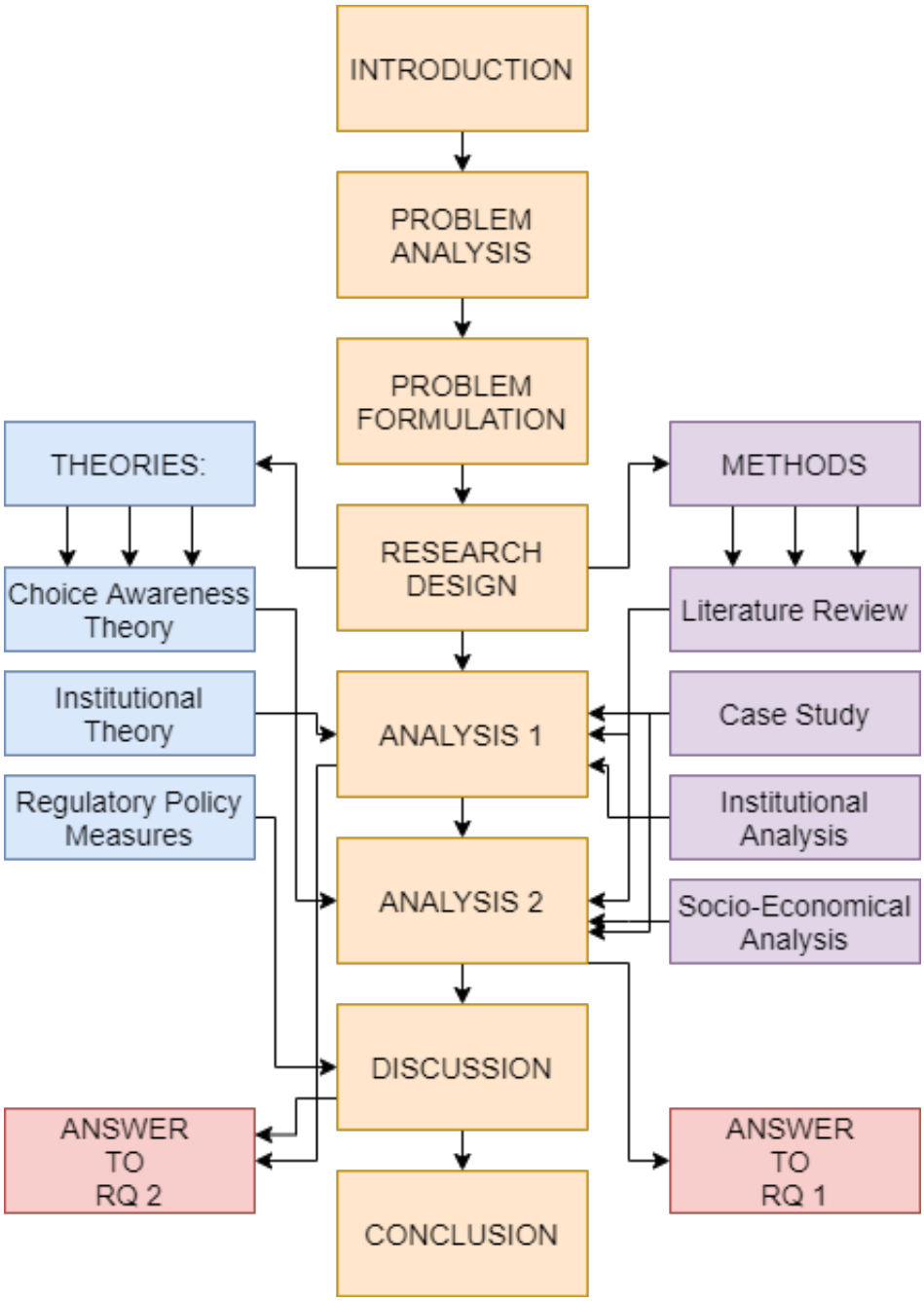

Figure 4.2. This figure is illustrating the project's structure.

Case Description 5

In this chapter the chosen case study of the Tuzla CHP plant and its impact on citizens of Municipality of Tuzla will be described.

5.1 Tuzla CHP Plant

The study case of this project is CHP plant located in the Municipality of Tuzla. The project is addressing the local air pollution problem that this CHP plant is making. The next two chapters will address the potential solar energy solution of the local air pollution that Tuzla CHP plant makes and investigate the obstacles that could appear in this transition. The municipality of Tuzla has 132,000 inhabitants. About 75% of the population of this municipality lives in an urban area, and the rest of the population is located in rural areas. Tuzla CHP plant is located close to the urban area of the city and represents the biggest CHP plant in Bosnia and Herzegovina which produces 50% of electrical energy in the aforementioned country, while also being the biggest air polluter among all the CHP plants in this country. It is owned by company called Elektroprivreda Bosne i Hercegovine. Tuzla CHP plant supplies the citizens of Tuzla Municipality with electric and thermal energy. Around 60% of households in this municipality are connected to district heating system. The district heating system of this municipality is the most developed one in the whole country of Bosnia and Hercegovina which supplies around 22 225 households with thermal energy.

The construction of this CHP plant has started in 1959. The first power block was finished in 1963 (32MW). The year after that, the second power block was built with the same installed capacity. In the following years of 1967, 1971, 1974 and 1978, power blocks three (100MW), four (200MW), five (200MW) and power block six (215MW) had been installed. In the year of 1996, the power block six received maintenance and installed capacity was raised by additional 8 MW, which in total makes now 223 MW. It currently has 4 operational power blocks, while the first two power blocks of installed capacity 2*32MW were permanently discontinued. Currently, the power block 7 is being built with the planned capacity of 450 MW. This project is estimated to be finished by 2023. Once this project is completed, the power block 7 will substitute power blocks 3,4 and 5 which will be permanently discontinued. Current total installed capacity of Tuzla CHP plant is 723 MW and it annually produces around 3.1 GWh of electrical energy.

Tuzla CHP plant annually burns from 3.3 to 4 million tons of coal. 70% of the mention coal comes from coal mine Banovici while the other 30% comes from coal mines in Gracanica and Bukinje. This coal is of low quality with high percentage of sulfur (up to 5%) and relatively high moisture percentage which reduces the efficiency of this fossil fuel. Annually, Tuzla CHP plant emits around 50 000 tons of sulfur dioxide, around 5 800 tons of NO_X, 1 200 tons of $PM_{2.5}$ and PM_{10}. In addition to, 4 million tons of CO_2 is being emitted every year. Besides the air polluters, another side product of coal burning is slag. Around one

million cubic meters of slag is being produced every year in this CHP plant. This slag is being deposited in 5 nearby neighborhoods named: Plane, Dreznik, Jezero, Divkovici I and Divkovici II. In the aforementioned neighborhoods, around 30 million cubic meters of slag have already been deposited. In these disposal sites and nearby them, high concentrations of nickel, chromium, arsenic and other life-threatening metals have been found. These metals represent a big treat to health of local people. Other waste liquids this CHP plant discharges into the rivers Jala and Spreca whose water uniformed locals use to irrigate their agriculture lands. This way, the safety of local agriculture products is being compromised. [centar za ekologiju i energiju, 2018]

Air pollution problem caused by Tuzla CHP plant is causing wide range of health problems of citizens living in the Municipality of Tuzla such as heart disease, respiratory problems, strokes and cancers. In the Municipality of Tuzla, each year, the air pollution caused by Tuzla CHP plant causes 1 death of newborn baby, 231 cases of chronical bronchitis, 1 143 bronchitis and asthma cases among children. Furthermore, each year due to Tuzla CHP's emissions, 17 new cases of hospitalization of patients with respiratory problems and 157 hospitalization of patients with heart problems are occurring. Moreover, these health-threatening emissions are causing 131 008 workdays to be lost due to sick leave annually among the population of this municipality. Finally, it is estimated that in the year of 2020, 67 million euros are lost due to Tuzla CHP plant's negative impact on citizens health. [CEE, 2013]

Municipality of Tuzla and Tuzla CHP plant have been chosen as a study case because of the following two reasons:

1. Municipality of Tuzla is one of the most polluted areas in Bosnia and Herzegovina.
2. Tuzla CHP plant is the biggest polluter among all CHP plants in Bosnia and Herzegovina.

Institutional Analysis 6

In this chapter, Tuzla CHP plant is analyzed as an institution through the institutional analysis to get a better overview on how the actors and their interaction could impact on the idea of substituting coal fired CHP plants with PV panels.

