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Conference Chair,

IRENEC 2017

Dear Colleagues,

In our journey of promoting 100% Renewable Energy, we have arrived the 7^{th} stop where we shall again share our research results and other achievements.

Every day we are discovering and practicing the good quality of renewable energies. The genie is out of the bottle. It is time to use the good quality of human beings to guide this opportunity effectively to the destination. The qualities of human beings can play its role if the individuals and countries talk together and define problems correctly and find solutions that can be implemented.

In our planet earth, energy problem started with industrial revolution which required huge amounts of energy. Coal combustion in the atmosphere caused the death of millions of people. Switching to petroleum as a solution ended up with the wars where millions of people killed each other. Using nuclear waste heat between 1973 and 1978 from nuclear weapon production facilities to produce electricity did not work because of the costs involved during construction, operation, decommissioning and waste storage of nuclear power plant facilities.

Fossil fuels are available in certain parts of the planet earth and owned by the local people and needs to be protected by the locals against the foreigners. When more people like to use these fuels, the market price increases due to high demand and cost of military operations and weapons needed to protect the site from the foreigners.

Renewable energy resources at each corner of the atmosphere are readt be converted to electricity and process heat locally when needed. Kinetic energy of the moving air, chemical energy stored in biomass, heat and light of the sun and geothermal resource are available all over our planet earth free of charge. As the main energy source of living space on earth, sun and its derivatives where available before, are available today and will be available in the future.

The problem was the unavailability of the technologies to convert renewable energies to electricity and process heat. Beginning with late 1970s, OECD Countries decided to cooperate in IEA Technology Initiatives program to develop clean coal technologies, safe nuclear power plants, energy end use efficient equipment, renewable energy technologies and energy decision support tools.

As a result, energy decision support tools were developed and used for designing the future energy systems with the technologies of the future; energy efficient end use equipment and renewable energy technologies developed became commercially available.

The efforts to develop clean coal technologies and safe nuclear power plants proved to be not feasible due to externalities involved and nuclear accidents respectively during 1990s.

Global support provided for the renewable energy made the market penetration of renewables possible. Today wind and solar energy became the cheapest wat of producing electricity in many parts of the world.

Cities and countries who are trying to reach 100% renewable energy mix are working on preparing the infrastructure necessary to be able to supply more renewable energy for industry, transportation and buildings by smart grids and renewable energy storage systems.

Since renewable energy is available at every corner of our atmosphere, Community Power (the involvement of the local people individually or through their cooperatives and municipalities in the decision making process and ownership of their energy production facilities) is becoming the most effective approach for transition to 100% renewable energy future.

During IRENEC 2017 we shall share and learn the global experiences on difficulties, barriers, opportunities and solutions for transition to 100% renewable energy societies and make our contribution to Global Transition to 100% Renewable Energy.

Tanay Sıdkı Uyar

Conference Chair, IRENEC 2017

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Full Research Papers

Analysis of Funded PV Battery Systems in Germany: Prices, Design Choices and Purchase Motivation

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ABSTRACT. Grid parity of residential photovoltaic (PV) power generation and retail electricity prices make self-consumption of solar power increasingly interesting for private households. Residential PV Battery Systems provide the opportunity to store solar energy that is not locally consumed during the day and make it available for self-consumption in the evening, thus cutting the electricity bill. Moreover, decentralized stationary battery systems are a promising technology to deal with grid problems that can arise due to high local penetration of solar power generation. Because relatively high system costs for small stationary battery systems still pose an obstacle for a broad market launch, the German Federal Government has issued a market incentive program to stimulate the market and boost technology development of PV Battery Systems. In order to additionally gain a better understanding of the technology under realistic operating conditions, an accompanying scientific monitoring program has been established. This paper outlines the most important terms and conditions of the market incentive program, the methodology of the monitoring program and presents current results of the market situation of government-funded PV Battery Systems in Germany. Note, that this paper is a short version update to an existing paper published by Kairies et al. in *Energy Procedia Volume 73* [1].

Keywords: PV Battery Systems; Grid integration; Market incentive programm; KfW funding; Decentralized storage

1 INTRODUCTION

As part of its internationally much-noticed transition towards renewable energies (Energiewende), Germany faces an increasing penetration of PV power generation in its electricity grid: In 2016, a production of 38.2 TWh of solar power covered more than 6.4 % of the German net power consumption [2]; in early 2017 more than 1.58 million photovoltaic power plants with an accumulated nominal power of ca. 41.2 GW were installed [3]. Since 80 % of the German PV power generation and feed-in occurs decentralized in the low voltage distribution grids, significant challenges for the local electrical equipment can arise as large numbers of individual PV systems add up to considerable power levels. This can lead to regional problems with respect to the voltage stability or overburden the local electrical equipment such as power cables or medium voltage transformers [4, 5 and 6]. PV Battery Systems can reduce the described problems by absorbing the peak solar power generation that is produced during noon time and make it available for local self-consumption in the evening, thus relieving the low voltage distribution grids [7, 8]. In order to promote the use of PV Battery Systems and examine their grid-relieving potentials under realistic operation conditions, the German Federal Ministry for Economic Affairs and Energy issued a market incentive program accompanied by a scientific evaluation program.

2 THE MARKET INCENTIVE PROGRAM

The German Federal Government and the state-owned KfW banking group issued a market incentive program for PV Battery Systems in the year 2013. Due to its huge success, the funding program was re-launched in 2016 for another three years till 2018. The program aims towards an accelerated market introduction of PV Battery Systems that increase self-consumption and act grid-relieving at the same time. The funding is intended to stimulate the market, thus promoting technology development and bring down retail prices for small stationary battery systems in the long term. For this purpose, the KfW banking group provides loans for PV Battery Systems at reduced rates with an additional repayment grant. This grant is – starting from 25 % at the beginning of 2016 – decreased by 3 percentage points every six months, which leads to a current rate of 19 % of the eligible costs in May 2017. To ensure an expedient development of the technology and a grid-relieving operation of the subsidized devices, the funding is subject to several requirements. The most important technical requirements include a fixed maximum feed-in power of 50 % of the corresponding PV power generator and a battery warranty of at least 10 years. Furthermore, all funding recipients need to register with a scientific monitoring program and provide the technical data of their PV Battery System. Both, the amount of funding and the funding requirements are laid down in guidelines which are continuously amended, taking account of the current state of market developments [9].

3 THE MONITORING PROGRAM

Several studies have shown a positive influence of PV Battery Systems on low voltage grids by using computer simulations (including [7], [8] and [10]). However, the impact of larger numbers of decentralized PV Battery Systems in the field today can only be estimated. To gain a profound understanding of their effects under real term conditions, the market incentive program is supervised by a monitoring program funded by the Federal Ministry for Economic Affairs and Energy (BMWi) from the start. The monitoring program gathers several kinds of data:

- **Core data** like the number and type of battery systems, their dimensioning and average retail prices as well as the geographical distribution of PV Battery Systems in Germany
- **Electricity meter data** like the PV System's monthly power generation, electricity consumption of the household (kWh per month), grid feed-in (kWh per month) or the battery system efficiency
- **High-resolution measuring data** like irradiation, power generation of the PV power generator, three-phase currents and voltages of the household and the PV Battery System, battery temperature and state of charge, power line frequency and harmonics, grid feed-in power, self-consumption, et cetera.

This data is used to track market developments, to evaluate system performances and to provide acquired knowledge to the interested public.

4 RESULTS OF THE MONITORING PROGRAM

The following chapter presents an evaluation of the core data gathered from the program's beginning in 2013 until April 2017. After an introduction of the analysis' marginal conditions in Chapter 4.1, the results of the analysis are presented in sections 4.2 to 4.4.

4.1 Data Cleansing

The results of the core data presented in this paper illustrate an analysis of the ongoing monitoring program. The technical data of the PV Battery Systems is manually entered into a web interface including free text fields; as a result, incorrect or mixed up entries can occur. To consider these circumstances, autonomous algorithms are developed and additionally manual reviewing through experts is done to improve quality of the data base. **Error! Reference source not found.** shows an extract of validity conditions, which are defined within the scope of data-cleansing.

Table 1. Technical validity conditions for the shown analysis.

Value	Validity Condition
Stated installed capacity	Larger than 1 kWh, smaller than 100 kWh
Stated usable capacity	Larger than 1 kWh, smaller than 50 kWh
Stated battery technology	Lead-Acid or Lithium Ion
Storage system price incl. battery	Larger than 2,000 €, smaller than 30,000 € (incl. VAT)

4.2 Technical analysis of the registered PV Battery Systems

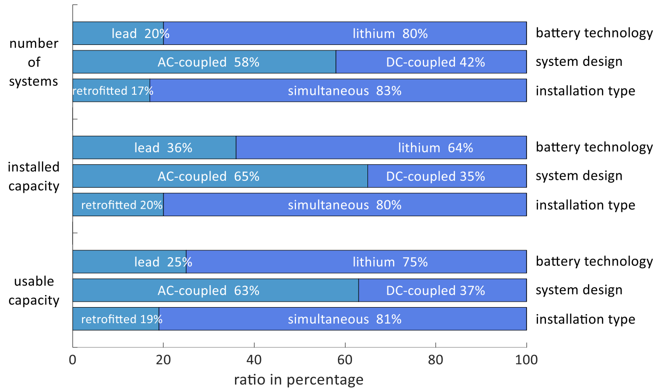
In **Error! Reference source not found.** (left), the distributions of three major technical system properties (battery technology, system design and installation type) of the registered PV Battery Systems depending on three different evaluation criteria (number of systems, installed capacity, used capacity) are shown. The installation type is dominated by simultaneous installations with more than 80 % for all three criteria. More than half of the installed systems are AC-coupled systems with shares around 60 %. While the first two system properties are similar throughout the different evaluation criteria there is a higher variation concerning the ratio of the battery technology. The spread of 15 percentage points between the lead share regarding the criteria number of systems and the installed capacity can be explained by the differences in system dimensioning of lead-acid and lithium-ion batteries. **Error! Reference source not found.** (right) displays these differences showing the average battery sizes of the registered PV Battery Systems according to the battery technology used. First of all, it can be seen that lead-acid batteries on average feature usable capacities of about 8.8 kWh whereas lithium-ion based systems are smaller designed, featuring average usable capacities of about 6 kWh. The installed capacities that are needed to make these usable capacities available differ even more significantly. Lead-acid batteries usually utilize only 50-60 % of their installed capacity, leading to average installed capacities of ca. 16 kWh to obtain reasonable lifetimes. Most lithium-ion batteries on the other hand are able to utilize 80-100 % of their installed capacity. Thus on average installed capacities around 6.7 kWh can be observed for lithium-ion systems. This typical dimensioning seen in the PV Battery System market complies directly with well-recognized studies on battery aging and international standards to maximize the lifetime of stationary battery systems, as presented in [11, 12 and 13] for lead-acid batteries or in [14, 15] for lithium-ion batteries.

4.3 Price analysis of the registered PV Battery Systems

In **Error! Reference source not found.** (left) the development of the retail prices (incl. VAT) of PV Battery Systems with different battery technologies, related to one kilowatt-hour of usable capacity, is pictured. It has to be noted that the prices for the first half of 2013 and for the first half of 2017 are considered to be less sufficient than the others due to the relatively small number of datasets. It can be seen, that there is a continuous decrease in system prices since the beginning of the market incentive program in May 2013. While the average lead prices decreased from around 1,400 €/kWh in the end of 2013 to 1,200 €/kWh in the end of 2016 by ca. 14.3 %, the average lithium prices fell by 41.6 % from the end of 2013 (2,640 €/kWh) till the end of 2016 down to ca. 1,540 €/kWh. The first 96 registered lithium systems in the beginning of 2017 indicate that this course continues. Reasons for the observed price decreases can be found, among others, in decreasing battery costs and a larger production scales. It should be noted though, that parts of the pictured (average) price reduction can be traced back to the fact that increasing amounts of AC-coupled systems and/or single-phase systems enter the market. These systems both feature fewer components and are usually cheaper than comparable DC coupled systems or systems featuring a tri-phase grid connection, thus lowering the average market price.

4.4 Attitude towards PV Battery Systems

The registration process for funded systems includes a short survey of questions considering the motivation of acquiring a PV Battery System and the experiences made while purchasing it. In **Error! Reference source not found.** (right), the participants' main motivations of acquiring a PV Battery System are displayed for the registered systems clustered by the kind of installation. Remarkably, the results for both installation types are almost identical: The three main reasons to invest in a PV Battery System today are hedging against increasing electricity costs, contribution to the German Energiewende and a general interest in storage technology. On the other hand, only a few of the participants pointed out that a discontinuation of their guaranteed feed in tariff, the use as a safe investment or a protection against power failures were valid reasons to invest into a PV Battery System. This clear division into two categories as well as the parity of the results for



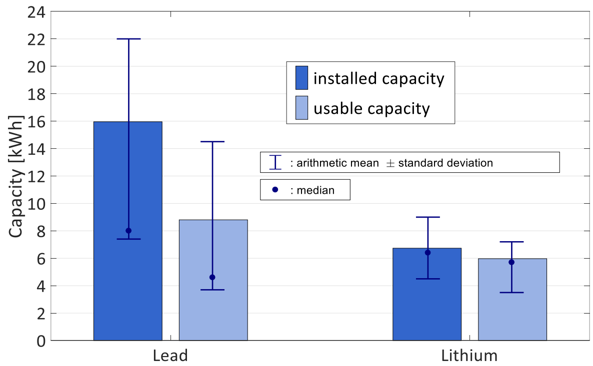


Fig. 1. Overview about typical system configurations (up) and average installed and usable capacity of the registered PV Battery Systems (down).

both installation types indicate that today especially ‘soft factors’ are predominant reasons to invest into residential solar storage system.

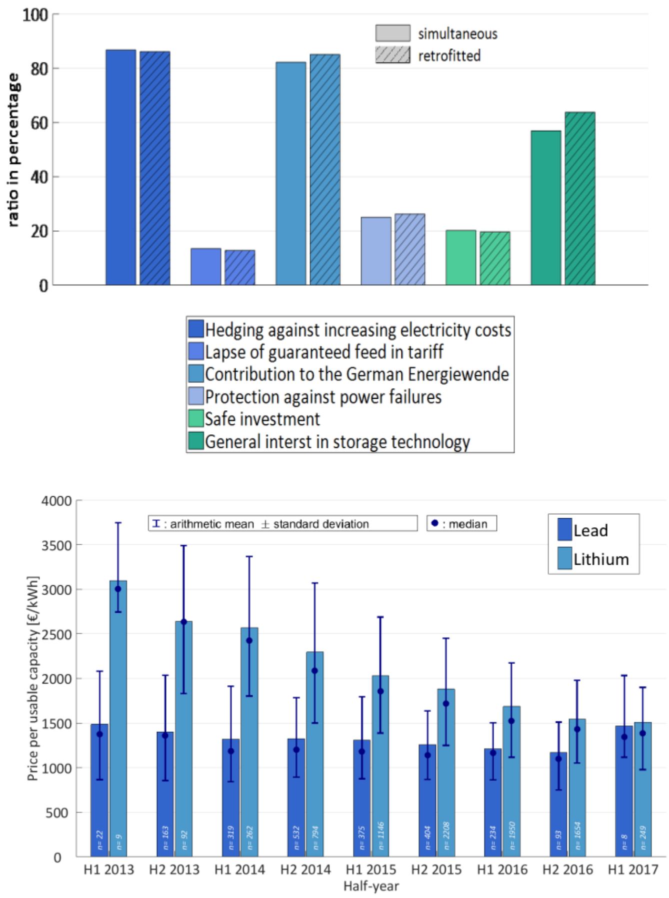


Fig. 2. Evolution of the average net system prices of the registered storage systems without assembly prices (left) and main purchase motives (right).

5 SUMMARY AND OUTLOOK

The Scientific Measuring and Evaluation Program for Photovoltaic Battery Systems (“Speichermonitoring”) started its monitoring activities in September 2014. A steadily growing database of comprehensive information regarding PV Battery Systems allows continuous in-depth analysis of the German market for decentralized storage systems. Additionally, high-resolution measurements (T=1s) of 20 privately operated storage systems in Germany are conducted since 2015. This data is used, among others, to evaluate the real-life operating behaviour, system efficiencies and potentials for bi-directional grid services. Results are regularly published on conferences, in journals and on the project website www.speichermonitoring.de. The next annual report of the monitoring program will be published at the beginning of July 2017. It will provide further and more detailed information regarding the technology- and market development of PV Battery Systems in Germany and also feature results of the monitoring of the operating data.

