INFLUENCE OF PV SYSTEM INSTALLATION ON THE RESIDENTIAL ELECTRICITY CONSUMPTION

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ABSTRACT

The motivation behind this idea was to gather information about the consumption changes and discuss about the impacts of these changes onto residences and electricity distributors. Since 2014, there are more than 1000 applications to the Renewable Energy Committee about making an investment in solar photovoltaic energy systems. More than 800 residences have access to net-metering and the number is increasing. Considering most of the applications depends on the electricity grid, impact on overall change will eventually affect the main electricity supplier in some fashion.

After gathering required information on residential systems and relevant sources, compiling and analysing all the data, the true consumption by residences is found. The results show a trend indicating major changes in energy consumption after installing solar photovoltaic systems. There is a considerable increase in consumptions which is almost 50% in total energy consumption and approximately 90% of the residents are accountable in this increase.

1. INTRODUCTION

The human civilisation needs to consume energy on various things to facilitate their lives, such as electricity, transportation, heating and cooling systems and etc. As the technology develops and population increase, the amount of required energy increases. Since the industrial revolution this demand to consume energy increase even faster. The civilisation of humans is confronting a major problem to satisfy their need for the rapid growth in energy consumption. According to the United States Energy Information Administration's International Energy Outlook 2016 [1], the world energy consumption will increase by 48% between 2012 and the 2040. Additionally, the big chunk of this increase will occur in the countries who are not in the Organisation for Economic Cooperation and Development (OECD). There are several reasons behind this suggestion such as the population growth and the increasing standards of living for many people in developing countries and strong economic growth [1].

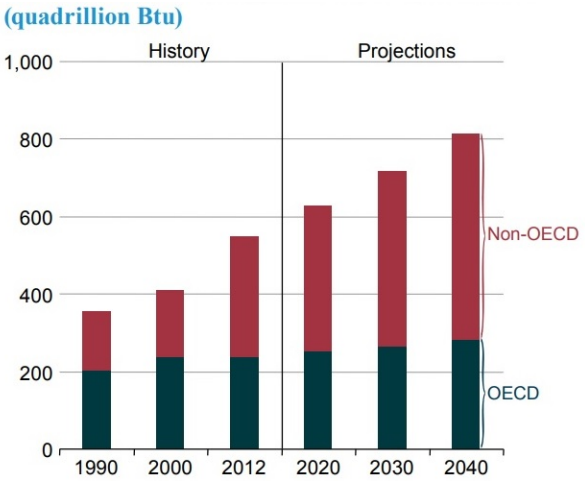

Figure 1: World Energy Consumption, 1990-2040 [1]

As the energy demand increases, the fuel consumption will increase proportionally. The increase in fuel usage can and will cause serious problems such as more greenhouse gas emissions, faster depletion of fossil fuels, limitations for possible opportunities and etc. To reduce the impact caused by this problem, new ways of reducing fossil fuel usage are searched. One of these ways is energy efficiency. The definition of the energy efficiency is to do the same amount of work with a lower usage of energy. IEA executive

director Dr. Fatih Birol, places energy efficiency at the heart of the global energy agenda [2]. One of the other alternative way is adopting renewable energy technologies which is also the best way. The renewable energy sector is the most rapid growing energy sector. There are several reasons for that. Firstly, as mentioned before, the population growth and standard living improvements, secondly the necessity to reduce the greenhouse gas emissions which is the main cause for the climate changes and global warming, thirdly the limitations and depletion of the fossil fuel resources and lastly reduce the importations of the fossil fuels which causes a noticeable economic aspect.

1.1. Solar Photovoltaic Energy

PV systems are already in a competition in many major pricing areas because of the incentives and regulations and they will continue to dominate the market in the upcoming years [3]. Moreover, the prices for renewable energy systems are dropping in a very fast pace. Solar electricity generation systems getting cheaper and cheaper since 2008. As the technology develops and new markets emerge the demand increases to the solar systems which also creates a lot of opportunities while reducing the value of the modules and systems. [4]

1.2 Objective

The main idea behind this paper was to inspect the Turkish Republic of Northern Cyprus citizen's consumption habits before and after installing solar photovoltaic systems and gaining access to net metering system. With the data gathered, the amount of energy consumption prior to solar photovoltaic installation and after the installation can be easily compared to see the impact of the renewable energy systems such as solar photovoltaic system on residential usage on domestic and governmental size. The results will show the change of general pattern with the introduction of solar systems. The impacts can be seen as in whole periods of time such as one year (12 months) or in seasonal basis therefore we can compare each subscriber to each other as well as to themselves to see the change both in long time period and seasonal scale.