The purpose of this analysis is to understand the political structure of the Bosnian Energy sector. The focus of the institutional analysis will be in actors which has interest in Tuzla CHP plant. This analysis will be obtained in 4 steps, as described in the Research Design chapter.

6.1 Goals of Bosnia and Herzegovina's Energy Sector

As a member of the UN, Bosnia and Herzegovina has complied on achieving SDGs set by the UN. Of a big interests in terms of this project, are goals 7 and 13 which are to combat the climate change through the CO_2 emission reduction and to ensure affordable and clean energy. Moreover, in order to reduce air pollution, Bosnia and Herzegovina has adopted National Emission Reduction Plan in the year of 2014. The focus of this plan is the reduction of emissions emitted in CHP plants in country of Bosnia and Herzegovina. This plan refers to reducing emissions of 3 most predominant air polluters: SO_2, NO_X and PM. National Emission Reduction Plan is a 10-year plan for the period between 2018 and 2027. The goal of this plan is to gradually reduce the SO_2, NO_X and PM emissions over the mentioned ten years. The referent year of the plan is the year of 2013. The goal is to reduce the emissions of NO_X 2.35 times in the year of 2027 compared to referent year of 2013. Furthermore, the goal of reduction of particular matters emissions in 2027 is 4.5 times compared to 2013. And finally, the SO_2 emissions are to be 22.75 times reduced in the year of 2027 compared to 2013. [EIA, 2015]

However, it has been proven that none of the 5 CHP plants are following the aforementioned plan. Only in the year of 2018, the maximum values of all 3 polluters have been significantly exceeded by all 5 CHP plants. The biggest problem was with sulfur dioxide (SO_2). It has been discovered that SO_2 emissions from CHP plants in the year of 2018 were up to 9 times higher then allowed. [Ioana Ciuta, 2019]

6.2 Actor Analysis

Actor analysis is the second step of the institutional analysis and it will analyze actors and political structure of the institution. Actor analysis will only consider and include relevant actors which are defined as actors with economical or political interest or strong interest in Tuzla CHP plant and are able to make decisions on the behalf of Tuzla CHP plant. To get a better overview, actors relevant to Tuzla CHP plant are divided into the following 5 categories: Educational institution, Energy and Environment NGOs, Political institution, Companies and Local community, and are shown in figure 6.1.

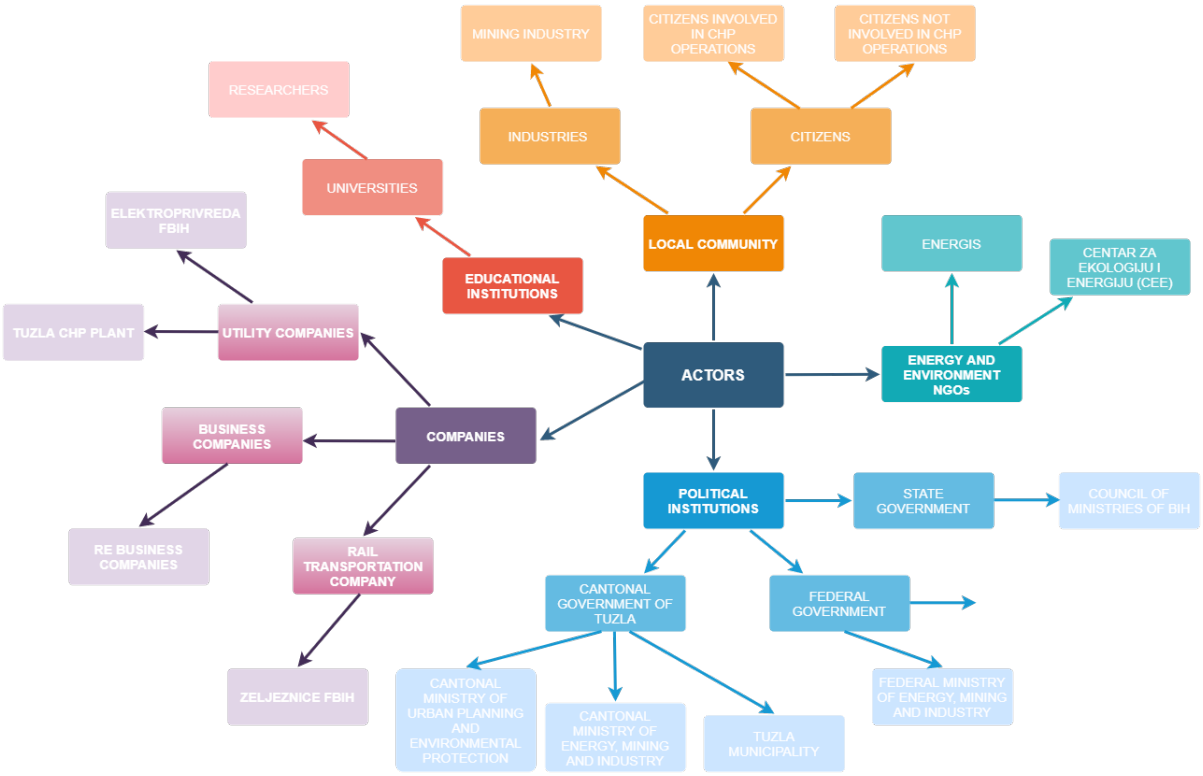

Figure 6.1. This figure shows actors relevant to Tuzla CHP plant. Each category is assigned by a different color to get a better overview in the rest of the institutional analysis.

Actors' involvement can be explained through their value, perception and resources. The actors' value represents the interest in going a certain direction or desired future situation. The interest of actors can also be described as their main goal or an objective. The actors' perception is an actor's worldview on both, the institution and the other actors. Actor's resources represent their economic capacity and they determine the possibility of reaching each actor's objectives.[Wil A. H. Thissen, 2013]

In the following 5 sub-chapters, all the relevant actors will be described as well as their values, perceptions and resources. In other to compare all the relevant actors and analyze how likely each one of them is to participate actively in reaching the goals of Bosnian Energy sector considering their resources, two assessment will be made. First assessment is regarding each actor's objectives and perception. According to the following criteria,

each actor will be assigned a score from 1 to 5:

- Actors will get score 5 if they are actively participating in achieving of the BIH's Energy Goals
- Actors will get score 4 if they are planning to participate in achieving goals
- Actors will get score 3 if they have an interest in Bosnian Energy Sector
- Actors will get score 2 if they have to be persuaded to participate in reaching goals
- Actors will get score 1 if they are against the goals of the BIH's energy sector

Second undertaken assessment is regarding each actor's resources and is similar to the first assessment. The score each actor gets regarding their resources is based on the following criteria:

- Actors get score 5 if they already have allocated resources for reaching the BIH's Energy Goals
- Actors get score 4 if they have plans for allocating resources for reaching the mentioned goals
- Actors get score 3 if they have allocated resources for a certain part of the goals
- Actors get score 2 if they have possibility for allocating the resources for reaching BIH's energy goals
- Actors get score 1 if they have no possibility of allocating resources for achieving mentioned energy goals

6.2.1 Political Institutions

Relevant actors under Political Institution Category are divided into 3 sub-categories in order to get a clearer overview of them. The first category is The State Government of Bosnia and Herzegovina. Since there is no ministry of energy on a national level, the only relevant actor to Tuzla CHP plant under this political institution is The Council of Ministries of Bosnia and Herzegovina. Council of Ministries of BIH is a body that adopted the BIH's National Emission Reduction Plan. Therefore, the Council's perception and objectives match the Bosnian energy goals of emissions' reduction. Consequently, they will be given a score of 5. However, even though they have adopted the NERP, the Council of Ministries of BIH have not created a clear plan for allocating resources to achieve aforementioned plan, but rather have forwarded that task to the Federal Government who is also a majority shareholder of Elektroprivreda of BIH (90% of all shares) who is the owner of Tuzla CHP plant. Therefore, they have been given a score of 2. The second sub-category is The Federal Government of BIH. Under this institution, actors relevant to the Tuzla CHP are The Federal Ministry of Energy, Mining and Industry and The Federal Ministry of Environment and Tourism. Under the BIH Constitution, these ministries have to follow guidelines and plans set up by The Council of Ministries of BIH. Therefore, The Federal Ministry of Energy, Mining and Industry and The Federal Ministry of Environment and Tourism are actively participating in reaching BIH's energy goals and are both given a score 5. Furthermore, these ministries have been allocating resources for a part of the plan in terms of sulfur filters for CHP plants and are given score 3.