6 ACKNOWLEDGEMENTS

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The Renewable Energy Act in Germany: Its Basic Idea and Recent Developments

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ABSTRACT. The Renewable Energy Act (EEG) in Germany is the foundation for the worldwide expansion of renewable energies and its application led to their cost decay, which was anticipated only by very few experts. The basics of the EEG has been copied in more than 50 countries supporting the use of renewable energies. This contribution explains the basics features of the EEG and derives the factors for its success. Furthermore, it gives a personal view on the recent development of this law in Germany and the resulting development of renewable energies in Germany.

Keywords: Renewable energy, legislation, Renewable energy act, Germany

1 INTRODUCTION

The Renewable Energy Act (Erneuerbare-Energien-Gesetz, EEG) in Germany can be considered as the base for the amazing growth of Renewable Energies in the last decade. This growth can best be visualized in a figure with logarithmic scale as shown in **Error! Reference source not found.** (Data sources listed in the figure). If the growth dynamic of the first decade of this millennium had continued, the electrical energy demand could be covered by 100% with renewable energies in 2020. However, the growth has been reduced meanwhile. Nevertheless, about one third of the electric demand can be supplied by renewable energies today. During some hours in the year, the electrical demand can already even be covered by 85% of renewable energies in Germany (see **Error! Reference source not found.**) **Error! Reference source not found.**]. What is the reason for the success of this regulation?

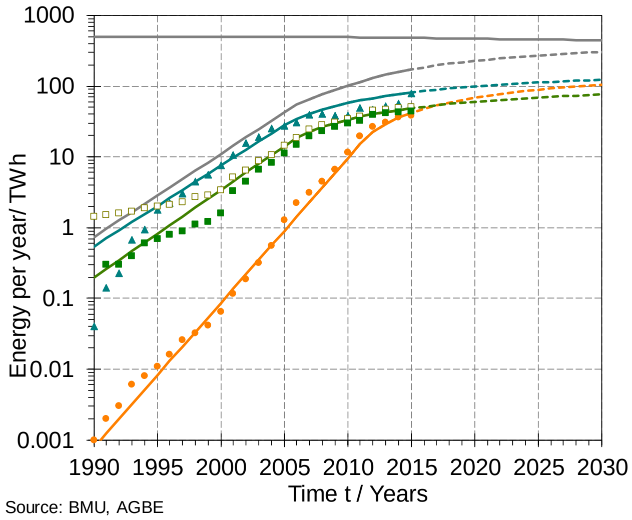

Fig. 1. Development of the energy feed-in from renewable energy sources in Germany.

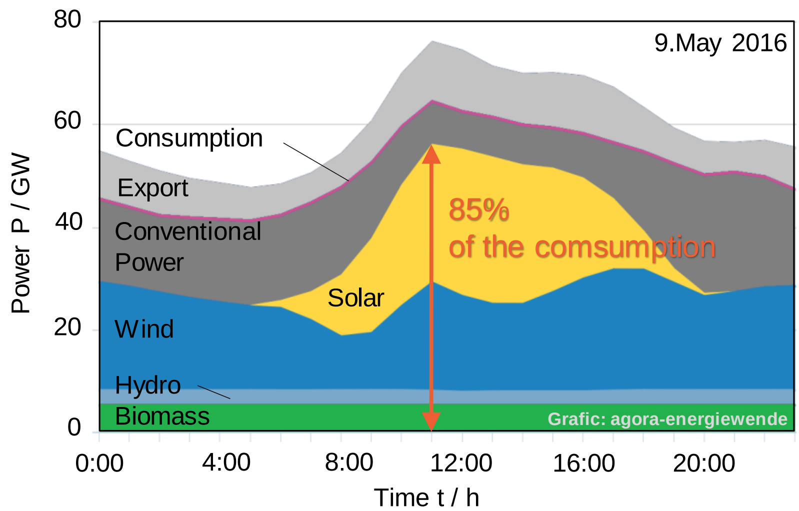

Fig. 2. Example for an extreme daily feed-in of renewable energy sources and consumption of electrical power in Germany **Error! Reference source not found.**].

2 DECENTRALIZED GENERATION

Renewable energy sources are by themself distributed and decentralized. Thus, physics supports an energy system owned and maintained by many individual citizens rather than large companies. Such citizen's transformation has several advantages:

- It can be faster, because private persons are satisfied with less profit that large companies. Thus, the same money can be used for more investments
- It can be faster, because additional capital can be raised from many small investors, which otherwise wouldn't have use the money.
- It can be faster, because a contribution of citizens (financial contribution and responsibility) results in faster agreement and less confrontation.
- It can be faster, because many more people can act in parallel.
- If we really want to realize the results from the climate conference in Paris, we are forced to act much, much faster. Therefore, the energy transformation must be decentral and citizens owned.

3 THE THREE PILLARS OF THE RENEWABLE ENERGY ACT

The EEG supports a decentralized „Bürger-Energiewende", a transformation towards an energy system owned and maintained by citizens. The basic, original idea of the EEG is based on three pillars: cost-covering feed-in tariff, cost sharing among all customers and fed-in priority for renewable energies (see also illustration in **Error! Reference source not found.**).

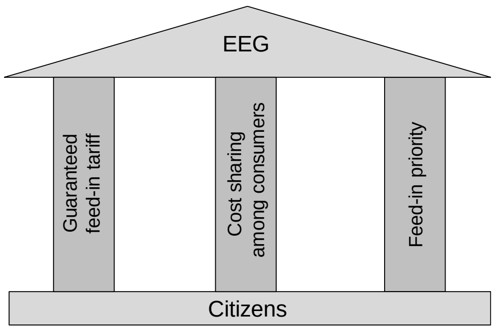

Fig. 3. The tree pillar of the German Renewable Energy Act (EEG).

3.1 Cost covering guaranteed feed-in tariff

The cost-covering feed-in tariff has significantly contributed to the success of the transformation of the energy system. It is set such it allows a depreciation of the investments within the lifetime of 20 years with a reasonable profit. Contrary to a direct subsidy for the investment, this principle forces the owners to maintain the equipment. Otherwise, their financial investment would be lost.

The feed-in tariff is fixed at the time the equipment is installed and then it remains guaranteed for 20 years. This gives safety for the taken investments and readiness of the banks for giving loans. This is important to put the energy transition on a broad base. The investment into an own photovoltaic (PV) system or in other citizen energy projects must as predictable as buying a car. The height may be discussable, especially with the background of a possible self-consumption (see below). However, such a guarantee must be available also in future.

The feed-in tariff for new installed equipment reduces by time. Due to a huge production extension and corresponding learning rates the cost of renewable energy sources reduces year by year. Especially the photovoltaic costs have been decreased drastically beyond any expectations. **Error! Reference source not found.** shows the decrease of the feed-in tariff for home PV system smaller than 10 kW **Error! Reference source not found.**]. Before the year 2000 local initiatives implemented a similar remuneration scheme. At that time, a feed-in tariff of about 1 €/kWh was given to operators of the first PV systems. In addition, it has to be noted that today in sunny areas of the world PV production cost of about 3 €ct/kWh are possible for large scale systems. PV has become the cheapest energy supply of all.

Error! Reference source not found. also shows for comparison the typical price of household electricity including all tax and further fees. The data is taken from the corresponding author's personal electricity bill in Aachen, Germany. Since a few years, PV energy is significantly cheaper than electricity bought from the grid. This is becoming the main motivation for using private PV systems in Germany. The difference is even high enough to pay for first battery storages. The majority of actually built PV systems in Germany are sold with a battery storage now.

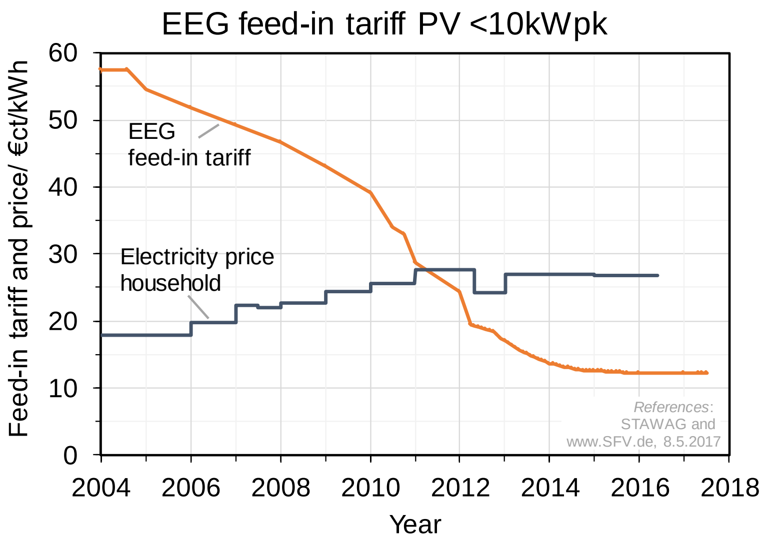

Fig. 4. Development of the feed-in tariff for small PV systems (<10 kWpk) compared to the household electricity price in Germany.

3.2 Cost sharing among all customers

The cost of the feed-in tariff is shared among all customers using electrical energy. Every user has to pay a certain amount for each spent kWh, the "EEG allocation", which is about 6.9 €ct/kWh in 2017. This is a very fair principle: Those who use more energy have to pay more. In Germany, this is organized by the grid operators, not by the government. Therefore, the cost does not put any burden on the public tax system. In addition, this avoids unsuitable influences by politics. If the cost were organized by a public tax system, criticism on spending "public money" could easily raise.

However, additional burdens are put on this EEG allocation, as illustrated in **Error! Reference source not found.**. The figure shows the development of the EEG allocation **Error! Reference source not found.**] in comparison to the payments to the operators of renewable energy systems **Error! Reference source not found.**]. At the beginning until 2009 the two curves follow each other, as expected. After 2009, the EEG allocation increased over-proportional compared to the expenses for the system. This results from two reasons. First, politics changed the mechanism for calculating the EEG allocation then. The allocation only includes the "additional cost" for renewable energies, with the cost for conventional electricity as a reference. From that time on, the price at the stock exchange was taken as the reference. But this price is heavily reduced due to renewable energies. Therefore, the difference increased and the EEG allocation as well. Furthermore, energy intensive industry was exempted from the EEG allocation in order to keep that industry in Germany. However, the cost had to be shared by less customers, leading to an increase of the EEG allocation for the remaining electricity users.

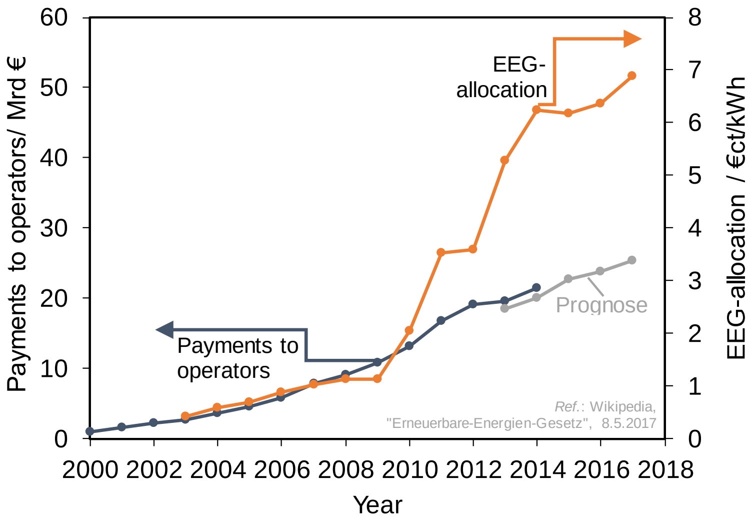

Fig. 5. Development of the EEG allocation compared to the payments to operators of renewable energy generators in Germany.

3.3 Feed-in priority

The third pillar is the feed-in priority for renewable energies. Conventional power sources are supposed to reduce or even shut down their generation before any renewable energy sources are cut. If the power cannot be distributed due to grid constraints, the operators are obliged to extend their grid "immediately".

This is not to be confused with a feed-in guarantee. We need to maintain the balance between generation and consumption. When in the near future the generation with renewable energy sources exceeds 100% of the power need for some hours, it will be necessary to limit the feed-in. Also the possibility to store energy can be used to relieve the grid. However, in any case, first fossil and nuclear power has to be shut down in such a case.

However, the EU commission is going to abandon the priority dispatch for renewable energies in Germany and other countries leading in Renewable Energies. As soon as more than 15% of the electricity is generated from renewable energy sources, the priority dispatch for renewable energies shall no longer be applied **Error! Reference source not found.**]. As a consequence, feed-in of Renewable Energy could be cut not only by technical reasons, but by commercial reasons to give priority to energy delivered with dumping prices from lignite or nuclear power plants.

4 CONCLUSION

Concluding, I consider the German renewable energy act (EEG) as the base and one of the best legislatives for a decentralized and distributed energy transition to renewable energies. The guaranteed feed-in tariff reduces the risks and stimulates investments also by ordinary people. The share of the cost among all customers is fair and relieves the public tax system from additional burdens. And the feed-in priority forces the grid operators to adapt and extend the power grid.

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Performance Comparison of Multi-Effect Solar Assisted Absorption Refrigeration Systems Using Libr-H_2O and Licl-H_2O Working Pairs

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ABSTRACT. The present study is conducted to evaluate and compare the energy and exergy analysis of solar assisted single effect, series flow double effect, and parallel flow double effect absorption cooling cycles using LiBr-H_2O and LiCl-H_2O working pairs. The nanofluids of Aluminum Oxide Water (Al_2O_3-H_2O) are used as heat transfer fluids (HTF) in the parabolic trough solar collectors and the results compared with that of pure water (H_2O). The energy and exergy analysis of the integrated systems are performed to evaluate the effect of nanofluids on the coefficient of performance (COP), as well as the exegetic efficiency of the systems. The results confirmed that the thermal conductivity of the nanofluid, Al_2O_3-H_2O is observed to be 11.32% higher as compared with H_2O and heat transfer coefficient observed to be 33.43% higher as compared with H_2O. The COP of LiBr-H_2O observed to be 6% higher as compared to LiCl-H_2O as working pair in absorption cooling cycles. The results show that the COP of single effect and double effect absorption cooling cycles increases with the increase in evaporator temperature. The COP of the series flow double effect absorption cooling cycle observed to be 55.5% higher as a compared single effect absorption cooling cycle and exegetic efficiency observed to be 4% higher as a compared single effect absorption cooling cycle. The parametric studies are performed, and the optimized COP of the single and series flow double effect the cycles are observed to be 0.8925 and 1.396 respectively.

Keywords: Nanofluids, Absorption cooling, Energy, Exergy, COP

1 INTRODUCTION

To overcome the environmental effects related to air conditioning and refrigeration systems, it is important to start using no-pollution energy sources in the system. Using the sun as a direct primary energy source makes this sustainable and economically feasible because of its immense availability and environmental friendliness. Researchers have exposed that solar energy is a perfect energy source for heating application [1]. The heat energy uses by many industries, produce by the burning of non-renewable energy resources. This industrial process releases heat to the environment as a waste heat. However, the waste heat can be used as a source of energy for absorption refrigeration system, where it is transformed into valuable heat for refrigeration cycle as heat source [2]. Usually, the performance of absorption refrigeration cycle is related to thermodynamic properties of the working fluids [3].

The lithium bromide-water (LiBr-H_2O) is the working fluid in the absorption cooling system because it has the high latent heat of vaporization. However, LiBr as absorbent and H_2O serve as a refrigerant, with the low operational temperature at temperatures about 5°C [4]. Wide analysis of the literature shows that LiBr-H_2O working pair is superior and suitable for the refrigeration systems operating about 5ºC. The decrease in the generator thermal load improves the coefficient of performance (COP) of the system. From many studies that were carried out by researchers on both single and double effect absorption cooling system, the COP and exegetic efficiency of the double effect absorption system are high as compared with single effect systems [5]. The highest exergy destruction found in the generator, which made it be the most significant component of the system and discovered that the solution heat exchanger is more effective when compared with a refrigerant heat exchanger for improving the performance of absorption refrigeration system [6]. The second law analysis of a series and parallel flow double effect solar assisted absorption cooling systems carried out with LiBr-H_2O as working pair established on the idea of equilibrium temperature at the low-pressure generator. The result shows that the maximum achievable COP for parallel flow cycle is superior compared to series flow cycle for all range of working conditions considered. The COP of parallel flow double effect solar assisted absorption system is more sensitive to the effectiveness of low-pressure heat exchanger when compared with series flow double effect solar assisted absorption system [7]. The second law based analysis shows that the exegetic efficiency of double effect absorption cooling system increase a little when compared with the exegetic efficiency of the single effect absorption cooling system [8].

