JOURNAL OF SCIENCE

SAKARYA UNIVERSITY

Sakarya University Journal of Science

Title: The Potential of the Karaman Wastewater Treatment Plant to Generate Electricity
with MHP and Reduction of Electricity Bill Amounts by Adjusting Working Hours of
the Facility

Authors: Ufuk SÜGÜRTİN, Türker Fedai ÇAVUŞ

The Potential of the Karaman Wastewater Treatment Plant to Generate Electricity with MHP and Reduction of Electricity Bill Amounts by Adjusting Working Hours of the Facility

Ufuk SÜĞÜRTİN[*1], Türker Fedai ÇAVUŞ[2]

Abstract

In this study, in order to reduce the electricity consumption / cost of the Karaman Wastewater Treatment plant, which has the highest flow and electricity consumption in Sakarya, the arrangements that can be made during the working hours of the treatment plant and the generation of electricity by the MHP that can be installed between the outlet of the facility and the discharge point of the wastewater are examined. A change of 17% in the electricity bill costs and up to 50% in the flow rates were observed. Wastewater treatment plant projects keep their capacities high, considering the needs of the next 20-30 years. Based on these results, it is determined that if the electricity consumption amounts in the peak time interval where the unit price of electricity is high is shifted to day and night time zones, the electricity costs of the facilities will decrease. In addition, it has been shown that a part of its own electricity consumption will be met by the micro hydro power plant to be installed between the outlet of the facility and the discharge point.

Keywords: Micro hydro power plant, electricity, wastewater treatment plant,

1. INTRODUCTION

According to the water pollution control regulation, wastewater is defined as contaminated or partially or completely altered waters as a result of domestic, industrial, agricultural and other uses [1]. The wastewater infrastructure facility is defined as the systems and facilities in which wastewater is treated and the final disposal of treated wastewater is achieved through the entire

---
[*]Coresponding Author: ufuk.sugurtin@gmail.com
[1]Sakarya University, Electrical Electronics Engineering Department,Turkey.
 ORCID: https://orcid.org/0000-0002-0889-5684
[2]Sakarya University, Electrical Electronics Engineering Department,Turkey. E-Mail: tfcavus@sakarya.edu.tr
ORCID: https://orcid.org/0000-0003-1399-8044

Ufuk SÜGÜRTİN, Türker Fedai ÇAVUŞ

The Potential of the Karaman Wastewater Treatment Plant to Generate Electricity with MHP and Reductio...

sewage system that collects domestic and industrial wastewater. Turkey is an energy dependent country. In 2018, electricity consumption in Turkey was 304.2 TWh and electricity generation was 304.8 TWh. Electricity consumption is estimated to reach 375.8 TWh in 2023. The installed capacity of Turkey was 90.72 GW as of September 2019 [2].

As of September 2019, according to the sources where energy is produced, the installed power distribution in Turkey; 28.6% natural gas, 31.4% hydraulic energy, 8.1% wind, 6.2% solar, 22.4% coal, 1.6% geothermal and 1.7% is in the form of other sources. Turkey's electricity generation according to sources in 2018 are given in Table 1.

Table 1
Electricity Generation of Turkey In 2018 [2]

Electricity Generation of Turkey In 2018	
Coal	% 37.3
Natural Gas	% 29.8
Hydraulic Energy	% 19.8
Wind	% 6.6
Sun	% 2.6
Geothermal energy	% 2.5
Other Source	% 1.4

In Turkey, there are 597 hydroelectric plants and their total installed power capacity is 26.7 GW [3]. Aimed at reducing greenhouse gas emissions, the Kyoto Protocol was signed in Turkey. [4].

In 2017, 86.3% of total CO2 emissions are caused by energy. 34.6% of this constitutes electricity and heat generation. [5]. A large part of the carbon dioxide emission that causes greenhouse effect results from the use of fossil fuels in energy generation and consumption [6]. Therefore, increasing electricity production from renewable power is important. Turkey is a country rich in water resources, but this potential of Turkey cannot be utilized sufficiently.

In this article, a study was made to draw attention to the operation of wastewater treatment plants in an optimized way to reduce the electricity costs, in the Karaman wastewater treatment plant in Sakarya, and the earnings were calculated. Secondly, it is predicted that part of the electricity consumption of the facility will be met by the micro hydroelectric power plant to be installed between the outlet of the Karaman Wastewater

Treatment plant and the discharge point. There are two peak flows in one day. The first happens in the morning, when daily life begins, and the second happens in the evening. Minimum consumption during the day generally occurs around 4.00 AM [7].