The third sub-category is Tuzla Cantonal Government. The relevant actors under this institution are The Municipality of Tuzla, The Cantonal Ministry of Energy, Mining and

Industry and The Cantonal Ministry of Urban Planning and Environmental Protection. These 3 actors have more locally based priorities an perception of energy goals. However, all 3 bodies are actively taking part in achieving national energy goals through allocation of the part of the resources for achieving the plan. Hence, all 3 actors are given score 5 in assessment of perspective and objectives and score 3 in resource assessment.

6.2.2 Energy and Environment NGOs

Energy and Environment Non-Governmental Organizations are actors relevant to Tuzla CHP plant. Under this sub-category, there are two actors that are operating in the Municipality of Tuzla and advocating for cleaner energy and protection of the environment and therefore have an interest in operations of Tuzla CHP Plant as well. These actors/organizations are: "Energis" and "Centar za Ekologiju i Energiju". Investigating the way both organizations are operating, their visions, goals and projects they are working on, it is concluded that "Energis" is planning to engage in reaching Bosnian and Herzegovinian energy goals. Therefore, "Energis" is given score 4 on the objective scale. On the other hand, "Centar za Ekologiju i Energiju" is an organization that advocates for lowering emissions, but is not participating or planning in participating in reaching energy goals. Consequently, "Centar za Ekologiju i Energiju" is given score 3 on actor's objectives and perception scale. Investigating these two actors' resources, it has been found that both actors have not allocated yet any resources. However, both organizations have possibility of allocating the resources and therefore, both actors are assigned a score 2 on resources scale.

6.2.3 Local Community

Local community is a third sub-category of relevant actors. Under this category, there are 2 sub-categories. First one is industry and the relevant actor is mining industry. As previously mentioned, the biggest consumer of Tuzla's local mines is Tuzla CHP plant, and the mining industry business is uncertain in case of shutting down this CHP plant. Therefore, the whole mining industry in Tuzla Municipality, depends on operations of Tuzla CHP plant. The interest of the mining industry is to continue to supply Tuzla CHP plant with coal and therefore this industry has no interest in supporting energy goals nor has possibility of resource allocation. Consequently, mining industry as an actor is given score 1 on both, objective and resources scale. The second sub-category under local community are citizens. They are divided into two categories. First category of citizens are citizens that are involved in Tuzla CHP plant's operations which includes CHP plant workers, workers in local mining industry and workers in rail transportation services. (The involvement of rail transportation company will be explained in sub-chapter 6.2.5. Companies.) Due to bad economy situation and uncertainty of their job positions in case of reducing the CHP plant's operations, these citizens are expected to not have an interest in participating in reaching the goals. Therefore, they have been given a score 1 on an objective assessment scale. Furthermore, due to their inability of resources allocation, they have been given the same score of 1 on a resources' allocation assessment scale. The other group of citizens are citizens that are not involved in any Tuzla CHP plant related operation. Reaching energy goals and improving air quality is in the interest of this category of citizens. Therefore, this group of citizens is assigned with a score 3 on objective assessment and score 1 through

the resource assessment since they have no possibility for allocation of the resources for achieving NERP.

6.2.4 Educational Institutions

The fourth category of relevant actors is Educational Institutions. Under this category, university's researchers in field of energy and environment are considered as relevant actors. These researchers have interest and knowledge about the energy sector and could be able to allocate resources through processes of writing projects and applying for funds. Therefore, score 3 is given to them through the first assessment about objectives and score 2 is given on a second assessment regarding resources.

6.2.5 Companies

There are three sub-category of companies that represent relevant actors in this analysis and they are: Rail transporting company, Utility Company and Business Companies. In the Municipality of Tuzla, rail transportation is mostly used for the transportation of coal from the local coal-mines to Tuzla CHP plant. As mentioned before, coal from these mines is low in quality and therefore it would not be profitable to transport it anywhere else, export it or sell it. Therefore, interest of the rail transportation company called "Zeljeznice FBIH" is to keep the current situation and continue its operations of coal transportation to Tuzla CHP Plant. Any reduction of coal combustion in Tuzla CHP plant would have direct impact on the business of this company and would lower its profit. Therefore "Zeljeznice FBIH" are against aforementioned goals and are given score 1 on the objective scale. Moreover, "Zeljeznice FBIH" does not even have possibility for resources allocation for reaching energy goals. Therefore, they are given score 1 on the resources allocation scale as well. Second group of relevant actors are companies that own Tuzla CHP plant. Elektroprivreda FBIH is a major shareholder of the Tuzla CHP plant with more than 90% of shares and the rest shares are owned by number of companies and organizations. As these all companies have the same objective they will be assessed together as a CHP plant Tuzla. CHP plant Tuzla is obliged to comply with national emission reduction plan and reach national goals. However, it is proven that Tuzla CHP plant has not reached goals for the year of 2018 and therefore instead of score 5 it is given score 4 and score 3 for partially allocating resources for meeting the NERP's requirements since it has been investing only in measures to reduce NO_X. The third sub-category are renewable energy related business companies. These companies' interest is profit. Therefore they have an interest in the energy sector of Bosnia and Herzegovina and it is possible for them to allocate resources for achieving emissions reduction through investments in renewable energy. However, these investments must be proved to be profitable. Therefore, business companies, on objective scale, are given score 3 and score 2 on scale for allocation of resources.

6.2.6 Sub-conclusion: Actor Analysis

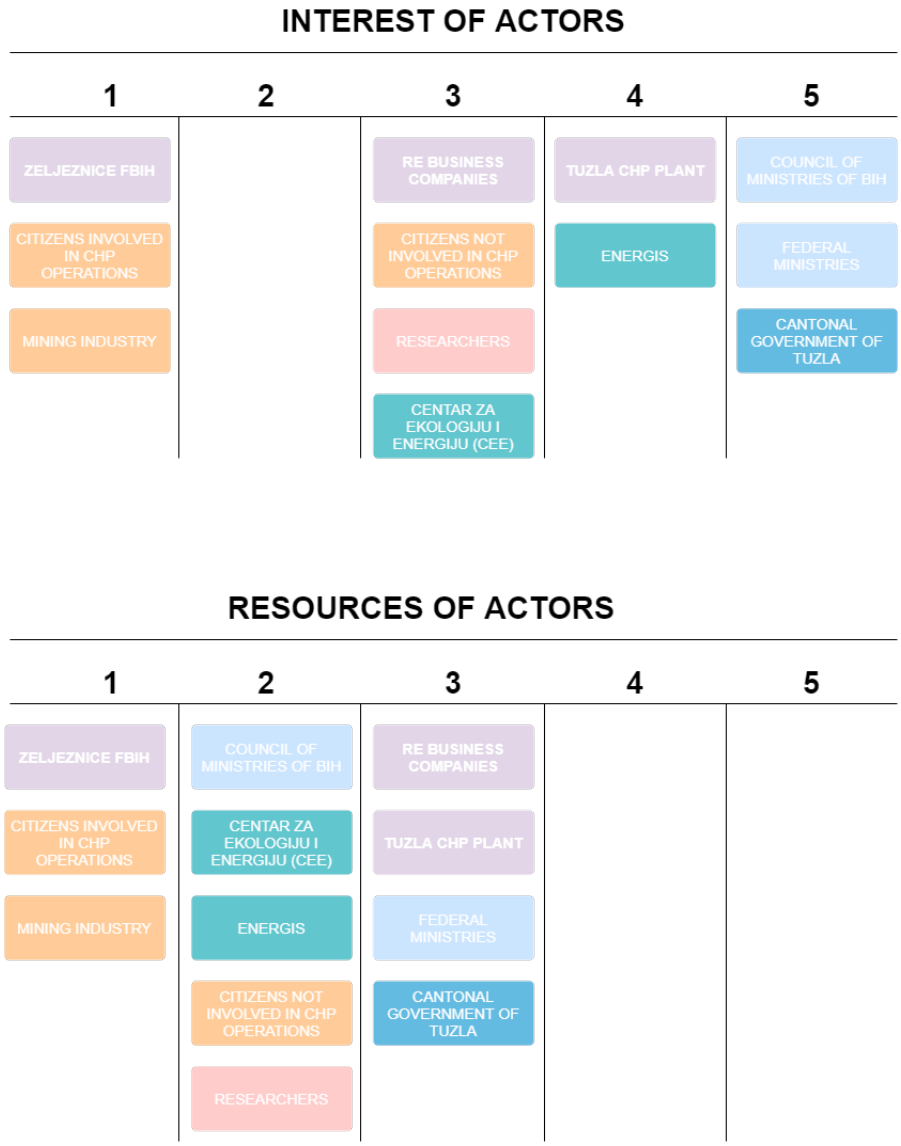

Figure 6.2. This figure shows the comparison of different relevant actors based on their interest and resource scores.