The aim of this paper is to design and analyze the single and double effect solar assisted absorption refrigeration systems and to evaluate their performance LiBr-H_2O/LiCl-H_2O working pairs. The effect of the nanoparticles as a heat transfer fluid in the parabolic solar collector is also evaluated using Engineering Equation Solver (EES) software. The effect of the heat source temperature on generator load, generator temperature, evaporator temperature, COP, and exergy efficiency will be observed using parametric analysis. The effect of nanofluids (Al_2O_3 H_2O) on COP as well as on exergy efficiency of the integrated systems is evaluated.

2 DESCRIPTION OF THE SYSTEM

The double effect series flow absorption cooling system is shown in figure 1 below. The system consists of an evaporator (ev), condenser (c), absorber (a), solution heat exchangers (HX_1 and HX_2), weak solution pump (p), high pressure generator (HPG), low pressure generator (LPG), two solution expansion valves (EV_2 and EV_3) and two refrigerant expansion valves (EV_1 and EV_4). There are three different pressure stages, which are HPG, LPG, and evaporating pressures. The absorber inlet and outlet pressure level is the same with evaporator inlet, and outlet pressure level and the LPG and condenser input and output are at the same pressure level.

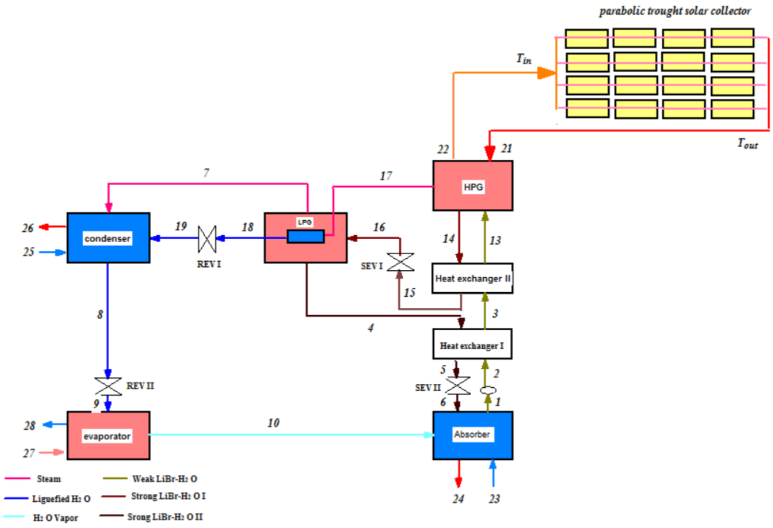

Fig. 1. The schematic illustration of solar assisted series flow double effect absorption refrigeration system,

Moreover, the HPG and the high-pressure condenser are at the same pressure level. LiBr-H_2O takes three different concentration stages, which are strong, stronger and weak solutions. The solution (x_1) is considered to be the weak solution at the outlet of the absorber, and strong solution is assumed to be at x_{14} and x_4 at the outlet of HPG and LPG, respectively. The HPG gets thermal energy, Q_g from parabolic trough solar collector with nanofluids as HTFs, the LPG gain heat from the high-pressure vapor exits from the HPG. The condenser and absorber loses heat Q_c and Q_a respectively, to the cooling water. The two heat exchangers (HX_1 and HX_2) ensures a thermal balance between the weak and strong solutions. The use of two heat exchangers decrease the supplied heat, Q_g and thus improves the COP and exegetic efficiency of the system. In double effect parallel flow absorption cooling system, the weak solution from the absorber gets distributed into the LPG and HPG. The rest of the parallel flow cycle works similar to series flow cycle [9].

3 METHODOLOGY

The thermodynamics analysis of the absorption refrigeration system applies the first and second laws of thermodynamics as well as the mass, energy and exergy conservation at each component of systems. The equations used to model the systems are presented in this section. The parabolic collector used in the present work is adopted from the literature [10]. The circulation fluids (HTF) used are pure H_2O and Al_2O_3-H_2O nanofluids. The mathematical model of the parabolic trough can be accessed from [10]. The absorption refrigeration cycles of single and double effect are adopted from [9] and standard mass, energy and exergy balance of the cycles is presented below. The mass balance at each component within the system assuming a steady state and steady flow system is as follows,

$$\sum \dot{m}_{in} = \sum \dot{m}_{out} \quad (1)$$
$$\sum \dot{m}_{in} x_{in} = \sum \dot{m}_{out} x_{out} \quad (2)$$

where, m is the mass flow rate of the fluid and x is the percentage of lithium in the solution. The energy and exergy balance for the steady flow devices is given as

$$\sum \dot{m}_{in} h_{in} + \sum Q_{in} + = \sum \dot{m}_{out} h_{out} + \sum Q_{out} \quad (3)$$
$$\dot{E} = \dot{m}(h - h0 + T0 s - s0) \quad (4)$$

where h0 and s0 are calculated at the location temperature, T0 = 293.15 K and atmospheric pressure P0=100 kPa. The following analysis uses temperatures in K. The general exergy destruction equation can be written as:

$$\dot{E}D = \sum \dot{E}_{in} - \sum \dot{E}_{out} \pm Q l - T0 T + w p \quad (5)$$

4 RESULT AND DISCUSSION

Simulations are carried out using EES software with constant cooling capacity Q_{ev} = 1000 kW, Pump efficiency (η_p) = 0.95 and heat exchanger effectiveness (ε) =0.7. The heat and pressure losses are not measured, the condensation temperature T_{cd}= 32 ^oC, and the absorber temperature T_{ab}= T_{cd}+0.2. The ambient temperature varied in the following range: T_0 = 25–50 ^oC. The cooling water temperature at the condenser and absorber inlet is equal to 29.4 ^oC and the water temperature at the outlet of the condenser and absorber is equal to 32 ^oC and evaporation temperature is varied in the following range: T_{ev} = 7–10 ^oC. The outlet temperature of chilled water assumed as T_{ev} + 4.5, and the inlet temperature of the chilled water assumed at T_{ev} + 0.25 ^oC. The generation temperature T_g varied from 70 to 100 ^oC and high-pressure generator temperature T_{hpg} ranges from 100-140 ^oC, the low-pressure generator temperature (T_{lpg}) fixed at 70.6 ^oC for double effect cooling cycle. The parabolic trough solar collector design with pure H_2O and nanofluid Al_2O_3- H_2O, the pure H_2O have higher useful energy when compared with nanofluid Al_2O_3- H_2O. The results shown in figure 2 states that the increase in inlet temperature (25 - 240ºC) increases specific heat capacity, and on the other hand decreases density of the fluids. It is also observed that the nanofluid has the higher density and observed to have the lower specific heat capacity when compared with pure water H_2O.

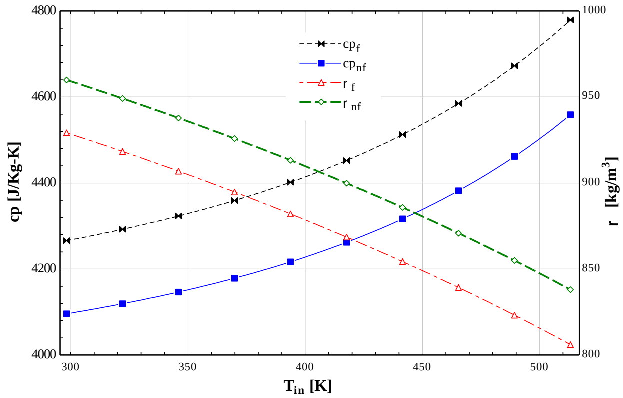

Fig. 2. Inlet temperature versus specific heat capacity and density for pure H_2O and nanofluid of Al_2O_3- H_2O.

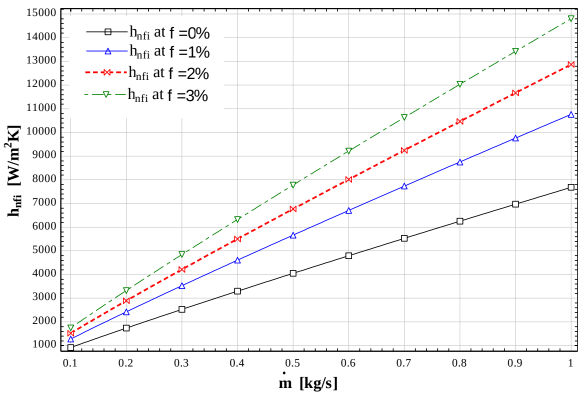

Fig. 3. Mass flow rate versus heat transfer coefficient for a different volumetric fraction of nanoparticles.

As shown in figure 3 the increase in mass flow rate increases the heat transfer coefficient of the fluid. The increase volumetric fraction of nanoparticle 0-3% inside the nanofluid Al2O3-H2O increases heat transfer coefficient of the fluid. The transfer coefficient of the fluid at volumetric fraction of nanoparticle (φ=0%, i.e., pure water) is observed to be lowest. The figure 4 and 5 shows that the increase of evaporator temperature increase COP and exegetic efficiency at fixed mass distribution to HPG and LPG. The results shown in figure 4 and 5 show that the lower the mass distribution ratio to HGP the higher COP and exegetic efficiency of the parallel flow double effect absorption refrigeration system.

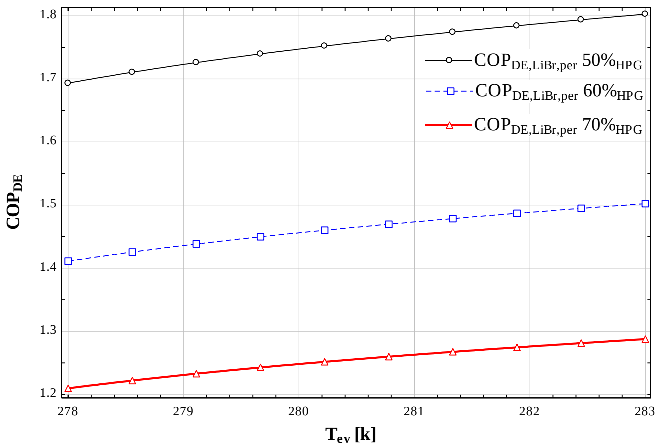

Fig. 4. Evaporator temperature versus COP for parallel flow double effect absorption refrigeration cycles for different mass distribution.

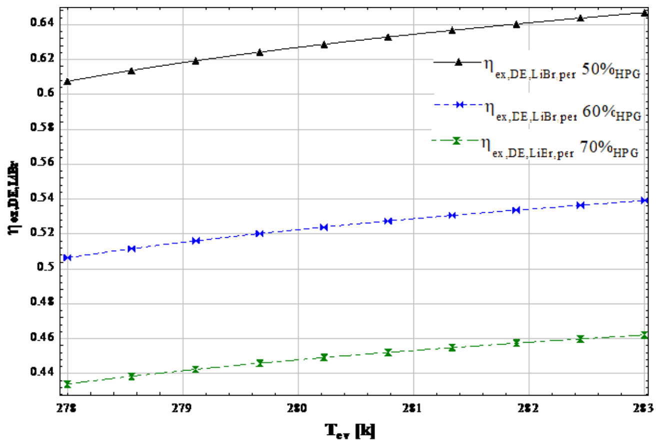

Fig. 5. Evaporator temperature versus exegetic efficiency for parallel flow double effect absorption refrigeration cycles for different mass distribution

5 CONCLUSION

The present study analyzes and compares the performance of single, series flow double and parallel flow double effect solar assisted absorption refrigeration systems with LiBr-H_2O and LiCl-H_2O as working pairs at cooling capacity of 1000 kW. The parabolic trough solar collector was designed with two different heat transfer fluids, pure H_2O and Al_2O_3-H_2O nanofluid to supply the required thermal energy for single and double flow absorption refrigeration systems. The results confirmed that the thermal conductivity of the nanofluid, Al_2O_3-H_2O is observed to be 11.32% higher when compared with H_2O and heat transfer coefficient observed to be 33.43% higher when compared with pure H_2O. Thermal energy input required for the generator to run the system decreases to 44.9255% for double effect absorption cycle when compared with single effect absorption refrigeration cycle. The result from the analysis also show that the COP of the LiBr-H_2O is 5-7% higher compared to LiCl-H_2O as working pair for single, series flow double and parallel flow double effect solar assisted absorption refrigeration systems. The COP of the series flow double effect is 55.5% higher than single effect absorption refrigeration system. The COP of the parallel flow double effect absorption refrigeration system depends mainly on the mass distribution ratio between the HPG and LPG.

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Turkey's Forecasting of Energy Demand with Artificial Neural-Network

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ABSTRACT. Energy demand is increasing day by day in parallel with economic growth, especially for the rapidly developing countries. In order to achieve a sustainable economic growth, long-term targets are being put to manage the operation of market in a good way. Turkey is an emerging and rapidly developing country so its energy demand has increased rapidly to meet the growing economy. Therefore, forecasting Turkey's energy demand accurately is of great importance to achieve a sustainable economic growth. The main goal of this study is to develop the equation for forecasting energy demand using the backpropagation algorithm which is one of the artificial neural-network models to determine the future level of energy demand. This study presents the predictions for the years 2017-2020. The results of the energy demand estimations found in this study are compared with the official estimations of the MENR. It is concluded that official estimations for Turkey's energy demand are dramatically higher than forecasting value presented in this study.

Keywords: Artificial neural-network, Turkey, Energy demand forecast

1 INTRODUCTION

Turkey's energy demand, one of the world's 20 largest economy[1], increasing day by day because of its expanding population, rapid urbanization and strong economic growth. Turkey's total primary energy supply is 129.7 mtoe[2] as of 2015. Majority of its energy demand is met by natural gas (30%), followed by oil (30%) and coal (27%) [2]. More than half of these primary sources are used for electricity generation. 68% of electricity generation is supplied by fossil fuels which are natural gas, coal and oil. On the other hand, hydropower has significant portion in the electricity generation

[1] Turkey is the 18th-largest economy in the world in terms of nominal GDP with 735.72 billion dollars in 2016 [1].
[2] Mtoe: Million tons of oil equivalent.

with 26%. Moreover, industry is the most energy consuming sector in Turkey with 31.974 btoe[3] [3]. Thus, production factors are more involved in the production process with industrialization i.e. rapid urbanization for Turkey. Increasing use of production factors in the production process leads to an increase in energy consumption. Industry is developing, energy investments become more efficient and production and employment increase with increased energy consumption. This process affects GDP in a positive way. Therefore, energy is one of the most important factors for Turkey's growth and it is important to make reliable demand forecasts for the future to sustainably meet the rising energy demand with growing population, increasing industrialization and urbanization in the framework of these developments.

Forecasting of demand refers to the process of organizing and analyzing past period data to determine and anticipate what a firm's or country's sales of products or investments will be for future periods [4]. Population growth, population composition, urbanization, industrialization and economic growth are generally accepted as components in the demand forecasting models [5]. Energy should be used more efficiently due to limitations of energy sources in addition to environmental factors. Therefore, demand forecasting is the most important instruments of energy politics. Forecasting methods are divided into two major groups which are qualitative and quantitative methods. Qualitative forecasting methods are based on the opinions and experiences of the individual who is expert on the subject studied whereas quantitative forecasting methods are based on mathematical models [6]. In this study, artificial neural-network (ANN) which is one of the quantitative methods are used.

The main goal of this study is to develop the equation for forecasting energy demand using the backpropagation algorithm which is one of the artificial neural-networks models to determine the energy demand in 2020. Based on our findings, some policy implications related to energy demand are also discussed. In this study, we will evaluate the energy consumption predictions to forecast the energy demand for Turkey for the next four years (201-2020) using the artificial neural networks. The results show that official estimations for Turkey's energy demand are significantly higher than forecasting value presented in this study.

Remaining of this paper is organized as follows. In section 2 literature review about energy demand of Turkey using ANN is presented. In section 3 regression analysis used for determining which variables should be used in ANN modeling is demonstrated. In section 4 ANN approach used in this study is explained and results of the ANN modeling and forecasting are presented. In section 5 conclusions about this study is discussed.

2 LITERATURE

There are many different forecasting techniques in the literature for estimating energy demand. For example, energy demand is forecasted using time series models, regression models, econometric models, decomposition models, cointegration models,

[3] Btoe: Billion tons of oil equivalent.