1.3 Contribution

This research can be a starting point to see the behavioural changes after the installation of solar photovoltaic systems. The law makers or executives in Energy Department of TRNC can consult on this to see the impacts on houses and the impacts of these houses to the electricity distributors. There are several reasons that the paper can be useful in different areas. One of the most important one is, since the renewable energy technologies are quite new in the TRNC. Solar photovoltaic systems are the most adopted renewable energy technology in TRNC and every year the regulations and government conditions can improve by adapting better to the developing technology of renewables. Since there are always room for improvement, this research can be used as consultation method to see the change in the residential energy consumptions and make large scale predictions based on the results in this work as a starting point to understand better about the behavioural changes after installation of solar photovoltaic systems. The use of this also can be helpful for lawmakers and energy distributors to adapt to changes and act accordingly to ease the transition to renewable energy sources to generate green energy.

Another substantial point was, while inspecting the causes that makes residents change their consumption habits, there were several researches about it such as impacts of giving feedbacks, education on residential consumptions, using environmental friendly electronic devices. However, there is not any research about the impacts of solar photovoltaic systems on consumption habits, therefore it might be considered one of the earliest research subject on this topic. This research can be used as literature for next researches about this subject which there is no examples like it.

2. ENERGY TRENDS IN TRNC

The total installed capacity of TRNC is 409 MW and the highest peak demand is recorded as 317 MW which was on 4th of August in 2016 according to the data collected and analysed in March 2017 [5]. As the rest of the human society, the demand in energy increases in TRNC as well. The changes in consumption increases are quite visible. In 2013, the total electricity usage was 1,353,735 million kilowatt-hour (kWh) [6]. In 2014, the total energy consumption increased by 1.91% making the total consumption value 1,379,613 million kWh [7]. Like the prior year, the trend of increase in energy demand continued. In 2015, the rise reached to 4.87% with 67,181 million kWh rise. The total energy demand hit to 1,446,794 million kWh [8]. In 2016, the total energy demand reached to 1,547,513 million kWh, increased 100,719 million kWh, showing a 6.96% growth compared to 2015 [9].

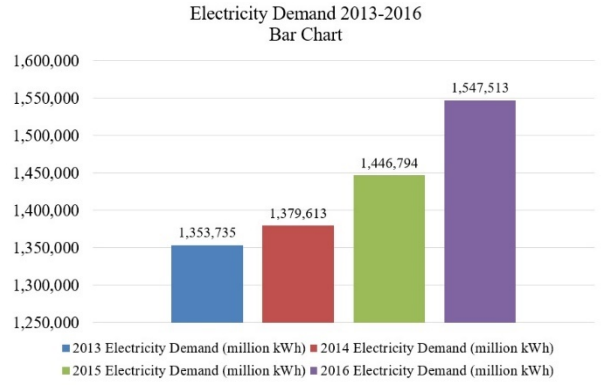

Figure 2: 2013-2016 TRNC Energy Demand Bar Chart [6,7,8,9]

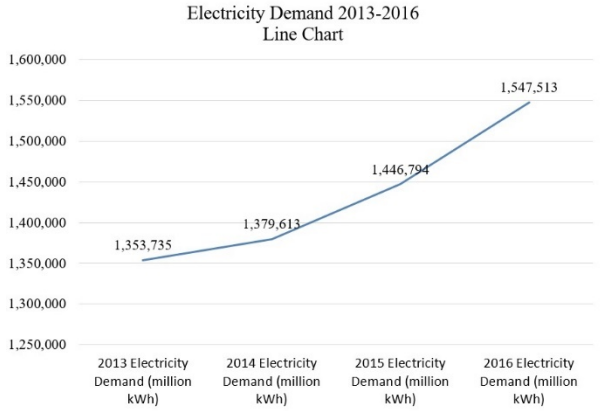

Figure 3:2013-2016 TRNC Energy Demand Line Chart [6,7,8,9]