On the figure 6.2. relevant actors are compared and grouped based on the score they were assigned in interest and resources assessment. The lack in resources in achieving lower emission goals is noticeable. This lack also justifies the fact that NERP has not been achieved for the year of 2018 due to the lack of resources.

In the following figure 6.3., relevant actors are compared based on both their objectives and resources. Actors in grey area are unlikely to participate in achieving BIH's energy plans and goals. Whereas, actors that can be found in circle are most likely to participate in this transition.

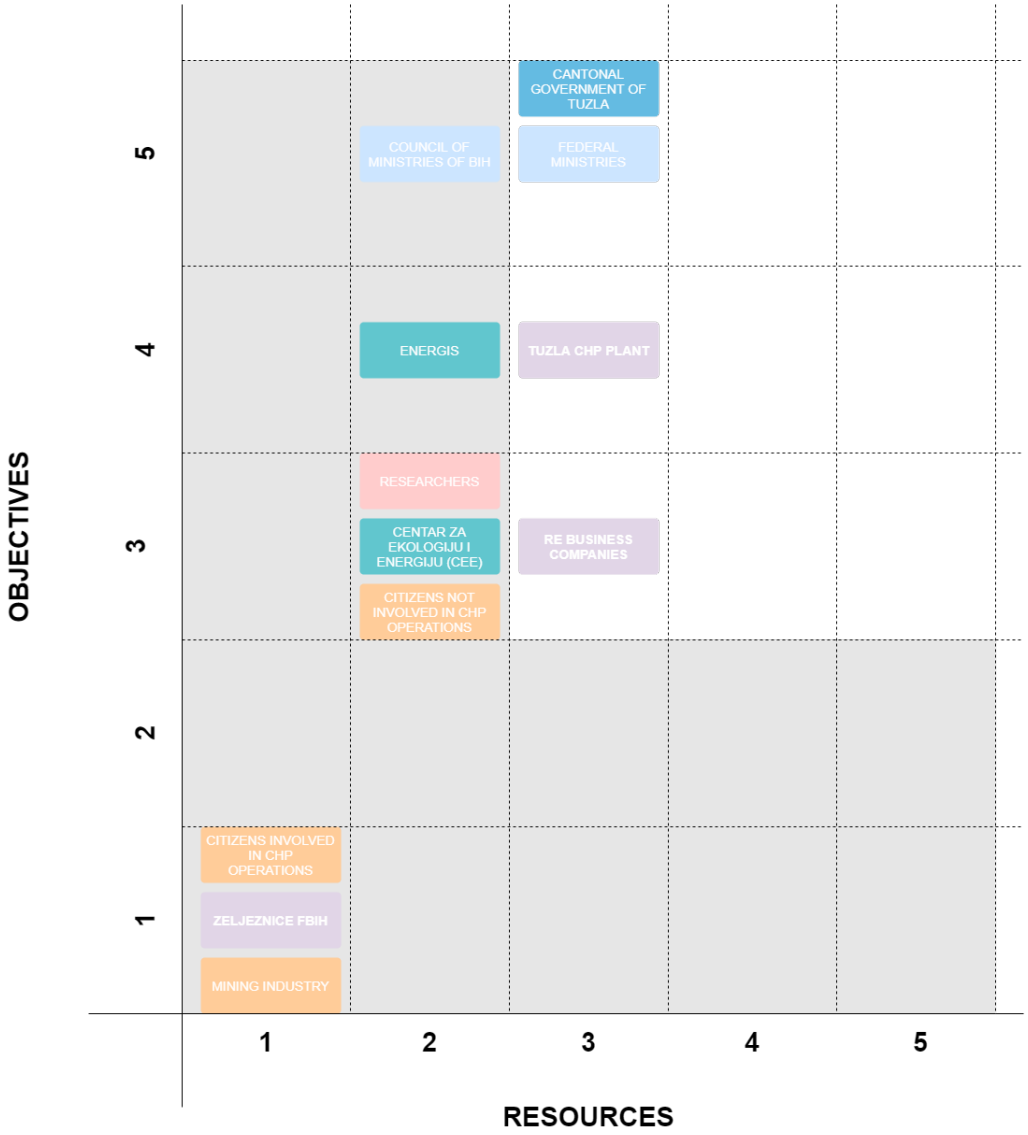

Figure 6.3. This figure represents the comparison of different relevant actors based on their objectives and resources and points out the actors that are likely to participate in achieving 2027 goals.

6.3 Actor Interaction

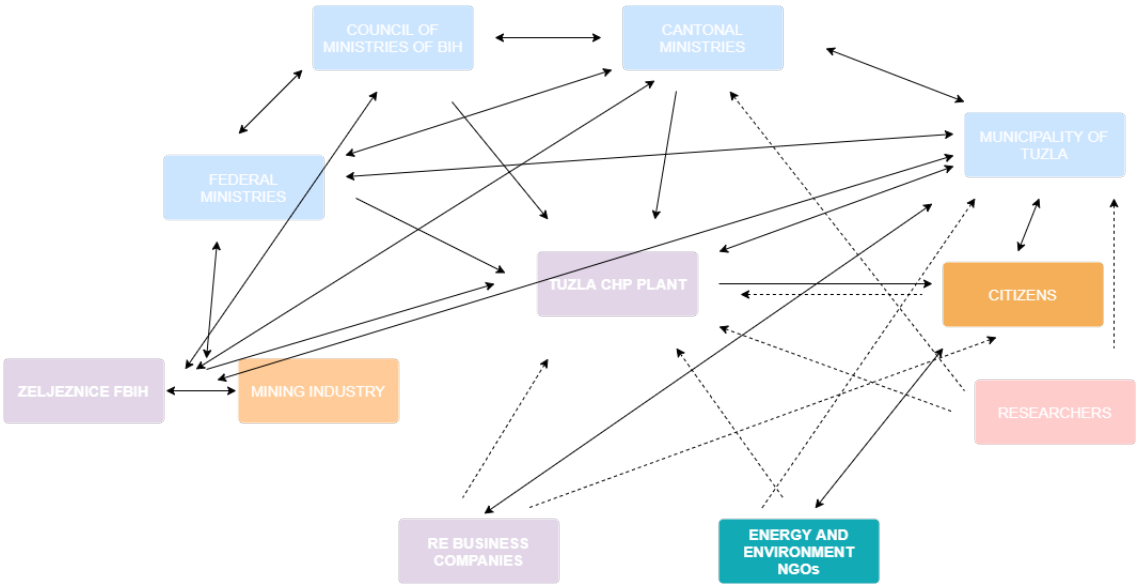

Figure 6.4. Figure displays the interaction between actors. Full arrow shows direct involvement and striped arrow represents indirect involvement.

The interaction between actors, analyzed in previous chapter, is shown on the Figure 6.4. All the actors are either directly or indirectly interacting with Tuzla CHP Plant. All three level of the Government as well as Municipality of Tuzla are directly interacting with each other and are directly involved in operations of Tuzla CHP Plant. Minding that mining industry and Zeljeznice FBIH are mostly owned by the Government, their mutual interaction is clear. The consequences of possible reducing the energy production in CHP plant would have a big impact on both rail-transporting company and mining industry. In this scenario, The Government would lose a lot of money by limiting the operations of the two mentioned sectors since the Government is their major owner. This interconnection seems to be one of the reasons for not achieving 2018 NERP's goals. Business companies are directly interacting with Municipality of Tuzla and indirectly their operations are affecting citizens. Researchers are through their researches indirectly impacting the operation of CHP plant and the Municipality of Tuzla under the assumption that mentioned researches are related to CHP plant emissions, renewable energy potentials and similar topics.