ARIMA models, artificial systems (expert's systems and artificial neural-network models), grey prediction models, and so on [7]. In Turkey, there are several articles on Turkey's energy demand forecasting. Models established by using artificial neural-network are illustrated in Table 1.

Çunkaş and Altun (2010) estimates the Turkey's long-term electricity demand for the years 2008 to 2014 by using ANN. In the study, they compared the forecasting results of two ANN models, three-layered back-propagation and a recurrent neural network and concluded that the recurrent neural network model produces the best forecasting results. Hotunluoğlu and Karakaya (2011) predicts Turkey's energy demand by using ANN and three different scenarios are developed which are static, sustainability and periodic-change scenarios. They found that MENR estimations for Turkey's energy demand are significantly higher than those presented in this study. Es et al. (2014) predict Turkey's net energy demand up to 2025 for the years 1970-2010. The study compared the prediction performance of built ANN model and a multiple linear regression technique and it is concluded that ANN is superior than the multiple linear regression technique. Bayrak and Esen (2014) analyzes the energy deficit and energy production predictions for Turkey for the years 2012-2020 by using ANN. They concluded that the energy demand is expected to rise at an annual rate of 3.2% with 152.492 thousand toe in 2020, so official estimations of the MENR is dramatically higher than those presented in this study. Yetiş and Jamshidi (2014) predict Turkey's electricity consumption for the years 2012-2023 using ANN and found that net electricity consumption is expected to increase to 373.09 GWh. Birim and Tümtürk (2016) predicts the Turkey's electricity demand for the years 2015-2023 by using multiple linear regression and ANN. Four different models were developed and it is concluded that Turkey's electricity consumption is expected to vary between 337087.4 and 385006.6 Gwh by 2023 and official estimations of Turkish Electricity Transmission Company (TEIAS) is higher than those presented in this study (except model 2).

Table 1. Studies on Energy Demand Forecasting of Turkey Using Artificial Neural Networks

Author(s)	Variables	Years	Demand	Forecast period
Çunkaş and Altun [8]	GNP, GDP, population, number of households, index of industrial production, oil price, electricity consumption per capita, electricity price	1981-2002	Electricity demand	2008-2014
Hotunluoğlu and Karakaya [9]	Population, export, import, energy intensity, GDP	1970-2008	Energy demand	2009-2030
Es et al. [10]	GDP, population, import, export, area of the build-	1970-	Net energy	2011-2025

	ing and vehicles number	2010	demand	
Bayrak and Esen [11]	Real GDP, Population, export, import, energy consumption	1960-2011	Energy demand	2012-2020
Yetis and Jamshidi [12]	GDP, index of industrial production, population	1992-2011	Electricity Consumption	2012-2023
Birim and Tümtürk [13]	GDP, population, import, export, employment, natural gas	1992-2014	Electricity demand	2015-2023

3 METHODOLOGY

3.1 Artificial Neural Networks Models

Artificial neural-networks are a mathematical model that tries to model the information processing capabilities of the biological neural networks [14]. One of the major application areas where ANN is being used is to forecast. "ANNs provide an attractive alternative tool for both forecasting researchers and practitioners". ANNs' features such as being data-driven self-adaptive methods, universal functional approximators, nonlinear and enabling generalize provide valuable and attractive results [15]. ANNs are systems consisted of certain artificial neurons that work together. The structure of an ANN consists of three major layers which are input layer (entry layer), hidden layer (mid layer) and output layer. The structure is illustrated in Figure 1. The information (which are independent variables in this study) is transmitted to the network through the input layer. They are processed in hidden layer, and then sent to the output layer [16].

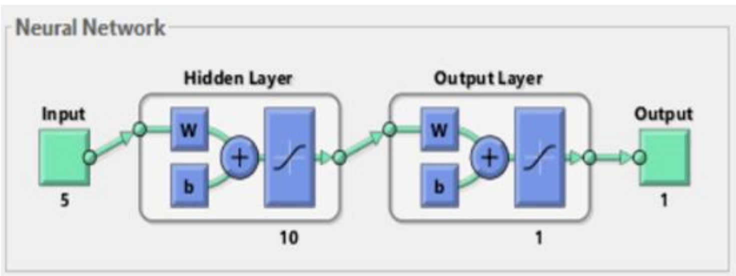

Fig. 1. Typical Processing Element of an Artificial Neural Networks

ANNs' models are divided into feed forward and backpropagation neural network. In this study, backpropagation neural network is used because in the backpropagation, historical data is used and "some of the information flows not only in one direction from input to output but also in opposite direction" whereas in feed forward, "information flows from inputs to outputs in only one direction" [17].

4 EMPIRICAL RESULTS

This section provides information on the data set and resources used in this study and evaluates the results of the artificial neural networks used for the data analysis. Besides, predictions are done for target years 2018 and 2020 made by MENR. The numerical analysis software MATLAB 2014 has been used to model the artificial neural networks.

4.1 The Data Set

Independent variables used in this study are GDP, GDP growth, population, export and import whereas the dependent variable is primary energy consumption. Figure 2 shows the values of these variables for 1965-2015. In order to see the fluctuations in the graph more clearly, the data are transferred by normalization. Firstly, the system will be tested with the data from 1965-2015 then; forecasting will be made for the years 2017-2020. The data set used in the analysis is gathered from different sources. The annual data on total energy consumption (million tons of oil equivalents) obtained from BP Statistical Review of World Energy 2016. The data for the GDP (current US dollars), GDP growth (%) and population are taken from World Bank, World Development Indicators. Export and import (thousand dollars) obtained from Turkish Statistical Institute, Foreign Trade Statistics.

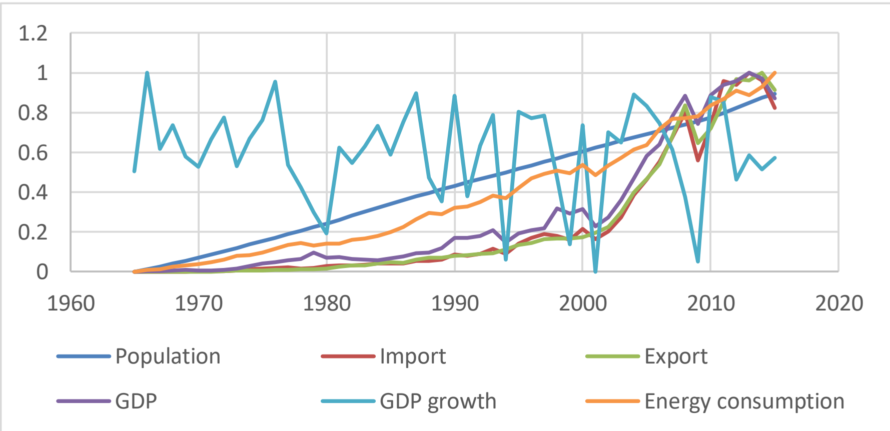

Fig. 2. Primary Energy Consumption and Independent Variables (1965-2015)

The raw data to be used in the development of the ANN must be normalized to see the fluctuations more clearly and to prevent the mistakes in the learning process. In this study, simple normalization is used and equation is as follows:

$$X^1 = \frac{X - X_{min}}{X_{max} - X_{min}} \qquad (1)$$

Xmin and Xmax constitute the minimum and maximum values of the parameters given in the data set whereas X1 is the normalized counterparts of data X.

4.2 Establishing the Network and Results

GDP, GDP growth, population, export, import and primary energy consumption are used to estimate the energy demand covered the years 1965-2015. Network structure of the model used in the ANN is illustrated in Figure 3.

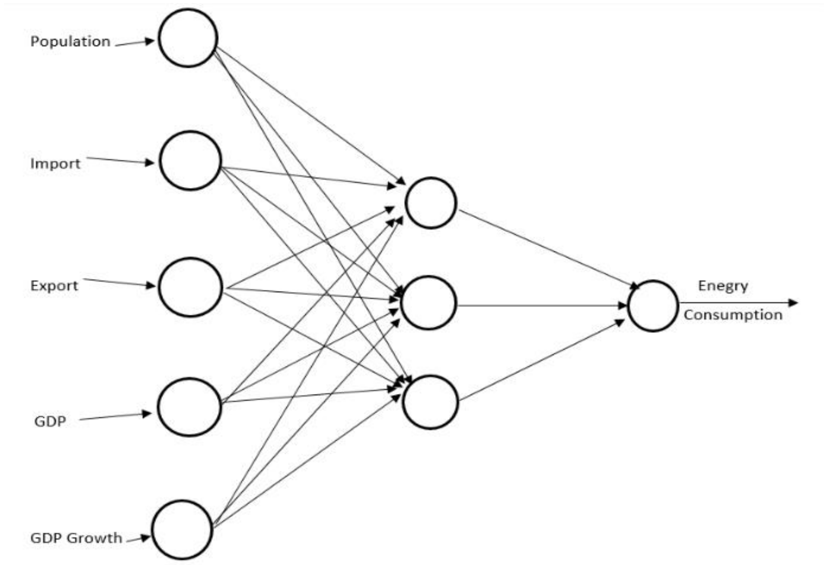

Fig. 3. The Artificial Neural Network Model Used in this Study

70% of given data is used for learning, 15% of given data is used for validation and 15% of given data is used for test group. After the algorithm learned the relationship between input and output, it can be estimated for the periods of 2017-2020 using given data. The given data is non-linear.

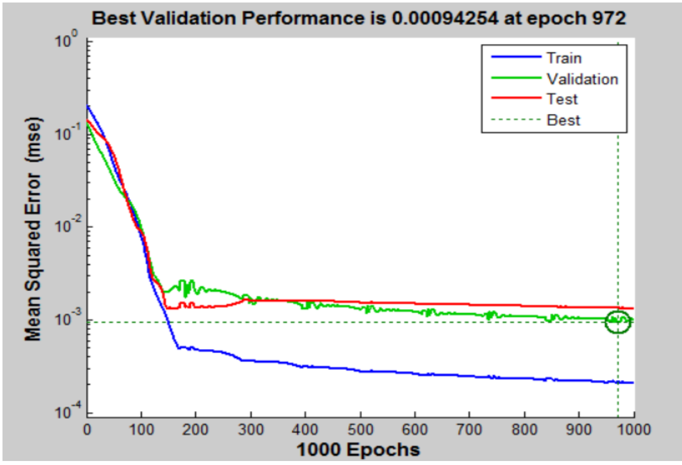

Fig. 4. The Performance Curves Designed according to ANN Model

In this study, mean squared error (MSE) is used to determine the performance of the network. At the shown Figure 4 the smallest mean squared error is reached at the 1000th iteration and it is recognized that the best learning occurred at this stage.

Prediction results are shown at the table 2. According to the results the energy demand, which was 131,324 thousand toe in 2015, will increase by 8,1% in total (from 2015 to 2020), reaching 141,971 thousand toe in 2020. GDP growth is estimated as 1,09% in 2020 whereas it was 3,97 % in 2015. Low increase in GDP growth causes the increased energy consumption as lower than estimated value of it.

Table 2. Prediction Results of the ANN

Years	**Population**	**Import**	**Export**	**GDP**	**GDP growth**	**Energy Demand**
2017	82761483	207806312	146924201	7,25276E+11	4,072285341	142,3838138
2018	80551266	208378265	155741687	7,13405E+11	-0,121815155	140,8231633
2019	81321569	208950218	156194268	7,12018E+11	0,456516817	141,4891891
2020	82076788	209522171	156505418	7,11012E+11	1,096740456	141,9711002
Years	Population	Import	Export	GDP	GDP growth	Energy Demand
2017	82761483	207806312	146924201	7,25276E+11	4,072285341	142,3838138
2018	80551266	208378265	155741687	7,13405E+11	-0,121815155	140,8231633
2019	81321569	208950218	156194268	7,12018E+11	0,456516817	141,4891891
2020	82076788	209522171	156505418	7,11012E+11	1,096740456	141,9711002

Figure 5 shows the changes of energy consumption from the year 1965 to 2020. Years between 2016 and 2020 are estimated by using ANN. It can be understood that the value of energy consumption will increase after 2015. This increase in the energy consumption will be higher than 2015 but it is not in the expected level.

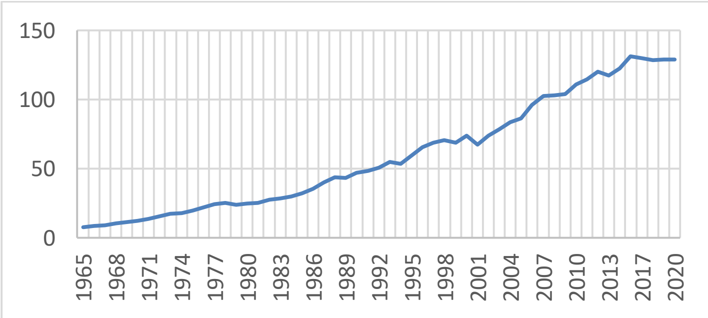

Fig. 5. Energy Consumption by the Years

5 CONCLUSION AND POLICY IMPLICATIONS

Turkey's energy policy is based on increasing the share of renewable energy sources, using energy efficiently, enhancing security of supply, meeting the growing energy demand in the sustainable way in terms of economic and environmental and achieving a competitive energy system that strengthens the strategic position of the country in international energy trade. In this regard, Turkey sets long-term targets to make investments properly. The main goal of this study is to develop the equation for forecasting energy demand using the backpropagation algorithm which is one of the artificial neural-networks models to determine the future level of energy demand. In this framework, the predictions of the energy demand for the years 2017-2020 are based on variables for the period 1965-2015. Based on energy consumption predictions made using the given data, the energy demand is expected to increase at 8,1% in total (from 2015 to 2020), reaching 141,971 thousand toe in 2020. The results show that official estimations for Turkey's energy demand are significantly higher than forecasting value presented in this study.

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Decision Support Model for Energy Cost Prediction

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ABSTRACT. The share of energy cost is one of the significant parts of the total cost. Because different energy sources can be used for energy production, the energy sources cost prediction has become very important for long and short term planning. Nowadays the accuracy of this predictions has become more important than the past. At this article, a new energy cost or price prediction method offers by using five components. These five components are as follows; political uncertainties, demand change, the discovery of new resources, development of new technology and the costs of future generations. The price or cost trends of various energy sources would be predicted by using the fluctuation of offered five factor. These factors may change according to various reasons. Thus energy prices would change accordingly.

Keywords: Energy cost calculation, Renewable energy, Decision support, Energy policy

1 INTRODUCTION

Nowadays energy is one of the most important concepts of our world. Energy is not only essential for industrial application but also the sustainability of daily life. The energy sources have been become more valuable than the past because of increasing demand. The traditional energy sources have been decreasing by day to day. The electric energy has an important share of energy demand except for motor vehicles. The main production methods were hydroelectric, thermal (coal, petroleum, natural gas) and nuclear. All of them are caused environmental problems. In order to protect the environment, the alternative electricity production methods should be renewable energy. The renewable energy could be produced by the wind, solar, biomass, geothermal etc. The renewable energy sources are local sources, so mainly the cost of the renewable energy will not be affected considerably from energy sources cost fluctuation at the international market if renewable energy infrastructure components can be produced locally. This is very important subject in terms of economic sustainability and stability of a country. The energy cost share is the very important portion at the total cost of any production or service. The energy cost stability contributes to the stability and durability of a company or country. It is an additional benefit of renewable energy.

The present prices/cost of the conventional energy source such as crude oil, natural gas, coal, nuclear changes according to some variables of the world market. At this article, five variables are suggested for predicting energy cost trend. These variables are political uncertainties, demand change, the discovery of new resources, improvement of new technology and the costs of future generations. These variables cannot be controlled completely by any country. These suggested five component variation would affect energy sources costs. For example, political uncertainty might decrease demand for energy so crude oil price decrease. Brexit decision in June 2016 has been caused 6% decrease in crude oil prices. A big earthquake has occurred in March 2011 in Japan. In short time world oil price, unusually, fell on news of the disaster. Japan economy is the world's third-biggest economy and third biggest importer of crude oil. As a result of this disaster, Japan's crude oil demand has declined in the short term. Because economic output has declined and factories were shut. A barrel of benchmark Brent crude oil was down %2,4. The improvement of new technologies and processes makes it possible to use an existing source with competitive cost advantage that could not able to used feasibly in past. The shale gas cost is one of the typical examples. The production of shale gas has been increased from 5% to 40% between 2007 and 2013 in total US gas production by using new developing Technologies [3]. As the conventional energy sources cause environmental problems, future generation cost factor has to be considered. The explosion on BP's offshore drilling rig in the Gulf of Mexico has resulted in the largest accidental offshore oil spill in the history of the petroleum industry in 2010. It caused environmental disaster about sea pollution and BP company has paid more than 7 billion US$ compensation.