2.1 Solar PV Trends in TRNC

Like most of the countries around the world, The Turkish Republic of Northern Cyprus (TRNC) or shortly North Cyprus is also adopted the renewable energy in its own way. The main demonstrator of this is, the effort and incentives shown in the new rules and regulations in the law. The first main effort on the law was made in 2011 and the regulations continued to develop until 2012 and 2013. In 2014, the law and regulations made its impact on society and people are started to make an approach to the one of the most popular branch of renewable energy technology, which is solar PV energy systems. Both on-grid and off-grid systems seen some attention but naturally the on-grid systems outweighed the off-grid systems. The main logic behind this was the lack of storage abilities and the technology made off-grid systems less cost-effective and risky. Additionally, people could get incentives for wiring their system to the grid. In the year 2014 there were total of 160 single phase (total of 665.82kW) and 38 (total of 301.61 kW) three phase on-grid residential application and 55 (total of 6519.77 kW) non-residential application about solar photovoltaic systems to the authorised ministry and to the renewable energy committee. Furthermore, there were 11 (total of 31.54 kW) single phase residential and 19 (total of 283.28 kW) non-residential off-grid photovoltaic system application was made, making a total number of 283 (7802.02 kW) application. The following year with the new developments in the technology and brief education for the citizens people started to adopting even more and more. In 2015 total of 331 application were made. 328 of these were on-grid systems. From these 328 systems, 259 of them were single phase residential (total of 1129.58 kW), 42 of them were three phase residential (total of 360.05 kW) and the remaining 27 of them making 8% were on-grid non-residential applications (total of 5345.56 kW). The rest 3 which accounts for the last 1% were off-grid applications which were non-residential (total of 30.0 kW). The prominence of solar PV systems become more visible in 2016. The applications to acquire

photovoltaic technology systems showed 10.67% increase compared to previous year 2015. The total number of applications reached a number of 363 and have a total capacity size of 2268.20 kW. However, the increase in application numbers did not have an impact to the total capacity size which showed a decline of 66.96%. In 2016, on-grid single phase residential project application continued to lead with a number of 265 (1108.00 kW). The three phase on-grid residential application became second with the number of 70 (490.05 kW) applied capacity size. On-grid non-residential investment applications holds a number of 23 (629.43 kW). The data collected from the first and second quarter of 2017 suggests that the solar PV system applications already passed 2015 and almost catch up to 2016, having an application number reached of 324 with huge escalation in installation capacity (kW) as well with 8835.56 kW achieving a record growth of 289.54% by increasing 6567.36 kW. The on-grid single phase residential applications continue to dominate having 241 and 75% with application having a total of 1131.44 kW (total of 13%) capacity. Three phase on-grid residential applications are still in the second place having 62 applications and 19% share and a total of 549.47 kW (6%) capacity and on-grid non-residential project applications holds a value of 20 and a share of 6% having the biggest capacity share of 81% with 7139.65 kW [10].

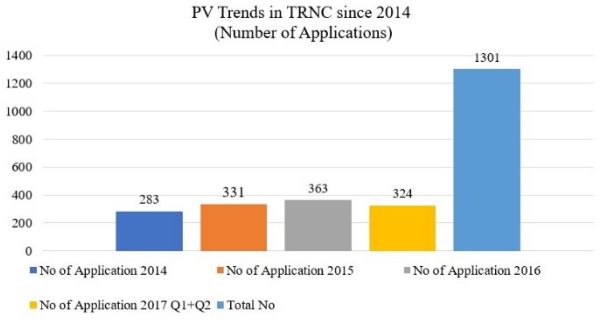

Figure 4: PV Trends in TRNC since 2014 [10]

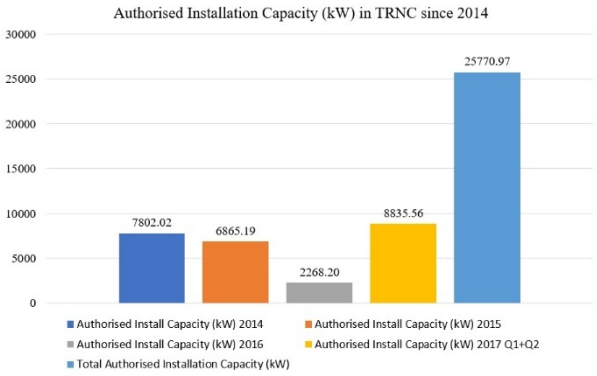

Figure 5: Authorised Installation Capacity in TRNC since 2014 [10]