2. WASTEWATER AND TREATMENT PLANTS

These are the facilities that ensure the treatment of wastewater coming through the sewage system that collects domestic and / or industrial wastewater, by subjecting them to processes that will not harm the environment and the receiving environment. Apart from rainwater, we can examine the wastewater in three groups as domestic, industrial wastewater and leachate [8]. While industrial water consumption is 5 billion m^3, it is predicted that it will be 22 billion m^3 in 2023 [9]. Wastewater treatment plants consume large amounts of electricity due to the devices / engines used in their processes during cleaning these contaminated waters. Considering of Turkey dependence on imported energy, it is very important to take measures to reduce the electricity consumption and costs of wastewater treatment plants. There are almost 250000 water service facilities in the world. Nearly 90% of these facilities are from municipalities.8% of these facilities are almost privately operated.

Municipalities discharged 4.8 billion m^3 of wastewater according to the results of the waste water statistics survey announced by TÜİK in 2018 and organized for municipalities. The average daily amount of wastewater per person discharged by municipalities by sewerage network was calculated as 188 liters [10].

2.1. Wastewater Treatment Electricity Consumption

Electricity consumption of wastewater purification facility varies depending on the methods selected for wastewater quantity, concentration, treatment processes, topography of the facility area, energy efficiency of the equipment used in treatment and the level of automation at the facility. In a study conducted in

Ufuk SÜGÜRTİN, Türker Fedai ÇAVUŞ

The Potential of the Karaman Wastewater Treatment Plant to Generate Electricity with MHP and Reductio...

Norway, 0.8 kWh of energy was consumed to treat 1 cubic meter of wastewater, which is twice the energy required to provide the same amount of drinking water [11].

2 to 3 % of the electricity generated in the world is used in the production, distribution and treatment of water [12].An average of 0.4 kWh electricity is consumed for 1 m^3 of wastewater treatment in Germany, and it is stated to be 0.29 kWh in China, 0.20 kWh / m^3 in the USA and 0.26 kWh / m^3 in Japan [13].The amount of electricity consumed for purifying wastewater in Turkey ranges from 0.08 to 0.5 kWh/m^3. In Karaman Wastewater Treatment Plant, this value is 0.3 kWh/m^3.

2.2. Karaman Wastewater Treatment Plant

Domestic wastewater from Adapazarı, Erenler, Serdivan, Arifiye, Sapanca districts is treated at the Karaman Wastewater Treatment Plant. Stage 1; It has the capacity to serve an equivalent population of 750000 people until 2015. 2nd stage; It will be able to serve a population of 1625767 people by 2035.

2.3. Karaman Wastewater Treatment Plant Electricity Consumption Times and Investigation of Paid Prices

When the electricity bills of the facility are examined, 12 month electricity consumption average of Karaman wastewater treatment plant for the last 4 years (2015-2016-2017-2018) is shown in figure 1.
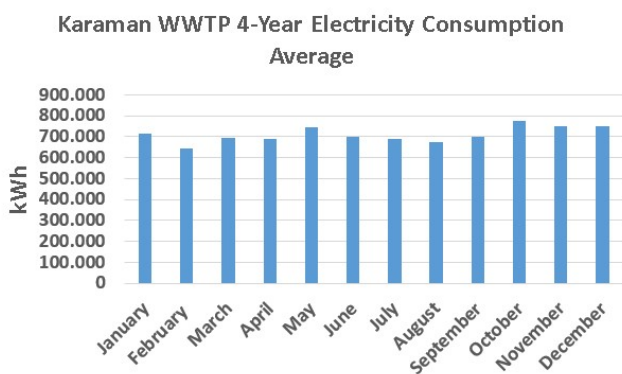

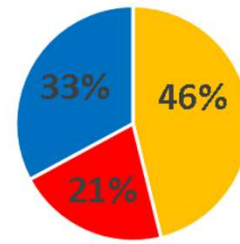Figure 1 Karaman WWTP Electricity Consumption

Figure 2 Karaman WWTP Electricity Consumption Distribution According to Daily Tariff
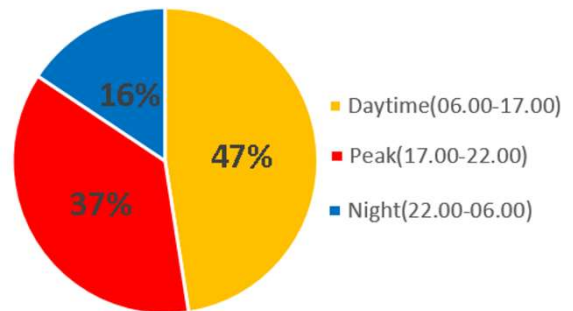

Figure 3 Karaman WWTP Electricity Consumption Prices

Karaman WWTP electricity consumption distribution (kWh) according to daily tariff is shown in Figure 2. Karaman WWTP Electricity Consumption distribution (TL) according to daily tariff is shown in Figure 3.