2 ENERGY COST CALCULATION COMPONENT

The following five components are suggested for predicting energy cost. The proposed components (variables) are political uncertainties, demand change, the discovery of new resources, improvement of new technology and the costs of future generations. We supposed that the fluctuation of these variables would affect energy sources costs. First of all, one of the energy source is selected for cost prediction such as crude oil, the sun, the wind etc. Then these five component is evaluated for selected source. Each of the five components is weighted as the percentage according to the influence of energy cost. The total of the weight should be hundred percent. A value between minus one to plus one is appointed for each component by taking into account of current conditions. The weight of each variable multiply by related appointed value. Finally, the sum of five multiplied values is found. It will be a positive or negative value between minus one to plus one. The positive numeric values show the decreasing trend of selected energy cost. The negative numeric values show increasing trend. The new values have to be calculated when one or more variables are changed considerably. At this method, each variables weight's and appointed score has to be tested in order to predict realistic value. So the energy cost is predicted by considering new conditions. All of the five factors are mutually interact with each other. By the using of the model more accurate cost/price prediction may be done. Thus the planning of the energy investment may be planned more effectively.

2.1 Political Uncertainties

The political conditions have been changing very rapidly according to previous times. The new cooperation or conflicts may arise between the countries in short time period. The acts of terrorism may affect current situation instantly.

2.2 Demand Change

Energy demand is increasing day to day. The increasing consumption and population are the main reasons for increasing demand. The growing economy means increasing energy demand. The supplying of energy demand may also be changed from one source to another in time. The major earthquake in Japan in 2009 led to damage to nuclear power plants. As a result, the conventional sources for energy production headed to Japan. This situation has increased the world's oil demand and has raised the price of crude oil. The similar case was also faced in Germany. Germany government decided to close nuclear power plants earlier than previously planned date. Thus current energy demand has directed to other sources. This condition caused to increase other energy sources prices.

2.3 Discovery of New Sources

The discovery of new sources will affect the amount of supply. So this may create decreasing trend for prices. The new source may be conventional new sources or completely new source such as shale gas. The new sources and/or technologies may decrease energy cost significantly.

Shale oil is rapidly emerging as a significant and relatively low cost new unconventional resource in the US. There is potential for shale oil production to spread globally over the next couple of decades. If it does, it would revolutionize global energy markets, providing greater long-term energy source security at lower cost for many countries. It is estimated that this increase could reduce oil prices in 2035 by around 25%-40%. [1]

2.4 Improvement of New Technology

The energy cost which obtained from different sources have to be competitive each other. Some sources could not be used because of higher costs in past. The improvement of new technologies, processes makes it possible to use them for competitive cost advantage. The shale gas cost is one of the typical examples [4].

3 Costs of Future Generations

The conventional energy sources caused environmental problems. It is very important subject for the more livable world. The environmental problems sometimes result as an environmental disaster.

The 20 April 2010 explosion on BP's offshore drilling rig in the Gulf of Mexico resulted in the deaths of 11 people and injured 16 people. It caused the largest accidental offshore oil spill in the history of the petroleum industry. BP company have to pay more than 7 billion US$ compensation.

This kind of environmental pollution is not acceptable for today and future generations. The sustainability is the most important subject. The cost of the future generations has to be considered the cost comparison of energy sources. The renewable energy has the important advantage at this point of the view.

4 ENERGY COST CALCULATION

Energy cost calculation component is described in section three. Each of the components is weighted according to the effected percentage of the energy cost. The total of the weight should be hundred. A number between minus one and one is determined as a score for each component by taking into account the current conditions. Each score is multiplied by the associated weight. So a numerical value is calculated for each five components. The sum of calculated numerical value describes the cost trend of related energy source. Finally, the sum of five values is found. It would be a positive or negative number between minus one to plus one. The positive numeric value shows the decreasing trend of energy cost. The negative numeric value shows increasing trend. The new value has to calculate if one or more variables are changed considerably. So the energy cost is predicted by considering new conditions. This method has to be tested in order to predict a realistic value for five variables.

Table 1. Cost Trend Calculation table

Variables	political uncertainties	demand changing	new resources	new technology	future cost	Total
Weight %	40	20	10	10	20	100
Scores	1,0	0,3	-0,8	-0,1	-0,1	
Weight x Scores	0,40	0,06	-0,08	-0,02	-0,02	0,35

At this example, Total Weight x Scores is 0, 35. This is a positive number so the available cost may decrease 3.5%. If this value 0 (zero) It will not expect any change in cost. The total of Weight x Scores may be in between -1 to +1. The negative value shows increasing trend and positive value shows decreasing trend of the energy cost. The cost fluctuation till %10 can be explained by this model at one step

A big earthquake has occurred in March 2011 in Japan. In short time world oil price, unusually, fell on news of the disaster. Japan economy is the world's third-biggest economy and third biggest importer of crude oil. As a result of this disaster Japan, crude oil demand was decreased in the short term. Because economic output declines and factories were shut. A barrel of benchmark Brent crude oil was down as much as $2.68 at $111.16. [2]

It is considered that four components of the model are same but demand change in this case. This condition is shown in Table 2.

Table 2. Cost Trend Calculation Table After Japan Earthquake 2011

Variables	political uncertainties	demand changing	new resources	new technology	future cost	Total
Weight %	40	20	10	10	20	100
Scores	0,0	1	0	0	0	
Weigh x Scores	0	0,2	0	0	0	0,2

At this example, Total Weight x Scores is 0, 2. This means is the available cost would decrease 2% according to this model. At the real case, benchmark Brent crude oil price was down %2,4.

5 RESULT

The new model is proposed to estimate cost trend for energy sources. Five variables are defined that affect energy cost. These variables are political uncertainties, demand change, the discovery of new resources, improvement of new technology and the costs of future generations. These variables cannot be controlled completely by any country. In order to make an accurate prediction, a reliable database has to be established for each variable.

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Determination of Ejector Performance for 4 KW SOFC System Through Geometrical Approach

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Abstract. One of the important energy saving tools used in solid oxide fuel cells (SOFCs) are the ejector systems which are capable of the recirculation of the unused fuels and/or the exhaust gasses including hot steam (H_2O) which is necessary for elimination of the carbon deposition and initiation of the reactions in reformer. In an ejector system developed for the SOFCs, the steam to carbon ratio (STCR) and entrainment ratio are the essential parameters for the determination of the ejector performance. These parameters can be engineered by modifying the geometric dimensions and operation conditions (i.e. pressure and temperature). This study focuses on the determination of the maximum STCR value and entrainment ratio via numerical analyses for a micro combined heat and power system based on 4 kW SOFC, utilizing methane. A detailed procedure for designing an ejector is provided and its efficiency is investigated for different critical dimensions (throat diameter, nozzle exit angle and nozzle position etc.). The results show that the nozzle positon and the nozzle exit angle significantly affect the STCR and entrainment ratio. 4032 different design points are investigated to determine the optimum nozzle position and nozzle exit angle. The entrainment ratio and STCR are determined respectively as 7.3 and 2.59 for a specific design created in the study.

Keywords: Ejector, SOFC, Geometrical design, Entrainment ratio, STCR

1 INTRODUCTION

Energy saving and effective usage are the most important issues because of the economic and environmental issues such as global warming and energy source shortage. Since ejectors provide compression of liquids or gases by mixing with other liquids or gases at relatively higher pressure without any moving parts and external energy, they can be a little part of the solution of the economic and environmental problem with reusing unused fuel as in micro combined heat and power (μ-CHP) systems based on

Solid Oxide Fuel Cells (SOFCs) for the recycling of the anode exhaust gases in order to supply steam at high temperatures to initiate reforming reaction [1-3] and recycle the unused hydrogen gas [3-5].

Most of the existing researches in the literature are based on the ejectors applied in cooling and refrigeration [6-11]. On the other hand, ejectors for the µ-CHP system based on SOFC are much different due to differences of high entrainment, admissible STCR, low pressure increment and overheated working gases compared to the cooling and refrigeration applications. Therefore, the optimum ejector geometry must be searched for the ejector used under the SOFC operation conditions in order to determine the most effective design point. The performance of an ejector related to STCR, entrainment and ejector outlet temperature are intensely influenced by the ejector geometry. It can be seen a large number of studies in the literature about the application of an ejector in SOFC systems for different ejector geometries [12-16]. But in most of them, the secondary flow (anode exhaust gases) is fed to the mixing chamber in the same direction as the primary flow (methane) and the studies are carried out in 2D.

In this numerical study, anode exhaust line is designed different from the literature and conformity with the real system conditions. 4032 different cases for various ejector geometries, such as nozzle exit position (NXP), throat diameter (D_1), mixing chamber diameter (D_3), converging nozzle length (L_1), converging nozzle angle (α) etc. are numerically investigated via CFD modelling technique to determine the optimum ejector geometry.

2 SOFC SYSTEM FOR ANODE GAS RECIRCULATION

A µ-CHP system based on SOFC which utilizes methane as a fuel and mainly consists of three components namely an ejector, a reformer and a fuel cell stack is shown in Fig.1. The low pressure anode exhaust gases composed of H_2O, CO, CO_2 and H_2 are entrained to the ejector and mixed in the mixing chamber of the ejector with primary flow (methane) as a result of that, while the high pressure methane passes through the primary nozzle of the ejector, its velocity increases and hereby the pressure decreases down to below the pressure of the anode exhaust gases. After then the mixed stream pressure increases along the secondary nozzle of the ejector up to the operating pressure of the reformer. The reactions taking place inside the reformer and SOFC are given below:

Reformer

$$CH_4 + H_2O \leftrightarrow CO + 3H_2 \quad (1) \qquad CO + H_2O \leftrightarrow CO_2 + H_2 \quad (2)$$

SOFC

Cathode	Anode	Overall
$\frac{1}{2}O_2 + 2e^- \leftrightarrow O^{2-}$	$H_2 + O^{2-} \leftrightarrow H_2O + 2e^-$	$H_2 + \frac{1}{2}O_2 \leftrightarrow H_2O$

The most effective parameters on the ejector performance are defined as the entrainment (ω) and STCR and they are given below, respectively:

$$\omega = msmp \qquad STCR = nH2OnCORecycle+nCH4Fuel \tag{3}$$

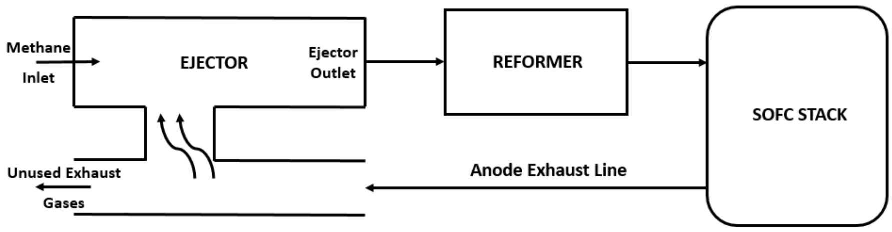

Fig. 1. A µ-CHP system based on SOFC with ejector

3 NUMERICAL MODELLING

Commercial software SOLDIWORKS as the geometry generator and Flow Simulation as the CFD solver are used in this study. The designed geometry of the ejector used in CFD analyses is illustrated in Fig. 2. The most important geometric dimensions which affect the ejector performance (STCR and entrainment) are NXP, D_1, D_3, α, L_1 that are determined from the literature. The considered design points are summarized in Table 1. 4032 different design points are created by changing these geometries within a certain range in order to determine the optimum value of the STCR and entrainment. The parameters used in CFD analyses are listed in Table 2.

Table 1. The ranges of geometric parameters

NXP (mm)	D_1 (mm)	D_3 (mm)	L_1 (mm)	α (degree)
6-10-14-18-22-26	0.6-0.8-1-1.2-1.4-1.6	6-8-10-12	2-4-6-8	2-3-4-5-6-7-8

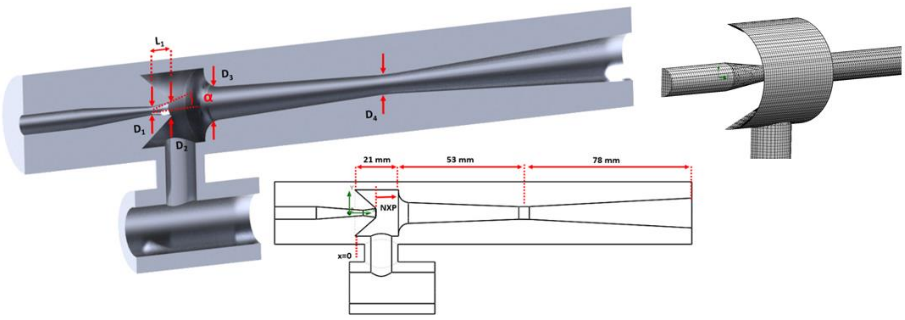

Fig. 2. Ejector geometry using in CFD analysis

Table 2. Operating condition of µ-CHP system based on SOFC using ejector

Parameter	**Value**	**Parameter**	**Value**
Ejector outlet pressure [bar]	1.17	System electric output [kW]	4
Primary flow inlet pressure [bar]	7	Fuel inlet composition [mass fraction, %]	CH_4 (100)
SOFC exhaust pressure [bar]	1.159	Exhaust (secondary flow) composition [mass fraction, %]	
Unused exhaust pressure [bar]	1.15	H_2	0.437
Inlet temperature of primary flow [K]	900	CO	4.69
SOFC exhaust temperature [K]	1100	H_2O	49.203
Isentropic coefficient of primary flow	0.98	CO_2	45.67
µ-CHP electric efficiency	0.48	Fuel (primary flow) inlet mass flow [kg/s]	0.000149

SOLIDWORKS Flow Simulation solves the mass, momentum and energy equations which are supplemented by fluid state equations defining the nature of the fluid and by empirical dependencies of fluid density, viscosity and thermal conductivity on temperature. SOLIDWORKS Flow Simulation employs transport equations for the turbulent kinetic energy and its dissipation rate, using the k-Ɛ turbulence model.

4 RESULTS AND DISCUSSIONS

4032 different scenarios related to NXP, D_1, D_3, α and L_1 are created to determine the most effective design parameters. The change of the STCR and entrainment are shown in Fig. 3. It is seen that the maximum value of the entrainment and STCR are determined at design point 175 as 7.3 and 2.59, respectively. The geometric dimensions of the design point 175 are given in Table 3. In addition, the changing of STCR and entrainment ratio with the critical ejector geometries are illustrated in Fig. 4. As it can be seen from the Fig. 4 (a), when the NXP increases up to a certain value which is 26 mm, entrainment and STCR increase because of flow characteristics which is free from the turbulence effect. This situation provides the higher pressure difference between the exhaust line and ejector flow line. However, it is seen from the Fig. 4 (b) and (c), as the converging nozzle angle and throat diameter increase, entrainment and STCR decrease since the turbulence flow characteristics is dominant through the ejector mixing line and prior the converging nozzle. The comparison of the best and worst situation's flow characteristics are given in Fig. 5. As can be seen from the figure the high performance ejector flow is more laminar than the worst one. One of the essential requirements at an ejector system is to obtain the high mach number flow which leads to low pressures and vacuum effect after primary nozzle diameter. According to the simulation results of the given design point, 1.8 mach is reached and pressure decreases to the about 0.5 bar. On the other hand, the temperature is the another critical parameter that trigger the chemical reactions in the reformer. For the given boundary conditions, 1000 K is obtained at the ejector out which is sufficient for the reformer system.