3. METHODOLOGY

1. Gathering data from KIB-TEK about residences who has net metering to see how much energy they purchased from grid and how much energy they sell to grid.
2. Gathering energy generation data from solar photovoltaic system, from PV System installation companies about residences who have net metering.
3. Cross-Checking the data after the PV installation period, from KIB-TEK and Governments to match the correct residents and their relevant data.
4. Using formula of;
   $E_{generated} - E_{given} = E_{internal\text{-}usage}$ (1)
   Where, $E_{generated}$ is the energy generated by the solar photovoltaic system (kWh), E_{given} is the energy given to the electricity/utility grid (kWh) and $E_{internal\text{-}usage}$ is the internal energy usage (kWh), which means the electricity used from the system's generation before giving it to grid. With this formula, the internal energy consumed by residence by subtracting the energy given to grid from total energy generated by solar photovoltaic system is found.

5. By using formula of;
   $E_{internal\text{-}usage} + E_{purchased} = E_{real\text{-}con}$ (2)
   Where; $E_{purchased}$ is the amount of energy purchased from electricity grid (kWh) and $E_{real\text{-}con}$ is the real/true consumption of the residence (kWh). To find true/real consumption, the

addition of the value of energy purchased by grid and internal energy consumption is done.

6. Find the average energy consumed by that residence before solar photovoltaic system installation and net metering for a time period by using "=Average" function in spreadsheet software (12 months).
7. Find the average energy consumed by that residence after solar photovoltaic system installation and net metering for equal time period by using "=Average" function in spreadsheet software (12 months).
8. Find changes in consumption in seasonal periods.
9. Create charts/graphs for each of the subscribers.
10. Create charts/graphs for overall data.
11. Analyse the charts/graphs to see the consumption habit changes.
12. Discuss the causes of the change in habits.
13. Discuss the impact on domestic and governmental size.

4. RESULTS

There are 823 residents who have access to net metering in July 2017 according to KIB-TEK. Most of the residents who have accessed to net metering, were installed in 2016. Having 298 net metered residents and 36.21% of the total net metered residents. 240 of the 298 are single phase residents and 58 of them are three phase residents. 2016 values are closely followed by 2015 with the 260 net metering access holding 31.59% of the total share. Like 2016, most of these 260 residents are single phase. There were 224 single phase residents who accessed to net metering in 2015 against 36 three phase residents. 160 residential net metering access with 19.44% in 2014. 126 of which are single phase residents and remaining 34 are three phase residents. In the first half of the 2017 with 105 residential net metering access with the remaining 12.76%, having 83 single phase and 22 three phase residents. The total installed capacity for single and three phase resident who has net metering has 4023.47 kW. The 2016 is also leading in this area with 1408.93 kW. 1006.16 kW of the total capacity is distributed in single phase houses and 402.77 kW of it is in three phase residents. According to the data 2015 is in the second place with 1280.59 kW. The distribution between single and three phase are 969.54 and 311.05 kW. There is a huge gap of 486.34 kW, suggesting 794.22 kW size net metering access houses in 2014. From the total access in 2014, 527.64 kW of them belong to single phase and the remaining 266.58 kW belong to three phase residents. Lastly in the first half of 2017, only 539.74 kW has accessed to net metering. Like previous years single phase residents lead in 2017 with 363.74 kW against 176.0 kW three phase residents. [11]

Table 1: Distribution of Net Metered Residences since 2014 [11]

	2014		2015		2016		2017	
Residents with Net Metering	Capacity (kW)	No	Capacity (kW)	No	Capacity (kW)	No	Capacity (kW)	No
Single Phase	527.64	126	969.54	224	1006.16	240	363.74	83
Three Phase	266.58	34	311.05	36	402.77	58	176	22
Total	794.22	160	1280.59	260	1408.93	298	539.74	105
Total over Years (kW)	4023.47							
Total over Years (number)	823							