6.4 Discussion

The discussion is the fourth step of the institutional analysis. In this chapter, it will be discussed weather different actors constrain or enable Tuzla CHP plant to reach NERP goals and participate in reaching SDGs. Furthermore, this chapter will seek for the answer why have not this CHP plant achieved goals for 2018 and what measures and policies could be implemented to achieve them until 2027. The Council of Ministries of Bosnia and Herzegovina is a governmental body that has adopted National Emission Reduction Plan for a 10-year period until the 2027. In the first year of 2018, goals for emission reductions from CHP plants have not been achieved. Some of the emissions have been exceeded up to 9 times. The reason lies in the fact that the Council has not allocated resources for achieving this plan and it is uncertain who is responsible for allocating the resources. Under the constitution, the Federal Government must follow decisions and plans of the State Government. The Tuzla CHP plant is in major ownership of Elektroprivreda FBIH, company owned by Federal Government. However, Federal Government is also an owner of Zeljeznice FBIH, a company assigned to transport coal from mines to CHP plant, as well as a major owner of mines which supplies CHP plant with coal. Therefore, if Federal Government invest in RET and lower the production, it will affect their profit from these other two state-owned companies. Importing higher-quality coal, that would reduce emissions would also affect the business of aforementioned companies. Since the current power-blocks are relatively old and are planned to be discontinued in the near future, investing in renovation of the old power-blocks to increase their efficiency is an unprofitable investment for the Government. Therefore, it is visible that the Federal Government is in position of choosing between profit and citizens and environment wellbeing. According to emission reports from 2018, it is clear that the Federal Government has chosen profit. If the Government continues to go at this pace, the goals for 2027 will not be achieved either. Therefore, new measures and policies need to be adopted. However, it needs to be mentioned that political structure of the institution is not constraining CHP plant to comply with the goals, but it is making it more difficult due to Government's interests in mining industry and rail transportation. The measures and policies that would support this transition need to be adopted on the state level. The Council of ministries of Bosnia and Herzegovina is the body that should be in charge of adopting them. Firstly, the Ministry of Energy on the state level should be established and one in charge of adopting other decisions. Furthermore, it should be decided who is in charge of allocating resources for reaching the plan. Moreover, anyone who is not meeting each year's goals should bear the monetary consequences. The aforementioned measures would support the achievement of goals set by NERP. Moreover, there is a need for a clear plan on how to reach 2030 SDGs. Lastly, the negative impact that this transition would have on mining industry and rail transportation need to be diminished and it needs to be assured that no person would lose their job. This requires a new project to investigate the possibilities to still profit from the coal with all the barriers that were mentioned previously in the project.

The next chapter will analyze the technical possibility of utilizing solar energy and that way reducing the energy production in the CHP plant in purpose of reducing emissions.

6.5 Sub-conclusion: Institutional Analysis

The institutional analysis is done in purpose of understanding how political structure of BIH's energy sector is affecting Tuzla CHP plant in achieving emissions reductions goals. It is concluded that different actors do have different interest and that conflict of interest is happening and resulting in barriers for reaching goals. The first barrier is the Government interest in mining industry and rail transport. These sectors would lose their profitability in case if Tuzla CHP plant would reduce its energy production. The second barrier are the workers that would lose job in these sectors in case of that scenario. Furthermore, it is found that there in no certain plan on who should allocate the resources for achieving the aforementioned goals. Moreover, it is found that one of the reasons for not achieving the goals of 2018, is the fact that no actor has fully allocated the resources.

Solar Potential Assessment Analysis

7

In this chapter the feasibility of implementing PV panels in order to reach NERP's goals will be analysed. Furthermore, social impact and acceptance assessments will be undertaken.

The analysis 2 will be discussed based on the criteria for meeting the NERP's goals for 2027 in reducing emissions from Tuzla CHP plant. As mentioned, there are different plans for different gasses, but the most demanding reduction is regarding SO_2 emissions which are to be reduced to 22.75 times before 2027 in order to meet the goals of the plan. In case of reduced energy production for meeting the 22.75 times reduced SO_2 emissions, NO_X and PM goals will be met as well. Currently, Tuzla CHP plant has not invested in any measures to reduce SO_2 emissions, whereas some measures have been undertaken for the NO_X reduction, which is the second reason for choosing to make a scenario for setting SO_2 emissions below 2027 limit. However, investing in renewable energy is not the only tactics for achieving these goals. There are some measures that requires investing in the current fossil fuel technology such as the installation of a desulphurization plant within the current CHP plant and investing in technologies that will increase efficiency of the current CHP plant. However, since the newest power block in Tuzla CHP plant was built 43 years ago, it is decided for this project to focus to new renewable solutions rather than to re-invest in the relatively old CHP plant.

As discussed in the problem analysis chapter, solar energy has an unused potential in Bosnia and Herzegovina. Therefore, this project will investigate the possibility of utilizing solar energy in order to reduce GHG emissions from Tuzla CHP plant.

This analysis will start with calculations of area needed for installation of PVs in order to reduce GHG emissions for reaching 2027 goals set by NERP. According to the obtained results and estimated possible panel placement space in the Municipality of Tuzla, it will be discussed whether it will be possible to implement that project and reach the goals only with this type of the renewable energy technology. Furthermore, the investment costs, profitability of the project and reduced emissions will be calculated as well as the amount of reduced costs spent on medical treatment of citizens with health problems caused by the air pollution. Moreover, the societal impact assessment and societal acceptance assessment will be undertaken at the end of the analysis.

7.1 Solar Potential Assessment

The average annual electrical energy production in Tuzla CHP plant is 3600 GWh annually. It requires 3.3 million tons of coal to be used in combustion process. Annual SO_2 emissions are directly proportional to the amount of coal burned in a thermal power plant, so is the annual production of electricity directly proportional to the amount of coal consumed. Therefore, to reduce SO_2 emissions by 22.75 times, the coal consumption needs t be reduced 22.75 times and so does the electrical energy production. Hence, without any additional technology installed in CHP plant for improving the efficiency and reducing SO_2 emissions, in order to reach NERP's plan, electrical energy production needs to be reduced 22.75 times in Tuzla CHP plant until the year of 2027. The yearly production of electrical energy in the year of 2013 was 3854 GWh and it required usage of 4103000 tons of coal through which combustion process it was emitted 65808 tons of SO_2 in the mentioned year. To meet the SO_2 emission 2027 NERP goals, the production of year 2027 should be reduced to 169.4 GWh/year. Therefore, the rest of 3684.9 GWh should be covered by solar energy. [EIA, 2015]

7.1.1 Estimation of solar irradiation power per m^2

For the estimation of solar irradiation power per square meter in the Municipality of Tuzla, monthly data for the solar irradiation for Tuzla has been obtained through PVGIS-SARAH for the year of 2016 as well as data for the annual average number of sunny hours. The yearly solar irradiation is calculated as a sum of monthly solar irradiation and is estimated to be 1268.92 kWh/m^2. The number of sunny hours estimated for the Municipality of Tuzla is 1928 according to "Fotonaponska postrojenja u Bosni i Hercegovini". Average solar Irradiation power per square meter is calculates as

P_{SI}=yearly solar irradiation/number of sunny hours

and for Municipality of Tuzla it is calculated to be 0.658 kW/m^2. [Abdulah Aksamovic, 2019] [Commission, 2021]

7.1.2 Estimation of the amount of area suitable for installation of solar technologies

In this sub-chapter, three different types of possible areas for installing PV power plants will be analyzed. Those are: residential buildings, water surfaces of accumulation lakes and macro-locations that are unpromising land.

Residential Buildings

There are two types of housing units in the Municipality of Tuzla, houses and buildings. In this assessment, they need to be separately analyzed due to the difference in their roofs. Houses have hip roofs, whereas buildings have flat roof. The average apartment area is 77 m^2. Number of apartments in buildings with the flat roof is usually 3 and more. [Dzemila Agic, 2016] According to Agency for Statistics Bosnia and Herzegovina, there are 22040 housing units with one apartment and 6477 units with two apartments. These are estimated to be houses with hip roofs with an average roof area of 105 m^2 according to the research "Fotonaponska postrojenja u Bosni i Hercegovini – stanje i perspective". However, usually only one side of the roof is used for solar technologies installation which is on the sunny side, and that halve the usable roof area to 52.5 m^2. In total it is estimated that there is 1157100 m^2 of the hip roof area available for solar technologies installation. [Abdulah Aksamovic, 2019] The usability of the roof depends on the orientation of the house. Depending on the orientation, houses can be roughly categorized into the following 4 groups: East to West, North to South, North-East to South-West and North-West to South-East. Depending on their orientation, each household will be assigned with the coefficient of techno-economic certainty of construction of solar plants in terms of house orientation. The most ideal one is East to West therefore their coefficient is 1. The most unfavorable orientation is north to south and is assigned with coefficient 0.2. The other two orientations are in between from aforementioned 2 cases and are assigned with factor 0.5. Due to the hilly relief, the orientation of the houses is usually formed according to the slope of the land, and the orientation towards the sides of the world is rarely used. Therefore, an even distribution of all directions is assumed. Taking aforementioned assumption and coefficient, the total amount of available roof area for installing PV panels and/or solar collectors is 636405 m^2. [Abdulah Aksamovic, 2019] [za statistiku BIH, 2013]