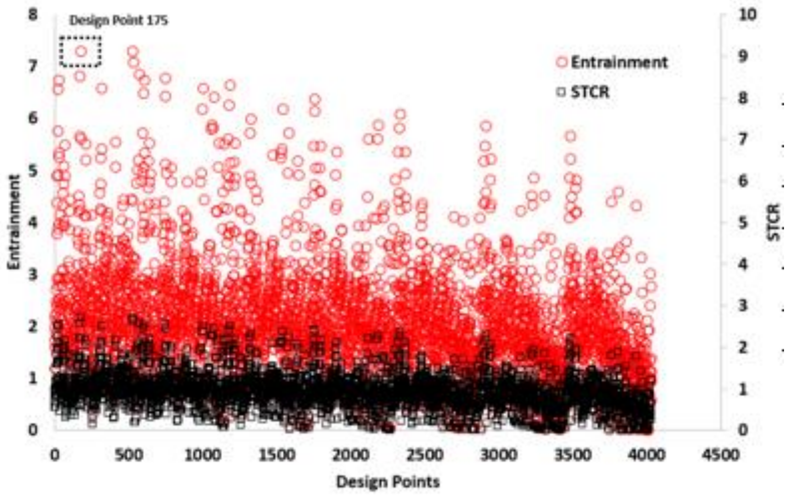

Fig. 3. Determination of design point

Table 3. Design point 175

Design point 175	
NXP (mm)	26
D_1 (mm)	0.6
D_3 (mm)	6
L_1 (mm)	4
α (degree)	2

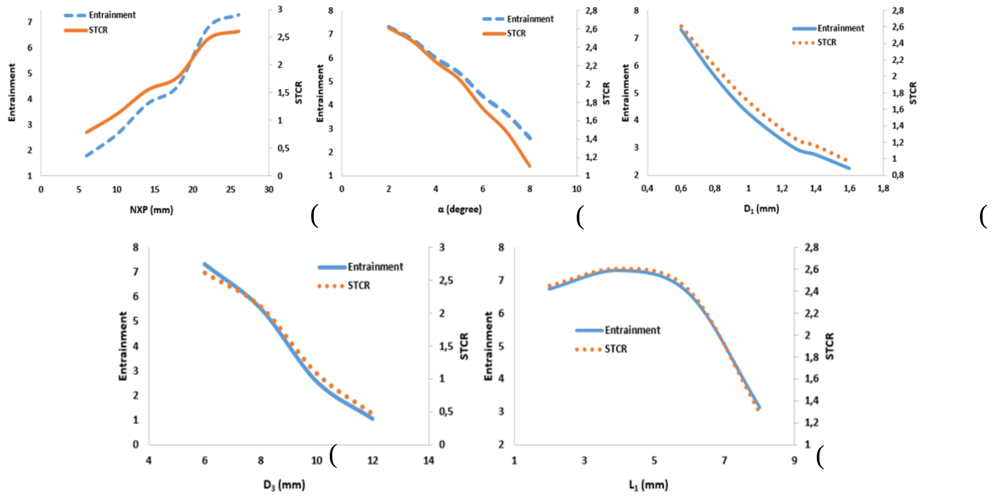

Fig. 4. The effect of the geometric parameters (a) NXP (b) α (c) D_1 (d) D_3 (e) L_1

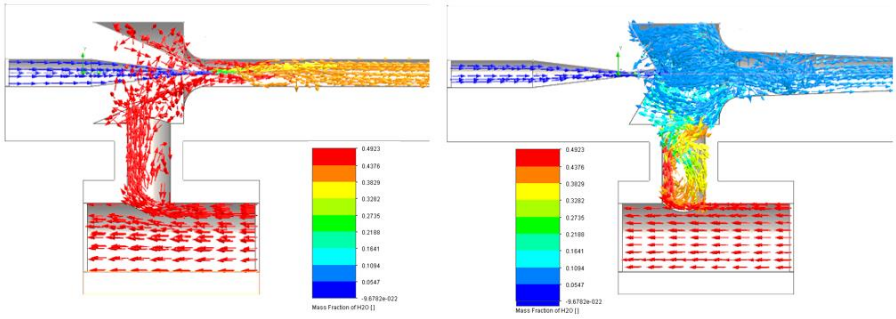

Fig. 5. The flow trajectories inside the ejector (a) the better design (b) the worst design

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The Impact of Renewable Energy on Employment in Turkey

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ABSTRACT . Energy consumption constitutes a vital part of the everyday life of today's human being. As the quantities of energy consumed increase day by day, topics such as energy efficiency and renewable energy become much more prominent. A review of the existing literature reveals that most studies focus on these two topics.

Considering the fact that fossil resources are being consumed at a great pace, the renewable energy has become a critical issue. Disproportionate consumption of energy sources, notably starting from the second half of the twentieth century, has brought about an elevated interest in renewable energy. It is widely accepted that in the field of renewable energy where advanced countries have already made significant progress, developing countries such as Turkey must put more effort to close the gap with developed countries.

Energy employment, one of the dimensions of renewable energy topic, is supposed to increase as the investment in energy sector grows. As a result of harmonisation of energy policies with energy investments and research on energy promoted by this harmony will pave the way for a considerable amount of energy employment. New investments in wind energy, solar energy, biomass and similar technologies will generate direct and indirect employment opportunities. Also referred to as green jobs, this segment of employment gradually grows into a distinctive job market, with the ability to develop and use its own technology. It is now clearer that an increase in employment of green-collars will put a positive impact on domestic economy, reducing unemployment. This study investigates workforce capacity created by green jobs in selected countries, as well as current situation in Turkey. It also makes an assessment of green employment capacity against various potential scenarios for the energy sector in line with our energy strategy under the 2023 vision.

Results obtained from the research, have been brought up the matters of the restrictive fossıl sources, the threat of the climate changes, environmental pollution and the losts getting cheaper make the countries stear them towards the renewable energy. In case of the renewable energy investment reach the target of 2023, it is estimated that approximately 2 million employments would have occurred. It's estimated that this employment foreseen for manufacturıng, consruction and maintenance activities will continue until 2030. Direct and indirect employment scenarios are included in the study.

1 INTRODUCTION

Energy is one of the most important issues in today's world. Since the available resources on the earth are scarce, people have headed towards alternatives in the field of energy, with ever-increasing efforts in renewable energy. Renewable energy sources are of utmost importance for sustainable use of energy. As it is directly linked to future use of energy, the topic of renewable energy has gained currency more frequently with an intensified level of awareness.

The primary focus of this study is to give an account of energy employment. Based on the literature review method, the topic of renewable energy is investigated. Through a review of the literature, the most up-to-date data concerning renewable energy employment in Turkey and some other countries has been included in the present study.

This study aims to contribute to the literature about energy, renewable energy sources and renewable energy employment. With its informative nature, this paper is also designed to provide an up-to-date picture of the renewable energy both in Turkey and across the globe.

2 LITERATURE REVIEW

In this section, the literature is reviewed under the following headings: the need for renewable energy, renewable energy sources, types of renewable energy, renewable energy technologies, renewable energy employment, efforts aimed at renewable energy employment in Turkey, and energy employment and related data for Turkey and the world.

2.1 The Need for Renewable Energy

The need for renewable energy is an obvious outcome of improving and developing world. In the context of this energy requirement, the following objectives have played determinative role: to develop new energy alternatives, to increase energy efficiency, to lessen the impact of energy consumption on climate change, and to ensure energy security (Erdal, 2012: 172). To put in a different way, these developments represent the underlying factors of the emergence of the need for renewable energy.

The factors under energy value chain show their effect in the content of renewable energy need. Renewable energy value chain consists of five basic factors as equipment production and delivery, project development, construction and assembly, operation and maintenance, intersecting activities (Arlı Yılmaz, 2014: 48). Each factor of the need for renewable energy takes part in this section since they are also related to energy employment.

Green works or sectors, which are being shown up and developed in order to protect the nature, are another factors contributing to occurrence of the need for renewable energy. In other words, green sectors include the need for new equipment, new technology and new infrastructure as well (Çondur, Erol ve Göcekli, 2016: 1087). This should be known as an information under the need for renewable energy.

2.2 Renewable Energy Sources

It is possible to make mention of two focal points when explaining renewable energy sources. Firstly, it is the energy approach that suggests continuous and complementary generation of power. The second one is the energy approach which supplements itself as it is consumed (Erdoğan, 2014: 12). Renewable energy sources can be explained around these two focal points.

It is widely appreciated that the need for energy increases all over the world with each passing day, and it is renewable energy sources that constitute the primary resource to meet this need. Efforts aimed at fulfilling the ever-increasing need for energy across the globe deepen in line with the rising interest in this field (Külekçi, 2009: 83). The limited nature of energy sources lies behind the emergence and escalation of the efforts devoted to utilization and popularization of renewable energy sources.

2.3 Types of Renewable Energy

Types of renewable energy sources can be listed as follows: (http://www.enerji.gov.tr/mavi_kitap_2016.pdf):

1. Hydroelectric power,
2. Solar energy,
3. Wind energy,
4. Geothermal energy,
5. Biomass energy,
6. Biogas power,
7. Hydrogen power,
8. Wave power,
9. Tidal energy.

Utilization of the above-listed energy sources must consider efficiency-based assessments. It can also be mentioned that measurements and projects conducted to this end have been designed in line with this requirement.

2.4 Renewable Energy Technologies

The topic of renewable energy technologies is, in the same breath, considered to be an extension of the types of renewable energy. Thus, the account of renewable energy technologies is given as part of the subject of types of renewable energy. Renewable energy technologies in the context of solar energy include thermodynamic systems, light emitting diodes, optical connectors and photovoltaic generators. The scope of solar energy is much wider than other types of renewable energy. Other elements to be prioritized for the purposes of renewable energy technologies include wind generator for wind energy, hydraulic turbines for hydraulic energy, and biodiesel for biomass energy (Görgün, 2009: 14).

2.5 Renewable Energy Employment

Another point to be stressed in this field of study is that renewable energy leads to new areas of employment apart from generating clean energy and ensuring fulfillment of energy needs (Kum, 2009: 215). Therefore, the countries that invest in renewable energy sources obviously create new opportunities for themselves, by forming new employment possibilities.

As the efforts on renewable energy sources generate new jobs in the field of renewable energy, the processes concerning different areas of employment can be observed. Product development, industrial engineering, production, pre-production and technology development all stand for new areas of renewable energy employment (Erdal, 2012: 174). Considering these new areas of renewable energy employment, it is understood that the existence of the labor processes in domestic and international markets have become prominent.

The processes caused by the interaction between employment and renewable energy is an important research subject. As a result of the studies on this subject, there have appeared strong arguments characterizing direct, indirect and stimulated impacts of renewable energy employment, which are regarded as positive effects. On the other hand, it should not be ignored that there are some opposing views suggesting that renewable energy employment poses negative effects (Erden Özsoy, 2016: 55).

2.6 Efforts Aimed at Renewable Energy Employment in Turkey

Since it was acknowledged from the experience of Spain that possessing the most advanced technology was not a must to get favorable results in the field of renewable energy, developing countries such as Turkey have intensified their efforts to enhance renewable energy employment (Kum, 2009: 221). The fact that efforts aimed at improving renewable energy employment will contribute to the growth of the Turkish economy is another primary factor that has motivated the studies on renewable energy employment.

OECD calls attention to three major factors regarding renewable energy employment. Given its membership to OECD member country, Turkey must take these factors into consideration when it comes to renewable energy employment. These factors are construction, manufacturing and industry (Arlı Yılmaz, 2014: 124). Through these factors, the data on regional employment variables can be obtained. Calculations to measure Turkey's performance will include these factors.

In the contexts of the studies on renewable energy employment in Turkey, the following goals are worth being underlined (Erdal, 2012: 175-176):

10. To generalize the utilization of domestic sources in order to reduce dependence on foreign energy sources,

11. To increase efficiency by way of stimulating orientation to renewable energy sources,
12. To promote nuclear energy initiatives,
13. To prevent loss and illegal use of energy,
14. To ensure optimum utilization of domestic energy sources, and
15. To benefit from energy technologies to the greatest extent possible.

So as to achieve the abovementioned goals "General Directorate of Renewable Energy" was established, by which it was ensured that efforts devoted to renewable energy employment were centralized. With this step, it was aimed to get more effective results in respect of renewable energy employment.

Efforts also include 2023 targets set by Turkey for renewable energy employment. In this context, the available data is demonstrated here in below.

Table 1. Turkey's 2023 Vision on Renewable Energy

Turkey's Electric Energy and Security of Supply Strategy Paper sets the following targets for 2023 - To ensure that the share of renewable sources in electricity generation is increased up to at least 30% by 2023 - To ensure that technically and economically available hydro-electric potential is fully utilized - To increase installed wind energy power to 20,000 MW - To commission all geothermal potential of 600 MW that is currently considered as suitable for electric production - To generalize the use of solar energy for generating energy and ensure maximum utilization of country potential, - To follow and implement closely technological advances in the use of solar energy for electricity generation, - To prepare and produce plans that will take into account the potential changes in utilization potentials of other renewable energy sources based on technological and legislative developments. Turkey's Energy Policies Report published by the Ministry of Energy and Natural Resources on November 1, 2011 aims to increase installed solar energy power to 3,000 MW by 2023.

As it can be seen in Table 1, the 2023 vision on renewable energy aims to enhance renewable energy employment by increasing generation of renewable energy employment. Apart from this, reducing foreign dependency, amongst others, is set to be the most prominent target of Turkey related to renewable energy.

Any action taken to improve renewable energy has the potential of making major changes in production and employment structure of any given country. Considering such a considerable potential, it is possible to argue that each and every study on renewable energy employment in Turkey is of great importance.

2.7 Energy Employment and Related Data for Turkey and the World

Renewable energy involves great employment potential, and therefore, many countries aim to increase the number of their citizens employed, by intensifying their efforts about renewable energy. Renewable energy industry in the world produced an employment volume of 604.341 people across the globe, which is aimed to be increased up to 2.5 million by 2018 (Kum, 2009: 215). This data is of huge importance as it illustrates renewable energy is much more than producing added value. Moreover, these data become invaluable, as they provide insight into renewable energy employment.

To exemplify the transformations in renewable energy employment from other countries, as caused by investments, it could be underlined that investment in the field of renewable energy gave rise to 450.000 new jobs in the USA, 20.000 new jobs in Denmark and an overall volume of Euro 9 billion in Norway. It had better to keep these data in mind as they give an opinion about the level of renewable energy employment in the world.

Renewable energy employment data of some countries are illustrated below.

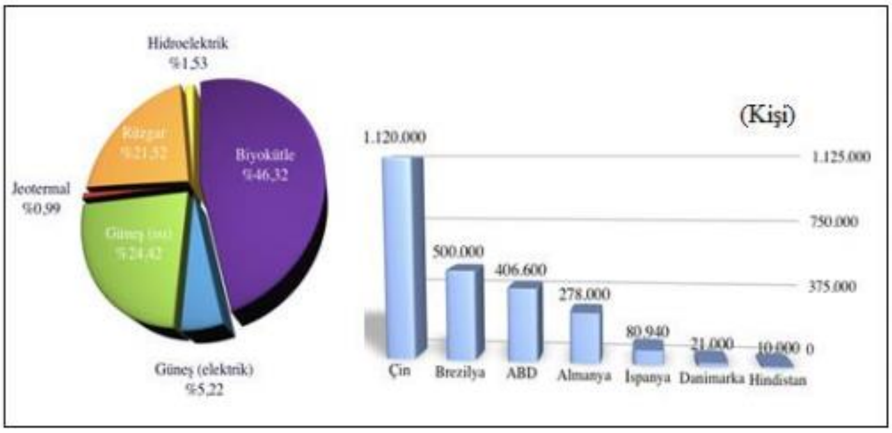

Fig. 1. Renewable Energy Employment Data of Selected Countries

As illustrated by Figure 1, China ranks number in the field of renewable energy employment, which is followed by Brazil, the USA, Germany and Spain, respectively. It also becomes apparent that it is the biomass energy which attracts utmost attention, which is followed by solar energy and wind energy.

3 CONCLUSION AND RECOMMENDATIONS

In this study aimed at researching renewable energy employment, some inferences have been made as to at which level renewable energy in Turkey and the world is. One of the main consequences of this study is that countries are turning to renewable energy because of limited resources. As a result of this tendency, it is seen that renewable energy employment in the world tends to increase.

In this study, it is shown that renewable energy employment in the world has provided employment for 600.000 people as of 2008, and it is estimated that employment expectation would be approximately 2.5 million people in 2018. A 4-fold growth expectation for renewable energy employment over a 10-year period is a very important data in terms of explaining the direction of renewable energy.

In the light of the results obtained, it could be suggested that renewable energy, as a research subject, deserves much more attention. Apart from this, it could be suggested that steps to reduce foreign dependency should be taken to enhance renewable energy employment. Increasing the diversification of renewable energy in Turkey would be one of the recommendations to promote renewable energy employment.

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Determination of Biothermal Power Capacity of Some Agricultural Compost Varieties

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ABSTRACT. The aim of this study is to determine biothermal power capacity of some agricultural compost varieties. Especially in recent years, using the agricultural wastes as natural fertilizer in agricultural farmland has been widely in Turkey. The main aim of these applications is to reduce chemical fertilizer and to get clean environment. In this framework, determining of the biothermal power capacity for new and clean alternative energy producing is very important.