In this research, the data access was around 200 residences but only 51 of those residential data which have a share little more than 6% of the total net metered houses can be used due to non-reliabilities, errors, and similar sort of problems. The analysed results of these data showed that only 11.8% which are equivalent to 6 residents who installed the solar photovoltaic systems and access to net metering has lowered their energy consumption. The remaining 88.2% which are equivalent to 45 residents increased their energy consumption. The mean result in these 51 residents were 48.68% increase in energy consumption with 261.47 kWh increase per month. Before installation of the photovoltaic systems the average of total consumption for these 51 residents were 774.93 kWh per month, however after the installation of the

solar photovoltaic systems in their houses, the total consumption became an average of 1036.40 kWh per month [11].

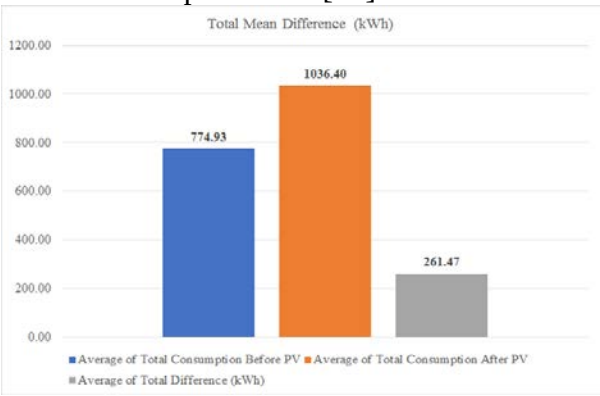

Figure 6: Total Average Differences in Consumptions [11]

Table 2: Total Average Consumption Differences [11]

Average Total Consumption Before PV (kWh)	Average Total Consumption After PV (kWh)	Average Total Difference (kWh)	Average Difference in Total Consumption (%)
774.93	1036.40	261.47	48.68

There are several categories to observe how much change happened in how many residents. In this research it is divided into 10 categories to get the numbers how many residents increased or decreased their consumption in percentage format. The increase of the consumption holds 7 categories and decrease holds only 3 due to the lack of residents who lowered their consumption. The increasing categories starts from 0 and goes until 60% by increasing 10% at a time and when at reached 60% it counts the rest of the residents who raised their consumption more than 60%. The decreasing categories has the same logic but instead of increasing, it decreased until -20% by 10% and after -20% it counts all the residents who lowered their consumption more than 20%. From the total number of 51 residents, 5 of them increased their consumption between 0-10%, 4 residents increased their consumption by 10-20%, 4 residents increased their consumption 20-30%, 8 of the houses increased their consumption by 30-40%, 3 of them increased their consumption by 40-50%, 5 of the residents increased their consumption by 50-60% and 16 residents increased their consumption by either 60% or more. In the decreasing groups 4 residents lowered their consumption by 0-10% and only 1 resident lowered its consumption by 10-20% and 1 resident decreased its consumption more than 20% [11].

Table 3: Distribution of Consumption increase per Percentage Category [11]

0-10 %	10-20 %	20-30 %	30-40 %	40-50 %	50-60 %	>=60 %	0 to -10%	-10 to -20%	<=-20 %
5	4	4	8	3	5	16	4	1	1

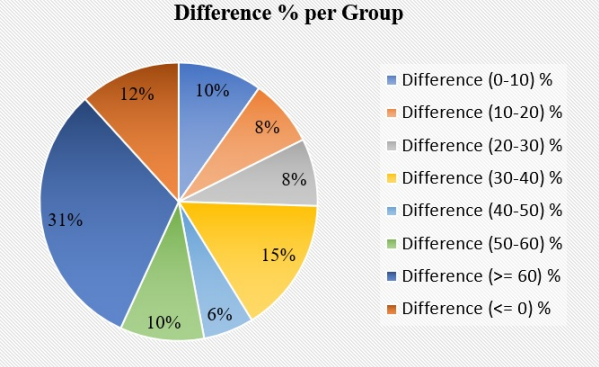

Figure 7: Difference Percentage per Group [11]