While the distribution of the electricity consumption amounts of the Karaman Waste Water Treatment Plant during the day according to time periods is shown in figure 2, the figure 3 shows the prices paid according to these consumption amounts (the most expensive time period (17.00-22.00))

Unit prices of electricity approximately are 0.39 TL for the daytime,0.63 TL for the peaktime, 0.19 TL for the nighttime in 2018

2.4. Evaluation of Wastewater Treatment Plant Electricity Consumption Data

When the electricity consumption of the Karaman Wastewater Treatment Plant is analyzed, up to 17 % change in electricity consumption (between the highest electricity consumption and the lowest

Ufuk SÜGÜRTİN, Türker Fedai ÇAVUŞ

The Potential of the Karaman Wastewater Treatment Plant to Generate Electricity with MHP and Reductio...

consumption on a monthly basis) was observed. The flow rate of the facility also varies up to a maximum of 50%. These kinds of investments are planned for 20-30 years, considering the wastewater formations in the coming years [14].

Based on these findings and information, we can assume that the wastewater treatment plant does not operate at the same capacity throughout the year.

It is considered that the amount to be paid for the electricity consumption of the facilities will decrease if the amount of work in the peak time interval where the cost of electricity consumption of the Wastewater Treatment Plants is shifted before (day) or after (night) in line with the facility facilities. Current electricity consumption and improved values of the facility are given in table 2.

Table 2
Karaman WWTP current and improved consumption amounts

	Current	Improved
Daytime	% 46	%47
Peak	%21	%19
Night	%33	%34

2.5. Calculation

The current electricity consumption costs of the Karaman wastewater treatment plant and the improved electricity consumption cost are shown in figure 4.
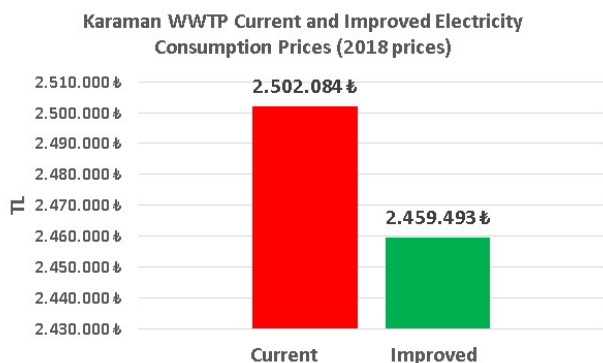

Figure 4 Karaman WWTP Current and Improved Electricity Consumption Costs

3. MICRO HDYROLECTRIC POWER PLANTS

Studies are carried out to produce electrical energy from large water resources in Turkey. It is important to do the same studies in the evaluation of small water resources.

With the regulation that came into force on 12/05/2019, an incentive was provided for micro energy production. Real or legal persons engaged in production activities in production facilities based on renewable energy sources with a maximum installed capacity of 1 MW are exempt from the obligation to obtain licenses and set up companies [15].

The study on micro-hydro power plants used for the recovery of energy in water pipelines by Williams are some of the earliest research records in this area [16]. Valves are used to control the downward flow pressure in water mains lines. The plants that generate electricity at the micro level will be integrated into the water network lines, while reducing the downward pressure made by the valves and generating electricity[17].

The service offered to consumers by water service providers will be offered at lower costs as energy costs are reduced.

There are similar facilities in Germany [18] and Scotland [16] that provide energy recovery. A micro hydro power plant was established in 1947 to gain energy from the flow between an upper storage reservoir and the treatment plant located at its lower level in Ireland.

In the study on the Applicability of Micro Scale Hydroelectric Power Plants for Energy Recovery in Wastewater Treatment Plants in Harran University in 2018, theoretically calculated the amount of electrical energy that can be produced through the wastewater flow [19].