To determine the power capacity of the waste mixtures, a Data Logger Assisted Heat Loss Calculation (DLAHLC) Software Program was used. Maize, sunflower wastes, horse manure and their mixtures were used as materials. As a result, the biothermal power capacities of some agricultural waste mixtures were determined and presented in this paper.

Keywords: Renewable energy, Biothermal energy, Thermal conductivity coefficient, Agricultural composting process.

1 INTRODUCTION

Because of the fossil-based energy sources are not endless and they caused environmental problems, obtaining energy from agricultural wastes is important for sustainability. Agricultural wastes such as wheat, barley, maize, rye, oat, sunflower, safflower, chickpea stalks and sugar beet leaves and alike are remaining on the farmlands after harvesting. A large amount of these wastes are used as animal feeds or usually burned in the farmlands. Besides of the economic value, burning the wastes is caused chemical and biological damage at the soil. The beneficial microorganisms such as bacteria, insects, etc. in the soil, destroyed by burning. In fact, this event is destruction of the equilibrium ecological system which is created by human.

Agricultural wastes are naturally obtained directly from agricultural areas. Also biothermal energy is the heat energy, achieved from biomass-origin materials such as livestock, domestic and agricultural wastes [1].

2 MATERIALS AND METHODS

2.1 Materials

In this research, maize, sunflower wastes and horse manure that obtained after harvest in Eskisehir province farmlands were used as materials. Seven equal-volume cylindrical tanks were used for compost mixtures in the project (Table 1.).

For a rapidly and uniform composting process, particle size of the waste is important and must be small. Studies show that, the optimum particle size value should be between 2 and 12 mm [4,5,6]. Therefore, the pieces of compost materials were grinded mechanically, in order to increase the effect of composting activity. After placing into tanks, each mixture compost materials were left to composting process (Figure 2.).

The conversion of agricultural wastes into heat energy is possible through the decomposing of organic material by the various microorganisms activity during the composting process [3].

Table 1. The Varieties of Agricultural Origin Compost Mixtures.

Sybol	Compost Variety	Content Ratio (%)
C1	Sunflower Wastes	100
C2	Maize Wastes	100
C3	Horse Manure	100
C4	Sunflower and Maize Wastes	50+50
C5	Sunflower Wastes and Horse Manure	50+50
C6	Maize Wastes and Horse Manure	50+50
C7	Sunflower, Maize Wastes and Horse Manure	33+33+33

The composting process is carried out by microorganisms in completely natural conditions. During this process, new microorganisms is produced and heat, carbon dioxide, water vapour and similar gases is released into the environment [4]

Fig. 1. Composting Process of Maize Wastes.

2.2 Methods

The amount of heat energy potential of any agricultural waste, depends on the sum of two thermal energy kinds, the first of all, is biothermal energy, which obtains from decomposing of organic matter by the various microorganisms activity. Second is thermal energy, which obtains from burning of this mass as bio fuels. The relationship between biothermal and thermal energy is given as [1,2];

$$E_t = E_{bt} + E_{bf} \tag{1}$$

Where, E_t (W) is the total energy E_{bt} (W) is the biothermal energy; E_{bf} (W) is the bio fuel energy.

As it is known, biothermal energy is based on the activity of microorganism, and it is not any combustion in case. If the humidity and the temperature conditions are appropriate, thermal heat will release continue, and this activity will continue until the organic matter is finished by microorganisms.

2.2.1 Determining Physical Properties of Compost Material:
Density and moisture rate of agricultural origin waste is calculated by using the following equations [3,6,7].

$$\rho_{cn} = \frac{M_{cn}}{V_{cn}} \quad (2)$$

$$N_c = \frac{M_{cn} - M_{cd}}{M_{cn}} 100\% \quad (3)$$

Where, ρcn (kg/m3) is the density of natural compost; Mcn (kg) is the mass of natural compost; Vcn (m3) is the volume of natural compost; Nc (%)is the moisture rate of compost; Mcd (kg) is the mass of dry compost.
The amount of dry mass from Eq. 3, can be expressed as follow:

$$M_{cd} = \frac{M_{cn}}{1 + N_c} \quad (4)$$

The moisture content of different compost mixtures can be written as:

$$N_c = \frac{\sum M_i . N_i}{\sum M_i} 100\% \quad (5)$$

Where, Mi is the mass of number i mixture; Ni is the moisture rate of number i mixture.
Moisture content is a critical factor to the composting process. If the composting material is too dry, biological activity will be slow. In this case, water should be added, until suitable moisture level is achieved. The research results show that, optimum moisture rate should be about 55% [4,5,6] for an effective composting process. It should be avoided of overwatering. If necessary, water must be added to compost material. The amount of water is calculated with the aid of the equation:

$$m_w = \frac{N_c - 0.55}{0.55 - N_w} \quad (6)$$

Where, mw (kg.water/kg.compost) is the amount of water needs to be added to the each kg of compost; Nw is the moisture rate of water and is equal to one.

By the usage of the Eq.6, the amount of water to be added, and new mass of the water-added compost:

$$M_w = m_w . M_{cn} \quad (7)$$

$$M_{cw} = M_w + M_{cn} \quad (8)$$

can be calculated by equations.
Where, ρcw (kg/m3) is the new density of water-added compost in the tank; Mcw (kg) is the mass of water-added compost in the tank.
For different mixtures of agricultural origin compost wastes, equal weight materials were placed into tanks. Similarly, for the equal masses (M1=M2) can be written as the following equation.

$$\rho_1 . V_1 = \rho_2 . V_2 \quad (9)$$

The diameter and length of cylindrical tank is 600 mm. and volume which was calculated is 0,17 m3. Consequently, by the Eq. 8 and Eq. 9,

$$V_1 = \frac{0{,}17}{\frac{\rho_1}{\rho_2}+1} \qquad (10)$$

$$V_2 = 0{,}17 - V_1 \qquad (11)$$

can be written as the new forms of previous equations.

All of these equations were used for determining the physical properties of the compost materials.

2.2.2 Determining Biothermal Power Capacity of Compost Material:

In this study, the agricultural origin wastes had been put into cylindrical tanks. In order to, for the minimum heat losses, tanks were isolated by 150 mm thick isolating material.

The heat generated by the microorganisms as decomposed of the compost material in the tank, is equal to that lost heat being transferred outside, and can be expressed as follows [2].

$$V_c.\int_{r=0}^{r=r_n}\left(\frac{dq_0^{''}}{dt}\right).dr = -U.A_c.\int_{r=0}^{r=r_n}.\left(\frac{dT}{dt}\right).dr \qquad (12)$$

Where, q0'' (W/m3) is the total amount of thermal energy derived from compost material; Vc (m3) is the volume of tank; U (W/m2K) is the average heat transfer coefficient; Ac (m2) is the total external surface area of the cylindrical tank.

Equation 15, means that the energy generated from the compost in the tank is equal to the lost energy transferred out by convection and conduction through. This situation will be continued until the compost temperature equal to air temperature value.

If the diameter and length value of tank is equal, for the new geometry, Eq. 12 can be rewritten as.

$$q_0^{''}.\left(\frac{\pi.D_1^{\ 2}}{4}.L\right) = U.\frac{3}{2}.\pi.D_2^{\ 2}.\Delta T \qquad (13)$$

After all necessary calculation (D_1=600 mm, D_2=900 mm)

$$q_0^{''} = 20{,}5.U.\Delta T \qquad (14)$$

It can be expressed as.

Where, ΔT (°C) is the difference between air and compost temperatures and is measured by the data logger.

This equation is necessary calculation of the "biothermal power capacities of compost mixtures" which is the main aim of the study.

Tanks geometry were chosen as cylindrical. This is because, simple production, minimize energy losses and to obtain the largest volume and smallest outer surface. The ratio of volume/external surface area of the cylindrical tanks is r/3.This ratio is important for heat losses.

Where, r (mm) is the radius of tank.

Overall heat transfer coefficient (U) is calculated by the following equation for model;

$$\frac{1}{U}=\frac{1}{h_i}+\frac{l_1}{k_1}+\frac{l_2}{k_2}+\frac{l_3}{k_3}+\frac{1}{h_o} \tag{15}$$

Where, hi (W/m2K) is the inside convection heat transfer coefficient of tank; k1,k2 (W/mK) is the thermal conductivity of tank material; k3 (W/mK) is the thermal conductivity of the isolation material; ho (W/m2K) is the outside convective heat transfer coefficient of environment; l1, l2, l3 (mm) are the wall thickness of the tank and isolation materials respectively.

Thus, the heat capacity of compost material [1,2];

$$q_c^{''}=\frac{q_0^{''}.V_c}{M_{cdu}} \tag{16}$$

can be calculated by equation.

Where, qc is the (W/kg) power capacity of compost, Mcd (kg) is the amount of dry mass of compost material.

2.3 Experimental Setup

In this study, seven cylindrical tanks were used. Every tank has top and bottom covers, and two concentric cylinders are given in Fig.3.

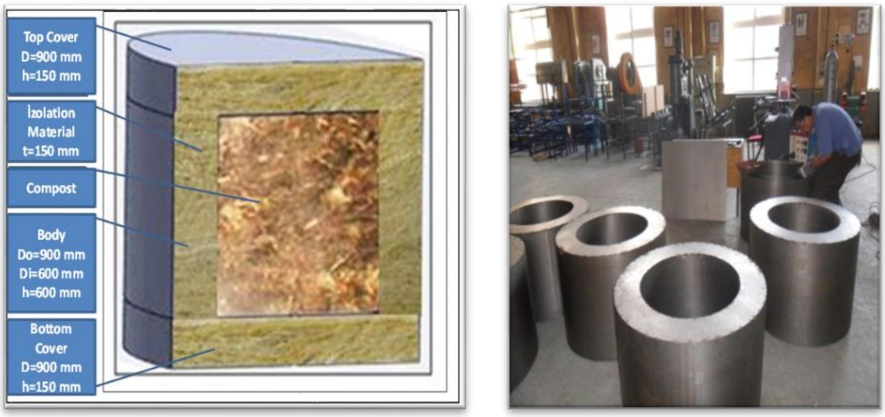


Fig. 2. Cross-Section and Production of Tanks.

Seven data logger device, which has four probes, were used for the temperature and moisture measurements. Before starting the measurements, each device was programmed for the purpose of the study. For each compost mixtures, all data logger, between minimum and maximum temperature limits from 10°C to 90 °C, and air temperature, from -30°C to 90°C were programmed.

Also, two of four probes to central points of tank, and other two probes to middle of edge and centre point of the tank were placed. This is because, to obtain more a reliable average value for the calculation. After placing all the probes into the tanks and programming the data logger devices, measurements were started (Fig. 4).

The control of the data loggers was performed regularly, and inaccurate probe was replaced with the new ones during the study.

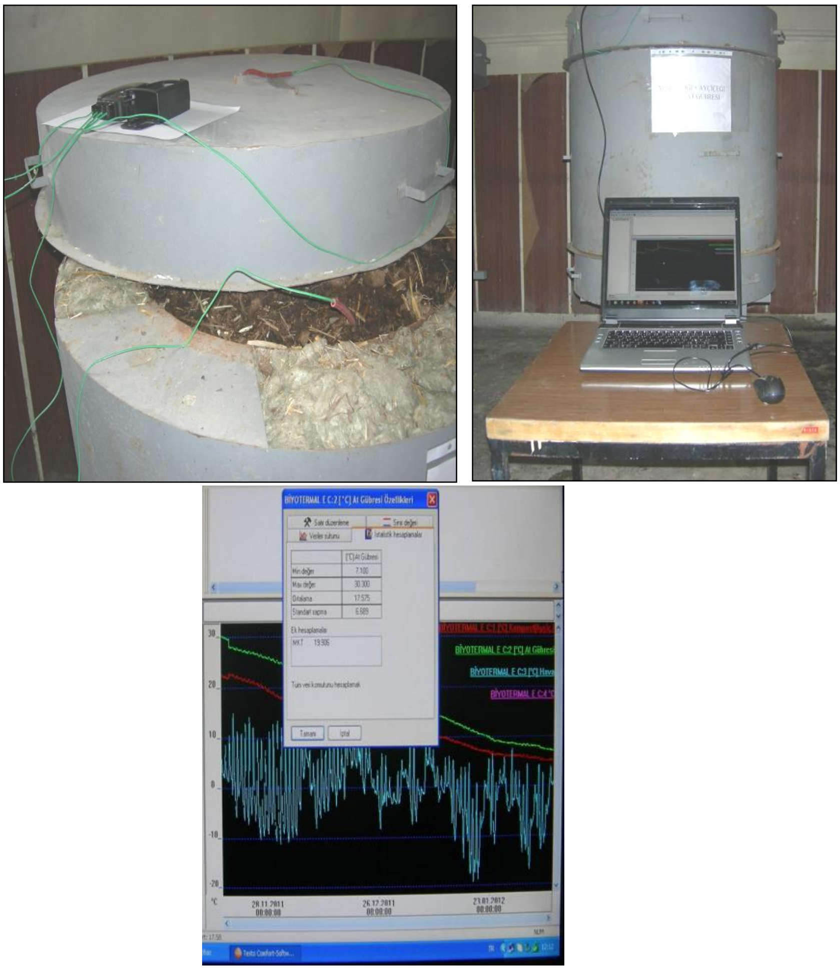


Fig. 3. The Experimental Sets of Maize, Sunflower Wastes and Horse Manure.

3 RESULTS

The annual average results of physical properties and analysis of the compost mixtures was determined by using the equation from Eq.2 to Eq. 11 are given in Table 3.

Table 2. The Annual Average Physical Properties of Compost Varieties.

Compost Varieties	Denisty of Natural Material (kg/m³) ρ_{cn}	Natural Mass (kg) M_{cn}	Moisture Rate (%) N_c	Dry Mass (kg) M_{cd}	Added Water (kg.w/kg.co.) m_w	Total Added Water (kg) M_w	Denisty With Added Water (kg/m³) ρ_{cw}
C1	165,36	28,26	31,26	21,42	0,53	14,93	252,80
C2	138,84	23,83	23,72	19,09	0,71	16,50	235,57
C3	573,33	52,49	51,28	64,51	0,39	8,60	623,58
C4	150,54	25,56	27,43	20,08	0,62	15,73	242,51
C5	256,74	44,05	41,05	30,99	0,31	13,53	336,08
C6	222,63	38,31	37,47	27,60	0,39	14,93	310,31
C7	199,41	34,21	35,25	25,03	0,44	14,90	286,67

The overall heat transfer coefficient, U, at reference conditions for the model; hi=0 (inside the tank), ho=23,222 W/m2K (outside), k1=k3=46,444 W/mK (for iron material) , k2=0,0406 W/mK (Rockwool isolation material), was calculated by Eq. 15, as 0,2675 W/m2K.
As a result, by the usage of the Eq. 16;

$$q_c'' = \frac{q_0''.V}{M_{cd}} = \frac{20{,}5.0{,}2675.0{,}17}{M_{cd}} * (T_c - T_a) \cong 0{,}9322 \frac{\Delta T}{M_{cd}} \qquad (17)$$

an empirical expression is obtained.

Where, Tca (°C) is average compost temperature; Taa (°C) is average air temperature.

For calculation of the biothermal power capacity values of the compost mixtures, these equations and data, which obtained from data logger were used and are given below in Table 5. and Figure 5.

4 CONCLUSION AND SUGGESTIONS

According to of the study, the following results and suggestions can be sorted:

1. In this study, biothermal power capacities of seven different compost varieties were calculated. The maximum value was measured in maize wastes as ***1064,90*** mW/kg-dry. The other average results are: sunflower wastes ***678,20*** mW/kg-dry, horse manure ***280,22*** mW/kg-dry, the mixture of maize and sunflower wastes ***938,25*** mW/kg-dry, the mixture of sunflower wastes and horse manure ***561,54*** mW/kg-dry, the mixture of horse manure and maize wastes ***673,66*** mW/kg-dry, and the mixture of sunflower and maize wastes and horse manure ***832,74*** mW/kg-dry respectively. The results were compared with literature and they show close similarity to the results obtained using different methods before.
2. The results show that, the climate at the place where crops are growing, soil characteristics, and meteorological conditions of agricultural products influenced the value of biothermal power capacity of any wastes. The low air temperature condi-

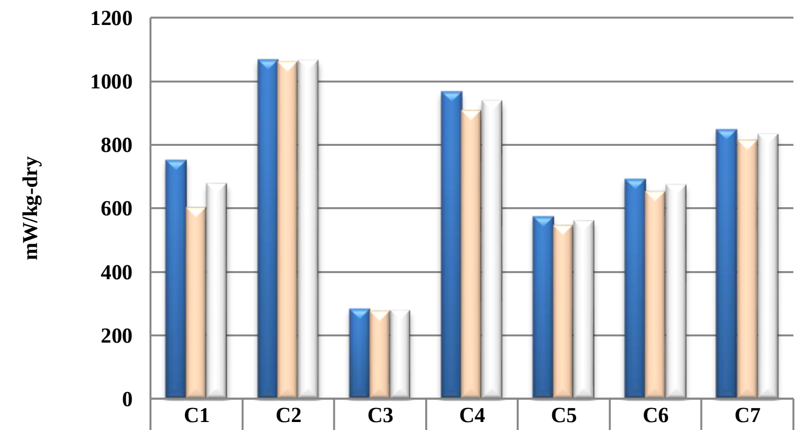
tions, an important negatively factor to affect the microorganisms and bacteria activity.
3. Turkey has a large agricultural wastes potential, so it is possible to use these wastes as organic fertilizers, and energy raw material.
4. Future studies, may be on improvement of new collection mechanization technologies and composting methods of agricultural wastes.
5. Furthermore, the results of this study can be used as crucial reference provide and guidance for biothermal energy researchers.