Another aspect of the consumption changes can be seen in seasonal format. The seasonal format is divided into two both having six months. Sunny Season includes months from April to September (inclusive) and Dim Season includes months from October to March (inclusive). The seasonal aspects contain 17 subscribers which have their system installed more than 12 months (1 year). The average consumption before solar photovoltaic system in sunny season has an average of 575.37 kWh and 619.60 kWh in dim season. However, after installation of solar photovoltaic systems, this number has increased 47.92% with 275.73 kWh making a consumption of 851.10 kWh in sunny season and even bigger escalation in dim season with 52.01% with 322.24 kWh increase to reach 941.84 kWh. [11]

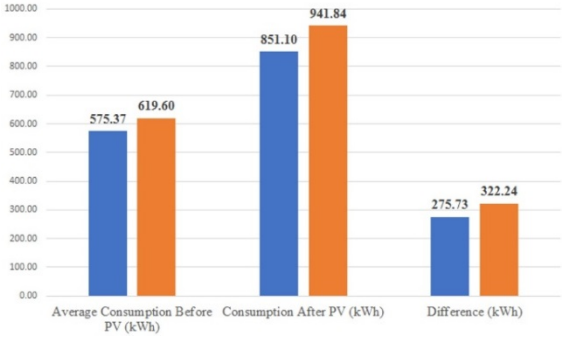

Figure 8: Impacts of PV in Seasonal Basis (kWh) [12]

5. CONCLUSION

The results show a trend that shows some major changes in energy consumptions after installing solar photovoltaic systems. As given in results section there is a considerable increase in consumptions and approximately 90% of the residents are accountable in this increase. The overall increase suggests that there is almost 50% increase in consumption rates which can be interpreted as a worrying trend. Additionally, the when we check the changes in the seasonal consumptions which is divided into sunny and the dim season, one being the sunny 6 months including spring and summer and the other being dim including autumn and winter season, the consumption change is still around fifty per cent. The average total consumption before solar PV system investment were 575.37 kWh and the consumption average escalated to 851.10 kWh after the investments done, creating a difference of 275.73 kWh which is equivalent to a 47.92% increase for the Sunny Season. For the Dim Season, the average consumption before the solar PV systems were 619.60 kWh and this amount changed to 941.84 kWh. The 322.24 kWh is equivalent to 52.01% increase which can be assumed as a worrying trend. The main reason for this is with the escalation in the residential consumptions which holds more than one third of the whole electricity consumption in TRNC, the new additions and investments most likely to be needed to made in electricity power plants. For the government, to give incentives and increase the maximum capacity for renewable technology investments, it is surely needed to invest more in electricity power plants or find a way to connect another country or government with interconnect system. The main reason for this is, the electricity distributors must be able to back up the residences and commercial investors if a problem occurs in their system. In a case of mass need for the electricity due to problems of the renewable energy sources in TRNC, the electricity distributors must be prepared for preventing harmful outcomes. The results showing increase due to several reasons such as lack of education on energy efficiency for housing or consumption of unnecessary energy and rapid change of consumption habits of residential solar photovoltaic energy investors, the investments on power plants to back up the renewable sector must be made sooner than expected. The increase in energy consumption also increases the energy consumed in peak hours which is directly related with the power plant's maximum capacity and without increasing the maximum capacity and backup capacity of power plants can cause power outages if the rapid increase out scales the maximum capacity of electricity power plants. To prevent this kind of problems, several ways can be used such as investing in capacity size of power plants, educating the people on energy consumption, making surveys to learn details of consumption habits to give feedback on people and creating incentives for energy efficient electronics and tools to reduce the unnecessary consumptions. Getting adapted to changes and possible outcomes and be prepared for the bad situations, is a vital point in any country and giving required attention to subjects like this always useful and helpful for a developing country like TRNC to advance faster in many areas since energy is major player in every government and economy.

5.1 Meeting the Objective

The objective of the paper is to see the correlation of the consumption change of residents after installation of solar photovoltaic system. To observe this, the gathering of accurate data played a vital part. With the analyses of these reliable data, we can see the changes clearly and design and devise a plan according to these changes to help the solar photovoltaic systems to have a positive impact. As a result of the reliable data and accurate analyses the results were definitive enough to make trustworthy conclusion, therefore the paper met its objective.

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