According to Agency for Statistics Bosnia and Herzegovina, there are 1959 apartments in the buildings in the Municipality of Tuzla. The average numbers of floors per building is 13 and the average number of apartments per floor is 3, which gives in total 39 apartments per building. In total it is estimated to be 50 buildings with the flat roof top of an area of 3 average apartments. That gives 50 buildings with 231 m^2 of flat roof, which is in total 11550 m^2 of the flat roof area. However, it is estimated that around 22% of flat roofs is unusable which leaves 9009 m^2 of possible used area. [za statistiku BIH, 2013] The total amount of roof area from both houses and buildings is 645 $414m^2$. This area is suitable for PV panels, solar thermal collectors and photovoltaic thermal hybrid solar collectors, depending if the priority is electricity or heat production or in the third case both. Since this project is regarding lowering the emissions from CHP plant that supplies citizens with both electricity and heat, the potential of third technology of photovoltaic thermal hybrid solar collectors will be analyzed.

Water surfaces of accumulation lakes

The second type of surfaces that are assessed for the solar technology implementation are the water surfaces of the accumulation lakes. Accumulation artificial lakes are suitable for the installation of PV power plants. This technology is slightly more expensive than terrestrial ones. It offers a number of advantages that should be seriously considered: better efficiency due to cooling of the panel, use of already occupied surface, less evaporation of water from the lake. [Pasalic, 2018]

The only accumulation lake nearby Tuzla Municipality, that is located in Tuzla Canton is the Modrac Lake whose water surface is 17 100 000 m^2 and is located on the elevation of 200 meters. However, this whole area cannot be used for installing PV power plant. It is estimated that if only 20% of the surface would be covered in PV panels, normal functioning of the accumulation will not be compromised which includes: functioning of accumulation in terms of required level variations, retention of existing secondary functions of accumulation, such as fishing, tourism, etc., as well as elimination of the influence of the shadow of the surrounding relief. [Abdulah Aksamovic, 2019] [Trapani, 2014]

Therefore, 20% of 17100 000 m^2 is 3 420 000 m^2 of a possible area for implementation of solar power plant.

Macro-locations - unpromising land

According to the study "Uticaj solarnih elektrana na elektroenergetski system Bosne i Hercegovine", the only favorable macro-location for the construction of solar power plants, nearby Municipality of Tuzla and located in Tuzla Canton, is in the area called Dubrave. Based on the mentioned study, this area has a surface of 4 000 000 m^2. [CEE, 2013] This macro-location is suitable for the installation of solar power plant and concentrated solar power plant. However, due to the higher affordability of the solar power plants, compared to the concentrated once, only solar power plants will be considered.

7.1.3 Estimation of the possible electrical energy production through solar technologies

The formula for calculating the electrical energy output is

E = A * r * H * PR

“A” stands for the area suitable for installing the photovoltaic panels and as discussed previously it is 645 414 m^2 of the roofs.

"H" is the annual average solar irradiation and in Tuzla it is 1268.92 kWh/m^2. [Commission, 2021]

“r” stands for efficiency of PV panel and is in average between 15% and 18%, for this project’s purpose, the efficiency of PV panels is accounted to be 16% will be used. [www.photovoltaic software.com, 2021]

“PR” is performance ratio or coefficient for losses and its default value is 0.75. [www.photovoltaic software.com, 2021]

E=98 277 448 KWh = 98.3 GWh, yearly. As seen from the calculation, the potential of the rooftops is covering 2.7% of the energy production needed to be covered to meet NERP’s goals.

Now, the solar energy potential of the water surface of the nearby accumulating lake is being calculated. The area is estimated to be 3 420 000 m^2, and due to the better cooling, the efficiency is set to be 18%. Other two parameters are the same as in the previous calculation. The energy output is: E=585 860 364 kWh = 585.9 GWh, yearly, which represents almost 16% f the amount of electricity needed to be generated out of the CHP plant to meet NERP’s goals.

Lastly, the energy potential of macro-location that does not have any potential is calculated. The parameters are the same as for first calculation. The area is estimated to be 4 000 000 m^2. The energy output is: E=609 081 600 kWh = 609.1 GWh, yearly, which covers around 16.5% of needed energy production outside the CHP plant for meeting NERP’s goals. To conclude, the solar yearly potential of Tuzla Municipality, including nearby accumulating lake and macro-location without agricultural or any other potential is calculated to be around 1293.3 GWh which covers a little bit more than one-third of energy production that needs to be generated from renewable sources to meet the National Emission Reduction Plan.

7.1.4 Impact of solar energy potential on the emission reduction from the socio-economic aspect

Further analysis of the scenario of utilizing total potential of solar energy will assess the reduced emissions from 4 most common polluter as well as the socio-economic aspect of the reduced emissions.

	SO_2	NO_X	PM	CO_2
Reduced emissions	23095.4 tons	2390.7 tons	452.7 tons	465552 tons

Table 7.1. This table outlines the possible amount of emission reductions in case of utilizing total solar power

In the Table 7.1. it is presented the amounts of possible reduction in emissions if the the total potential of solar energy is utilized. That scenario would reduce the electrical energy production in the Tuzla CHP plant for 35.1% and therefore each pollutant would be reduced by 35.1%. SO_2 emissions would have been reduced for 23095.4 tons, NO_X for 2390.7 tons, PM for 452.7 tons and CO_2 for 465 552 tons.

Furthermore, the costs for medical treatment and compensation of the loss of working days of affected workers caused by the air pollution from Tuzla CHP plant are calculated to be 99 million EUR for the referent year of 2013.[CEE, 2013] If the air pollution was lowered by 35.1%, so would be the costs. Therefore, the costs would be 64.25 million EUR. In other words, if the government has invested more in renewables, additional money would be saved that is now being spend on the consequences that air pollution has on citizens health. To precise, 35.6 million EUR could have been saved only in referent year of 2013.

7.2 Social impact assessment

In this chapter, societal impacts of the implementation of the possible solar scenario will be assessed. Therefore, PV panels technology implementation will be assessed through energy security scope, employment scope and environment scope. Energy security will address the impact that installed PV panels would have on the electrical energy security. Employment scope will assess impacts on the job creation whereas, environment will assess environmental impacts of implementing PV panels.

7.2.1 Energy Security

Generation of electrical energy in PV panels depends on the solar irradiation. Therefore, the scenario of having only solar energy technologies in the grid, would have negative impact on the energy security since solar energy cannot follow the energy demand, but rather only generate energy as much as weather conditions allow. However, in the estimated scenario of having only one-third generated electricity in the PV plants, energy security would not be compromised, since CHP represents a stable energy supplier.

7.2.2 Employment

Assessing the job creation that would PV plants inducted, a value chain of the project implementation is created and presented on the figure 7.1.

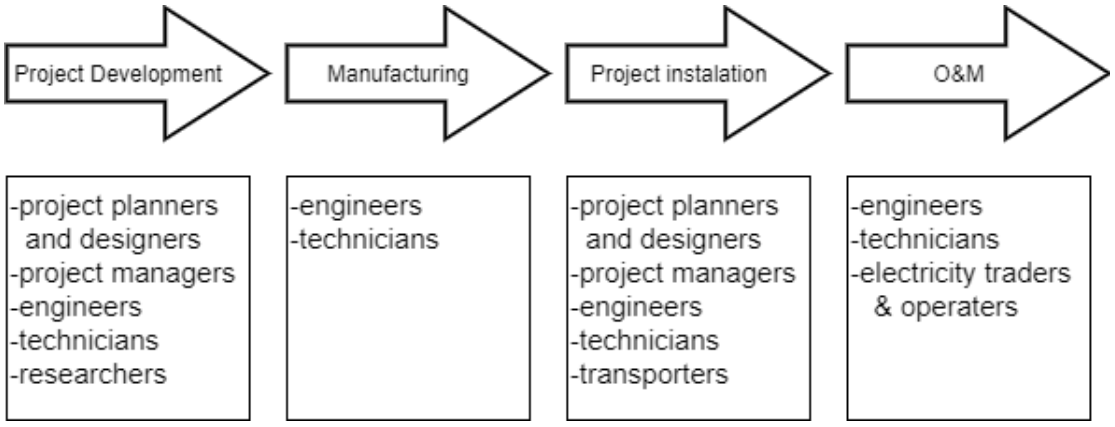

Figure 7.1. This figure presents impact of the PV plant on jobs creation in different phases of the project implementation.