In the UK, a micro hydro power plant was installed, which works with an archimedes screw system to generate energy from the outlet of a wastewater treatment plant.

Ufuk SÜGÜRTİN, Türker Fedai ÇAVUŞ

The Potential of the Karaman Wastewater Treatment Plant to Generate Electricity with MHP and Reductio...

The facility has two turbines with a total power of 180 kW. The facility provides € 160000 savings in annual electricity costs [20].

In Turkey, projects for the construction of micro hydro power plant accounts are being carried out and implemented in order to evaluate the water potential of wastewater treatment plants.

An example of this type of micro hydro power plant is installed at the outlet of the central waste water treatment plant of Gaziantep Water and Sewerage Works, and 1 million 500 thousand kilowatts / hour of energy can be generated annually [21].

Another similar study will be able to generate 8000000 kilowatts / hour of electricity per year, established in the wastewater plant of the Ankara Metropolitan Municipality Aski General Directorate [22].

3.1. Investigation of Energy Production with Micro Hydro Power Plant from Karaman Wastewater Treatment Plant

The most important parameters for the recovery of energy from the water infrastructure are the flow of water and the height at which water falls[23].Special conditions such as the pH value of water, high pressure pipe networks may affect the turbines that can be used in some plants, affecting energy recovery [24].

The potential to generate energy with micro hydro power plant from Karaman Wastewater Treatment Plant was examined.

3.1.1. Flow Detection

The data of the flow rate of Karaman Wastewater Treatment Plant were learned by means of the devices measuring 24/7 in the facility (Table 3).

Table 3
Karaman WWTP Flow Quantities

Karaman WWTP Flow Rates (m³/day)	
Max	93720
Average	82353
Min	52560

3.1.2. Detection of Level Difference

The height difference between the exit point and the discharge point of the Karaman Wastewater Treatment Plant was determined through the wastewater treatment project and has a drop of 2.86 meters.

3.1.3. Turbine Selection

Turbines are produced according to the specific flow values of each facility. If the flow values change, the energy produced will also affect the turbine efficiency, which will cause changes. PATs (Pumb as Turbine) have been assumed to be the most suitable turbines to be used for energy recovery from water pipelines in various studies [25].

For example; for PAT, which is designed according to certain values, a 50% increase or decrease in water flow will result in a 30% to 80% reduction in energy conversion efficiency.

It has been determined that the most suitable turbine will be the archimedes auger turbine according to the height and flow rates, the various turbine types according to the flow and the pressure according to the working areas(Figure 5)
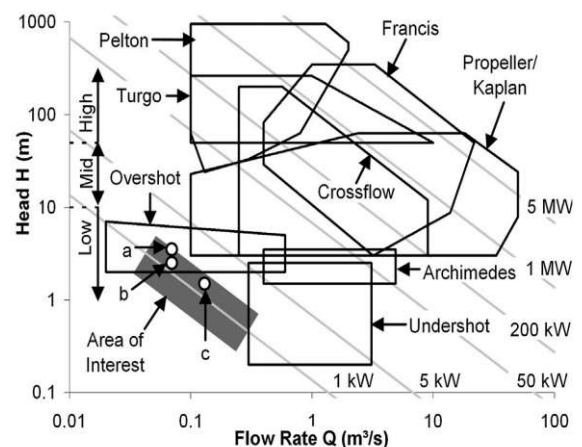

Figure 5 Turbine selection according to flow rate and pressure [26]

3.1.4. Installation Costs

Micro hydro power plant investment cost ranges from $ 1300-8000 / kW (€ 1000-6200 / kW).The

Ufuk SÜGÜRTİN, Türker Fedai ÇAVUŞ

The Potential of the Karaman Wastewater Treatment Plant to Generate Electricity with MHP and Reductio...

operating cost varies between approximately 1-4% of the investment value [26]. Investment cost per kW of micro hydro power plants varies between € 3000 and 6000 [27].

In the market research conducted for the Karaman wastewater treatment plant, the investment cost was determined as 300000 TL.

3.1.5. Operating Costs

The maintenance / operation costs of the archimedes augers to be installed are very low. The operating cost varies between approximately 1-4% of the investment value [26]. 3000 TL is assumed annually.

4. RESULTS

If the wastewater treatment plant's flow rate is 1 m^3 / sec, gravity acceleration is 9.81, efficiency is 70%, and the dream is 2.86, the installed power is calculated as 20 kW

Q=flow (m^3/sec)
P=Power (Watt)
p= density of water (kg/m^3)
g=gravity acceleration (9,81 m/sec^2)
H=current water height (m)
Ɛ= productivity
P=Q.p.g.H.Ɛ
P=1*1000*9, 81*2,86*0,7=20 kW

The wastewater treatment plant operates 365 days a year, with minimum flow rate of 0.6, m^3/sec, maximum flow of 1.08 m^3/sec, and average flow rate of 0.95 m^3/sec.

The amount of electricity produced with flow rates will vary proportionally. There are 8760 hours in a year.It is assumed to be 7700 hours considering the flow rates as the working period of the facility.

Annual electricity amount to be produced is calculated as 154.000 kWh / year. Operating Income = 7700 * 20 * 0.59 = 90.860 TL / Year (It is assumed that the unit price of electricity is 0.59 TL).

From the interoperability calculation methods, the repayment period of the facility was analyzed according to the management's economical feasibility and it was calculated that the investment cost was equal to net income after 3 years and 11 months (Figure 6).

With this study, in the wastewater treatment plants with suitable facility capacity ,it has been observed that the amount to be paid for electricity consumption will decrease when necessary arrangements are made for shifting some of the electricity consumption corresponding to the evening hours (17.00-22.00) to day and night time zones.
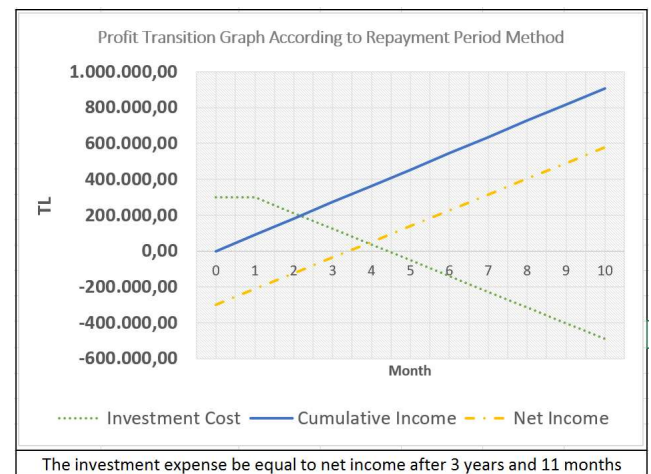

Figure 6 Profit Transition Graph According to Repayment Period Method

It was concluded that the potential water energy of the Karaman wastewater treatment plant, which has a flow rate and appropriate consideration, is converted into electrical energy and some of the electricity consumption amounts of the facilities will be met and this project to be invested is economically feasible.

Moreover, if wastewater treatment plants comply with the requirements of the legislation in Turkey, since up to 50 % of the electricity costs of wastewater treatment facilities are covered by the government [28].

Therefore, it is economically feasible to implement micro hydro power plant investments immediately for institutions that receive incentives from the state for electricity costs.

Ufuk SÜGÜRTİN, Türker Fedai ÇAVUŞ

The Potential of the Karaman Wastewater Treatment Plant to Generate Electricity with MHP and Reductio...

The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

The Declaration of Ethics Committee Approval

The authors declare that this document does not require an ethics committee approval or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

REFERENCES

[1] Resmi Gazete (31.12.2004 tarih ve 25687 sayılı). Su Kirliliği Kontrolü Yönetmeliği

[2] https://www.enerji.gov.tr/tr-TR/Sayfalar/Elektrik [Accessed-12-Jan- 2020]

[3] https://www.enerjiatlasi.com/hidroelektrik/ [Accessed-14-Jan- 2020]

[4] http://iklim.cob.gov.tr/iklim/Files/Mevzuat/kyoto_protokol.pdf [Accessed-14-Jan-2020]

[5] https://www.haberturk.com/seragazi-emisyonlari-2429941-ekonomi [Accessed-15-Jan- 2020]

[6] O. Çoban and N. Şahbaz Kılınç, The Relationship Between Renewable Energy Consumption and Carbon Emission: The Case of TR- Journal of Social Sciences Institute vol. 38, no.1, pp. 195-208,2015

[7] İ. Öztürk, Atık su mühendisliği. Teknik Kitaplar Serisi (İSKİ), 2017

http://www.iski.gov.tr/web/assets/SayfalarDocs/e-kutuphane/kultur/docs/at%C4%B1ksum%C3%BChendisli%C4%9Fi.pdf-[Accessed-12-Jan- 2020]

[8] A. Samsunlu, Atık suların arıtılması. Birsen Yayınevi, 2011.