Figure 7.1 shows the possible job creation through different phases of PV plant implementation project As seen on figure, there is a almost equal distribution of job opportunities through all the phases of the PV plant project implementation.

7.2.3 Environment

The impacts/benefits on the environment in terms of the reduction of the air pollution have already been discussed and showed in table 7.1. Moreover, roofs are areas impossible to be used for anything beside PV plants installation, an installing PV plants there have no negative impact on the environment. To exclude negative impact on the environment of the PV panels that are to be implement on the lake surface, only 20% of the lake surface is accounted for the PV plant implementation. This way the environment of the mentioned artificial accumulation lake and its primary and secondary functions are not disturbed. The third area assessed for the PV plant installation is the macro-location of un-promising land. Researchers have already made analysis of this area and it is concluded that are is not suitable for any kind of agricultural industry nor livestock breeding. However, natural habitat of the animals living in that area could be disturbed due to PV plant implementation. [CEE, 2013]

7.3 Social acceptance assessment

The last part of the second analysis is conducted through a hundred online questionnaires to assess the awareness of the citizens of the air pollution problem and how likely they are to implement PV panels on their rooftops. Each citizen is asked 5 questions and the answers are presented in the following subsections through charts.

7.3.1 How concerned are you about the air pollution in Tuzla?

The first question is related to how concern citizens are regarding the air pollution problem, and the answers are presented in the Figure 7.2.. It is noticeable that only 4% of the questioned citizens are not concerned at all about the on-going problem.

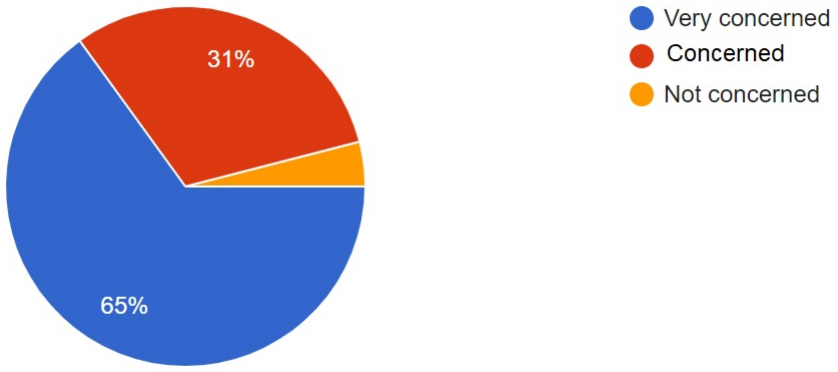

Figure 7.2. This figure presents the answers about citizen's concern of the air pollution problem.

7.3.2 Are you aware that one of the biggest air polluters is Tuzla CHP Plant?

The second question is about the awareness about CHP being the source of air pollution problem and answers are showed in Figure 7.3.. 12% of the citizens who took questionnaire did not now that CHP plant is one of the biggest sources of the air pollution problem in Municipality of Tuzla.

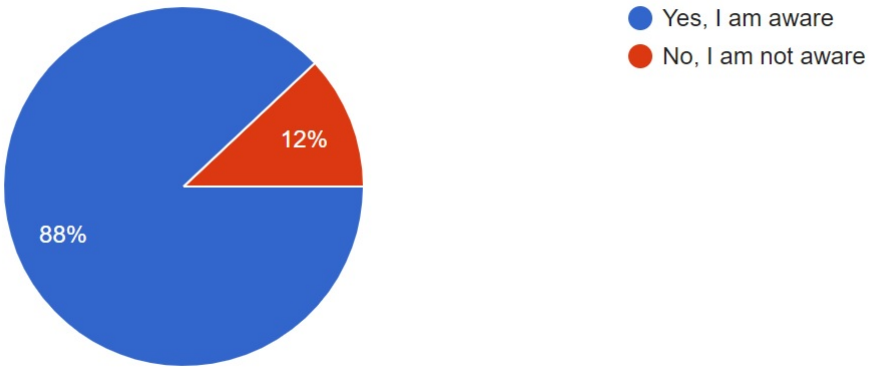

Figure 7.3. This figure presents the awareness of the citizens of CHP plant being the sources of air pollution.

7.3.3 Are you aware that implementation of renewable energy technologies would reduce air pollution in Tuzla?

Third question is related the implementation of renewable energy to reduce the local air pollution problem and the answers are presented in the Figure 7.4.. 11% of citizens were not aware that implementing renewable energy technologies, the air pollution problem would be reduced.

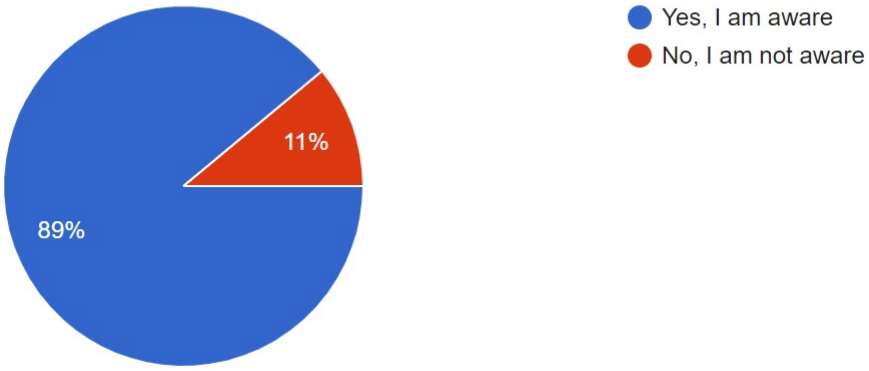

Figure 7.4. This figure presents answers on the third question of questionnaire.

7.3.4 Would you implement PV panels on your houses'/buildings' roofs? (The estimated payback time of this technology is 5-10 years.)

According to [Solarno, 2021], the estimated payback time for house solar power plant is between 5 and 10 years. Citizens are asked how likely they are to install this technology on their rooftops. The answers are presented in the Figure 7.5.. 75% of the citizens would install PV panels on their roofs, but majority of them would do it if the Government would offer subsidy on it's implementation.

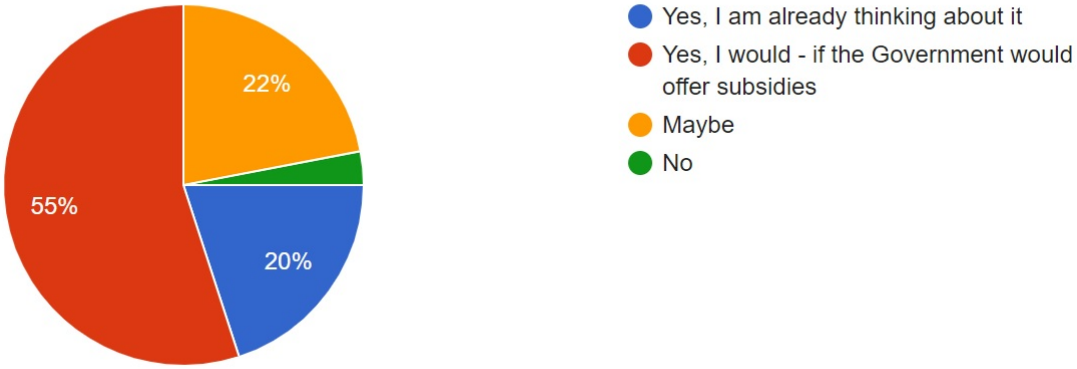

Figure 7.5. This figure presents the likeliness of citizens for installing PV panels on their roofs.

7.3.5 Are you familiar with National Emission Reduction Plan?

The fifth question is regarding citizens familiarity with National Emission Reduction Plan. It can be seen on the Figure 7.6., that 77% are not familiar with this plan.

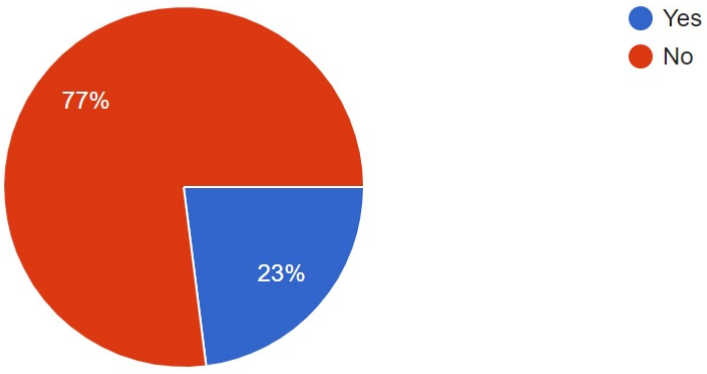

Figure 7.6. This figure presents answers on the question related to familiarity of citizens with NERP.

7.4 Sub-conclusion

The analysis 2 is done in order to answer the Research question 1: "To which extent can solar energy be utilized for production of electrical energy in order to reduce emissions produced by coal-based CHP plants in Bosnia and Herzegovina?" and partially answer to Research Question 2: "Which will be barriers to this transition and which measures could be implemented in order to outcome them?". Firstly, the potential of solar energy for Municipality of Tuzla is analyzed. The analysis has included three different types of areas for installation of PV plants: roofs, water surfaces and unpromising macro locations. The results of the analysis are discussed based on the NERP. The results showed that if maximum solar potential is utilized, it could only cover around one third of the electricity production that needs to be reduced from the production in the CHP plant to reach NERP's goals. Furthermore, the benefits of this possible scenario have been assessed from the perspective of reduced emissions. Possible emissions' reductions are shown in the table 7.2..

	$SO_2 2$	NO_X	PM	CO_2
Reduced emissions	23095.4 tons	2390.7 tons	452.7 tons	465552 tons

Table 7.2. This table outlines the possible emissions' reductions in case of utilizing solar power

Secondly, the benefits from socio-economical perspective have been calculated. It is estimated that only in the referent year of 2013, 35.6 million EUR could have been saved from medical treatments and lost working days.

Thirdly, the social impact assessment of implementation of PV technology has been made. It has been concluded, that if installed, this technology would not have any impact on energy security. Moreover, it would have positive impact in job creation. However, it could have a negative impact on animals' natural habitat on macro-location Dubrave.

Lastly, citizens were asked to fill questionnaires regarding their awareness of the air pollution problem and their willingness to install PV panels on their rooftops. The results showed that majority are aware of the problem and are willing to implement PV panels in case of Government subsidies. However, most of the citizens were not familiar with NERP. To support transition from fossil fuels technologies to renewable once to reach goals of NERP and to overcome possible barriers, Government should take into consideration subsidising implementation of PV panels. Moreover, both Government and NGOs should take measures for raising the awareness of the importance of NERP.

Discussion 8

In this chapter results from the both analysis will be discussed, policy measures to support emission reduction from CHP plant will be proposed and case study will be generalised

This project has been investigating the solar potential of the Municipality of Tuzla, and the way that solar technologies could contribute in emissions reduction from the local CHP plant. Furthermore, the barriers of this possible scenarios have been investigated and policy measures that are addressing them will be proposed in the next chapter.

Firstly, the institutional analysis has been undertaken. The institutional analysis results showed the complicated relations between actors around Tuzla CHP plant that are either directly or indirectly affecting Tuzla CHP plant in making decisions towards reduction of the emissions. The institutional analysis outlined the need of a body on the state level to coordinate National Emission Reduction Plan. The institutional analysis partially gave answers on the research question 2 regarding the possible barriers of NERP's goals achievement and regarding the policy measures that could be proposed to outcome mentioned barriers.

Second analysis is done to investigate the solar potential of Tuzla and the potential of it in contribution to emission reduction. Firstly, the yearly electricity production that needs to be generated out of the CHP plant in order for CHP plant to meet goals of NERP has been calculated. Later, the calculations of possible electrical energy generation from solar energy in Municipality of Tuzla have been made. It is concluded that solar energy can only cover around one third of the production. Therefore, total potential of solar energy in this Municipality can reduce one third of needed emission reduction. To conclude, beside utilizing maximum solar potential through PV plants there is a need for implementing another technologies for meeting NERP's goals. Later in the analysis, positive impacts from socio-economic perspective have been calculated and the social impact of implementation of PV technology has been assessed. It is concluded that a lot of money could be saved yearly on the medical costs and lost working days caused by the air pollution that Tuzla CHP plant is emitting as well as the positive impact on the job creation that the implementation of new technologies would have. However, there is a possible negative impact on the natural habitat of animals and plants living in the macro-location Dubrave area.

Furthermore, questionnaires have been to understand citizens perspective on air pollution problem, emission reduction plan, PV technology and transition to make further proposals of policy measures that could be implemented.

8.1 Policy measures proposals

Based on the institutional analysis and citizens' answer on questionnaires, following measures are proposed to outcome the barriers for Tuzla CHP plant achieving NERP goals:

- Establishing the State Level Ministry of Energy

  The results of the institutional analysis showed the need for establishing Ministry of Energy on a national level who will be in charge of making further energy plans and allocation of sources for the current plans.

- Making Plan for NERP's resources allocation

  The institutional analysis showed that it is uncertain who should be in charge of allocation of economical resources for meeting NERP's plan and in general emission reduction. Therefore the making of the economical plan is needed.

- Establishing monetary consequences for CHP plants that are not meeting goals

  Currently, CHP plants do not suffer any economic consequences due to non-compliance with NERP. Establishment of monetary consequences would give a motivation for CHP plants to meet NERP goals.

- Investigation the new profitable opportunities for mining industry and rail transportation

  There is a urgent need to investigate further opportunities of rail transport and mining industry, because these sectors will suffer the most with transition to renewable energy technologies.

- Ensuring no-one loses their job through this transition

  Keeping citizens as priorities in this transition is a must. It must be ensured that the transition will not cause any citizens to lose their jobs.

- Providing subsidies for citizens for implementation PV panels

  Questionnaires have provided results that citizens are willing to be involved in emission reduction transition through implementation of PV panels on their roofs. However, majority are willing to do aforementioned if The Government would provide subsidies,

- Promote concept and importance of the NERP among citizens

  The results from questionnaires showed that citizens are unfamiliar with the importance and concept of NERP. NERP should be promoted by both NGOs and the Government.

8.2 Generalization of the case study

In this project Municipality of Tuzla has been taken as a case study and the CHP plant located it this municipality. Therefore, the solar potential of this municipality has been assessed as well as the emission reduction that this potential could impact. Later the barriers of this transition have been examined and policy measures to outcome them have been proposed.

As known, solar potential of a certain region depends on the geographical and climate conditions. Therefore, each area in Bosnia and Herzegovina has different solar potential. However, solar potentials of others' CHP plants locations are not differing much from the solar potential of Tuzla. Therefore, it is possible to generalise the case of the solar potential of Tuzla to other cities. [Commission, 2021]

Policy measures proposed to support the transition of reduction of emissions from Tuzla CHP plant can be generalised and applied for other CHP plants case studies in Bosnia and Herzegovina due to their similar institutional structure.

Conclusion 9

In this chapter the conclusion of the project will be made.

This project has analysed the solar potential of the Municipality of Tuzla and potential of this renewable energy in reaching BIH's National Emission Reduction Plan fot Tuzla CHP Plant.

The solar potential of Tuzla Municipality have been assessed and calculations of emissions reductions from Tuzla CHP plant if this potential is used, are calculated. They have been discussed in comparison with NERP. It is concluded that solar power potential can cover one third of needed emissions reductions. However, it has positive impact from socio-economic perspective as well as on new jobs creation.

Futhermore, the possible obstacles of this transition have been analyzed through institutional analysis and it is noticed that current political structure and actors involved in the CHP plant's operations decisions are not favoring reductions of operations of the CHP plant. Furthermore, it has been examined that it is uncertain who is in charge of allocation of sources for reduction of emissions from the mentioned CHP plant. Questionnaires undertaken by the citizens of Tuzla, has showed the need for introducing NERP's importance and concept to citizens, as well as it showed potential of people getting involved in reducing emissions goals throug installation of PV panels on their rooftops.

Together, institutional analysis results and questionnaires results are used as a base for following proposing policy measures for supporting the emissions reductions from Tuzla CHP plant:

- Establishment of the State Level Ministry of Energy
- Establishing the plan for the NERP's resources allocation
- Establishing monetary consequences for the CHP plants which are not meeting goals
- Investigation new opportunities of rail transportation and mining industry
- Ensuring no job loss being a consequence of this transition
- Establishment of the subsidies for implementation of PV panels
- Promotion of the concept and the importance of NERP among citizens

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