[9] E. Özcan, Türkiye kıyılarında yüzme suyu profillerinin belirlenmesi ve turizmde atık su yönetimi, 2014.

https://webdosya.csb.gov.tr/db/tay/webmenu/webmenu13378.pdf- [Accessed-04-Jan- 2020]

[10] Tüik 2018, Belediye atık su istatistikleri. http://www.tuik.gov.tr. [Accessed-09-Jan- 2020]

[11] G. Venkatesh, and H. Brattebø, Energy consumption, costs and environmental impacts for urban water cycle services: case study of Oslo (Norway). Energy vol. 36, no. 2, pp. 792–800, 2011.

[12] S. C. Kwok, H. Lang, P. O'Callaghan, and M. Stiff, Water Technology Markets 2010, Key Opportunities and

Ufuk SÜGÜRTİN, Türker Fedai ÇAVUŞ

The Potential of the Karaman Wastewater Treatment Plant to Generate Electricity with MHP and Reductio...

Emerging Trends. Media Analytics Ltd, Oxford, 2010.

[13] http://www.emo.org.tr/ekler/38a62084d d5b1ff_ek.pdf [Accessed-12-Jan- 2020]

[14] https://www.tarimorman.gov.tr/SYGM/ Belgeler/ar%C4%B1tma%20norm%20 rehberi/AAT%20Tasar%C4%B1m%20 Rehberi%20(1).pdf .[Accessed-19-Jan- 2020]

[15] Resmi Gazete(12.05.2019 tarih ve 30772 sayılı). Elektrik Piyasasında Lisanssız Elektrik Üretim Yönetmeliği

[16] A. A. Williams, Pumps as Turbines for Low Cost Micro Hydro Power. World Renewable Energy Congress, Denver, USA, 1996.

[17] A. A. Williams, N. P. A. Smith, C. Bird, and M. Howard, Pumps as turbines and induction motors as generators for energy recovery in water supply systems. Journal of the Chartered Institute of Water and Environmental Management vol. 12, pp. 175–178, 1998.

[18] K. Mikus, Erfahrungen mit Kreiselpumpenanlagen zur Energieruckgewinnung aus dem Trinkwassersystem. Das Gasund Wasserfach – Wasser/Abwasser vol. 124, no. 4, pp. 159–163, 1984.

[19] D. Erkan, T. Yılmaz, A. Yücel, A. Yılmaz, A. Tel, and D. Uçar, Applicability of Micro Scale Hydroelectric Power Plants for Energy Recovery in Wastewater Treatment Plants. Harran University Journal of Engineering vol. 2, pp.1-6, 2018.

[20] Engineering & Technology Magazine Power generation by Archimedes screw, 2010.

[21] https://www.hurriyet.com.tr/gaski-atik-su-ile-enerji-uretecek-40215041 .[Accessed-18-Jan- 2020]

[22] http://www.yekenergy.com/referanslar/ aski-arsimet-burgulu-elektrik-uretim-santrali/ [Accessed-12-Jan- 2020]

[23] A. McNabola, A.P. Williams, and P. Coughlan, Energy recovery in water supply networks: an assessment of the potential of micro hydropower. Water and Environment Journal vol. 27, pp. 435–436, 2013.

[24] M. O. Engelhardt, P. J. Skipworth, D. A. Savic, A. J. Saul, and G. A. Walters, Rehabilitation strategies for water distribution networks – a literature review with a UK perspective. Urban Water vol. 2, no. 2, pp. 153–170, 2000.

[25] M. Giugni, N. Fontana, and D. Portolano, Energy Savings policy in water distribution networks. Proceedings of the International Conference on Renewable Energies & Power Quality, Valencia, Spain, 2009.

[26] http://www.mneproje.com/public/websi te/news/atiksu-aritma-hes_20200131070151.pdf-[Accessed-12-Jan-2020]

[27] Gaius-obaseki, T. Hydropower opportunities in the water industry. International Journal of Environmental Sciences vol.1, no. 3, pp. 392–402, 2010.

[28] Resmi Gazete (01.10.2010 tarih ve 27716 sayılı).Çevre Kanununun 29. Maddesi Uyarınca Atık Su Arıtma Tesislerinin Teşvik Tedbirlerinden Faydalanmasında Uyulacak Usul Ve Esaslara Dair Yönetmelik