5 ACKNOWLEDGEMENT

This study, as TAGEM-11/AGE/17 of project number was supported by Republic of Turkey Ministry of Food, Agriculture and Livestock, between the years of 2011and 2014. I would like to thank everyone who contributed to this project.

Table 3. The Annual Average Values of Time, Temperature and Power Capacity.

Compost Varieties	M_{cd} (kg)	t_t (h)	T_{ca} (°C)	T_{aa} (°C)	q_{co} (mW/kg-dry)
C1	21,42	2880	17,52	1,97	678,20
C2	19,09	2880	23,28	1,97	1064,90
C3	64,51	2880	21,35	1,97	280,22
C4	20,08	2880	22,16	1,97	938,25
C5	30,99	2880	20,63	1,97	561,54
C6	27,60	2880	21,90	1,97	673,66
C7	25,03	2880	24,32	1,97	832,74



	C1	C2	C3	C4	C5	C6	C7
2011-2012	751.95	1069.04	283.46	967.61	575.59	692.42	849.25
2012-2013	604.45	1060.76	276.98	908.91	547.48	654.91	816.22
Average	678.21	1064.91	280.22	938.25	561.54	673.66	832.74

Fig. 4. The Annual Average Biothermal Power Capacity of Compost Varieties.

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Exploiting the Potential of Untapped Energy Resources with the Radial Outflow Turbine Technology

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ABSTRACT . Social attention to energy sources and their utilization is nowadays constantly increasing and new solutions are developed to utilize unexploited energy resources as well as to increase resources exploitation.

A new turbine technology has been developed, engineered, manufactured and tested by Exergy, with the aim to exploit the potential of untapped energy resources: the radial outflow turbine technology.

This technology has in fact several unique characteristics which qualify this innovative configuration as advantageous for many relatively low temperature energy recovery applications, as it ideally matches the process conditions typical for these applications.

The purpose of the present article is to introduce the radial outflow turbine technology and present its advantages while efficiently harnessing the potential of a previously unexploited low temperature geothermal resource, located in Turkey.

Keywords: Unexploited energy resources, Energy efficiency, Radial outflow turbine, Geothermal resource

1 INTRODUCTION

Energy sources availability and proper exploitation has always been a key driver of human societies development, as it directly reflects on population wealth and healthiness. Due to the fact that energy resources availability appears to not being growing as much as populations demand, nowadays the social attention to these topics is constantly increasing.

Being able to harness a potential previously considered not exploitable or to increase the efficiency of energy conversion is therefore considered an important social achievement as it will lead to a further social growth. In addition to this, when the previously mentioned improvements are achieved in the renewable field, this is considered an important value added because it means it is also environmentally friendly.

Geothermal energy systems are environmentally friendly renewable energy sources, consisting in underground basins in which a certain amount of water, with dissolved minerals and gases, is stored and naturally heated by the heat flow which is flowing from the earth's core to the surface. These systems may be exploited for base load generation, thus to replace the not environmentally friendly coal, oil or gas power plant.

The exploitation of high temperature Turkish geothermal energy resources is ongoing since several years and, for a further development of the sector, it appear important to extend the resource exploitation range also to low temperature sources, thus the ones lower than 120 °C.

Geothermal energy exploitation for electric power production is possible by utilizing two main systems: steam turbines and Organic Rankine Cycle (ORC) binary power plants [1]. Considering the Turkish geothermal systems and ambient temperature conditions, steam turbines are generally used in geothermal fields with a bottom-hole temperature greater than 200 °C while ORC are used to exploit cooler resources with a minimum temperature of 120 °C. Whilst steam turbines with an axial configuration have traditionally been the technology of choice, the organic fluids' features allow the expansion in axial, radial inflow or screw expanders.

An innovative turbine configuration for geothermal applications, the multi pressure radial outflow turbine, was developed by the Italian turbine manufacturer EXERGY, in order to enlarge the geothermal resources exploitation range, thus to efficiently harness an unutilized geothermal resource located in Denizli – Turkey, with a bottom-hole temperature as low as 105 °C.

2 THE RADIAL OUTFLOW TURBINE TECHNOLOGY BY EXERGY

2.1 The radial outflow turbine technology

Ljungstrom and Parsons developed this turbine technology in the early 20th century, to expand steam, respectively in counter rotating and single-rotating configurations [2].

The vapor expansion in a radial outflow turbine is shown in Fig. 1: the fluid enters the turbine disk axially in its center and expands radially across a series of stages mounted on the single disk. At the discharge of the last rotor the flow goes through a radial diffuser and is then conveyed to the condensation section of the system, through the discharge volute.

High enthalpy drops, high volumetric flows and high volumetric ratios are typical while expanding fluids with low molecular weight, like water, at operative conditions which are typical for power production [3]. As a consequence the radial outflow turbine is not the technology of choice while expanding water steam, in fact a significant number of stages is mandatory to convert the enthalpy drop of the fluid into mechanical energy. This lead Ljungstrom to develop a counter rotating radial outflow turbine configuration, in order to reduce the number of the turbine stages by increasing their specific work. Additionally turbine blades would necessarily have a large height even for small power output turbines, due to the remarkable volumetric flow and its ratio between the inlet and outlet section (considerable for water steam).

Thus for the very large diameter disk necessary to accommodate all the required stages and for the too long blades, the radial outflow turbine configuration demonstrated serious limitations while processing steam and was therefore deemed not suitable.

These issues meant no significant development of the radial outflow turbines, which were phased out for steam applications by axial turbines.

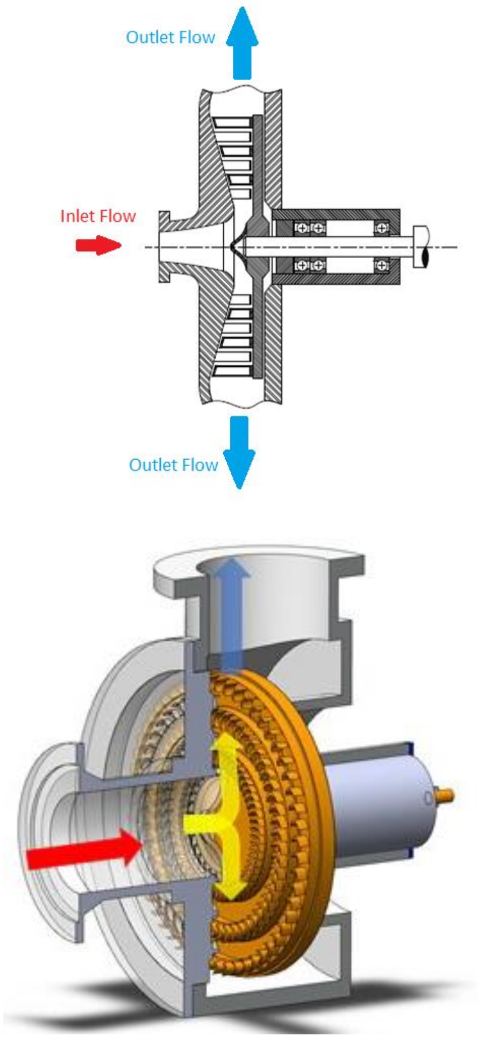

Fig. 1. 3D cross section of the radial outflow turbine.

Adopting organic fluids in geothermal ORC power plants lead to operative conditions which are significantly different from steam: enthalpy drops, volumetric flows and volumetric ratios are in fact significantly smaller [2]. Consequently, the intrinsic limits of the radial outflow turbine technology are no longer relevant for geothermal ORC application and this made possible for Exergy to reconsider this technology.

The radial outflow turbine has intrinsically the following beneficial characteristics:

- Single-disk/multi stage configuration (on a disk it is possible to insert more than one stage)
- Low vibration profile
- Prismatic blades
- More enthalpy head is developed in the more efficient stages, at the same pressure ratio
- Cross section encountered by the expanding fluid is increasing, partially compensating the increment in volumetric flow
- Pressure difference favors expansion without major 3D effects
- Relatively low rotating speed, meaning direct coupling with the generator
- Limited overhung mechanical structure

2.2 The multi-pressure radial outflow turbine technology by Exergy

Binary geothermal power plants may be developed as single pressure level cycle or as multi pressure level cycle systems. Generally, a system designed as multi pressure level can deliver a significant increase in the power output, in comparison to a single pressure level system: by vaporizing the organic fluid at more pressure levels along the geothermal fluid heat release curve, it is usually possible to reduce both the thermal irreversibility associated to such heat exchange and increase the cycle efficiency [1].

The state of the art indicates that the technologically advanced multi pressure level geothermal binary systems require at least one turbine per pressure level, to expand the organic vapor, and these turbines are normally installed with an overhung configuration.

The radial outflow turbine gives the possibility to employ a different solution: its unique single disk / multi-stage configuration makes it possible to enlarge the spacing between the stages (see Figure 2), allowing a low pressure flow to enter the turbine, whilst still maintaining an overhung configuration without any negative rotordynamic consequences.

The radial outflow turbine can therefore allow multiple pressure levels cycles to produce energy through the expansion of the fluid across a multi-admission single turbine.

The major advantages related to this configuration are the techno-economical savings associated with a lower number of turbines to install per plant. This minimizes the plant overall costs, and reduces the amount of rotating equipment, spare parts and maintenance. Furthermore, the plant layout is more compact, reducing the amount of foundations, control equipment and control complexity.

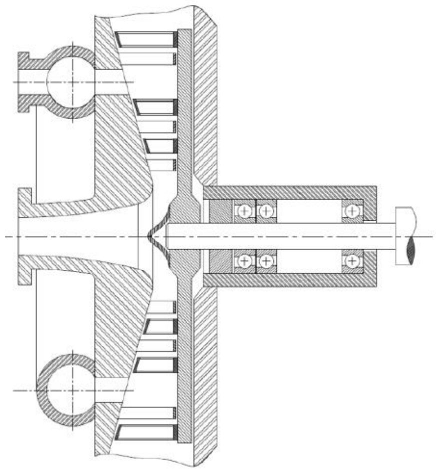

Fig. 2. Schematic drawing of the multi-pressure radial outflow turbine.

3 THE DENIZLI-TOSUNLAR MULTI PRESSURE ORGANIC RADIAL OUTFLOW TURBINE

This turbine technology has been developed in EXERGY have applied this unique and new configuration in the Denizli-Tosunlar geothermal field in Turkey, for Akca Enerji.

The Denizli-Tosunlar is of water dominated type and geothermal plant has the design characteristics presented in table 1 [4].

Table 1. Denizli-Tosunlar field characteristics

Mass flow per well [ton/hr]	**Geothermal fluid temperature** [°C]	**Reinjection temperature** [°C]	**Cooling water inlet temp.** [°C]	**Cooling water outlet temp.** [°C]	**Number of wells**
350	105	65	15	20	4

In order to evaluate the performances of different combinations of thermodynamic cycles and organic working fluids, a thermodynamic analysis has been performed based on the above conditions. Three different combinations have been investigated: single pressure level cycle with IsoButane, single pressure level cycle with R134a and two pressure level with R245fa. The first two fluids are commonly used in binary units while R245fa is still not common in Turkey and, although is much more expensive, has the advantage to lead to higher turbine efficiency, lower enthalpy drops and volumetric flows and ratios, thus to facilitate the expansion in a multi-pressure level turbine. In the comparison, the hypothesis considered are presented in Table 2.

Table 2. Hypothesis of the thermo-dynamic (theoretical) comparison for the Denizli-Tosunlar ORC binary power plant

Geothermal fluid temperature at ORC plant input [°C]	**Geothermal fluid temperature at ORC plant reinjection** [°C]	**Pinch point in the heat exchangers** [°C]	**Turbine mechanical efficiency** [%]	**Organic fluid Feed Pump mechanical efficiency** [%]	**Electric Generator efficiency** [%]	**Organic fluid Feed Pump electric motor efficiency** [%]
105	≥60	5.0	82.0	70.0	97.0	95.0

The results of the analysis are shown in Table 3 where is compared the power output of the three combinations, having put as basis the outputs realized adopting worst combination, thus the 1 pressure level cycle and Isobutane.

Table 3. Net outputs of four possible different combinations of working cycle and fluid, adoptable in the Denizli - Tosunlar geothermal field

1 pressure level with Isobutane [-]	**1 pressure level with R134a** [-]	**2 pressure levels with R245fa** [-]
1.00	1.03	1.19

In such conditions, a two pressure level optimized cycle delivers almost 20% higher power output than an optimized saturated or superheated single pressure level system. Such an increase is made possible by significantly reducing the thermal irreversibility associated to the heat exchange between the geothermal source and the organic fluid.

As shown in the process flow Figure 3, the Denizli-Tosunlar ORC binary geothermal power plant designed by EXERGY is exploiting a geothermal source with a saturated two pressure level cycle and is water cooled by the water delivered from the cooling system. No recuperator was foreseen due to the low amount of energy recoverable after the expansion of the organic fluid R245fa. The unique feature of the Denizli-Tosunlar plant is related to the turbine, able to expand the 2 pressure level flows on a single-disk radial outflow turbine. The performance of the turbine measured in operation show a greater efficiency than guaranteed, increasing the power output of the system to more than 22% higher than the single pressure level base case.

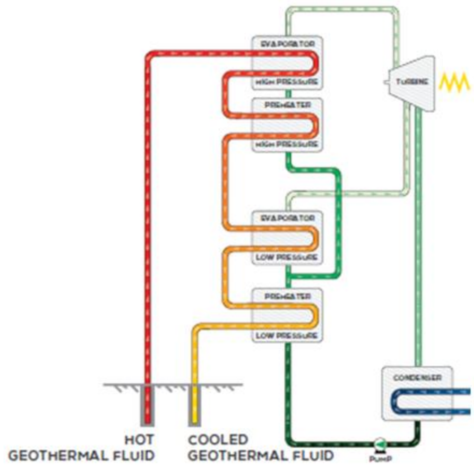

Fig. 2. Process flow diagram of two pressure level cycle with radial outflow turbine.

4 CONCLUSIONS

This paper has presented a new turbine technology for geothermal energy exploitation: the Exergy organic radial outflow turbine. The advantages of the overhung radial outflow turbine has been presented for the geothermal application. The above advantages have been demonstrated in the first installations of a multi pressure radial outflow.

The multi pressure radial outflow turbine is clearly an important innovation for the geothermal field, particularly for small size and low temperature geothermal applications, ie. less than 10 MWe with a resource from 100 to 150 °C, where the volumetric flows and enthalpy heads are thus limited. This turbine configuration will in fact allow to tap the potential of previously unexploited low temperature geothermal resources.

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Design and Performance Assessment of a Grid-Connected PV System for Residential Power Generation

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ABSTRACT. The residential photovoltaic (PV) power generation systems are the most installed grid-connected PV systems in real applications. Grid-connected PV systems have bidirectional power flow differing from conventional power plants. Thus, the grid connection is a significant design issue for residential applications. In this study, the design parameters for a residential grid-connected PV system are investigated. PV system components are designed for Bursa Technical University MimarSinan Campus environment with Matlab/Simulink. The design criterions a grid-connected PV plant are investigated and it is simulated under different climatical conditions for residential applications. Besides, the partial shading effect on the designed PV system and the performance assessment of the whole system is investigated in the study. The results verify that the proposed system will also make a contribution to the researchers for selecting the proper electrical and climatical criterions by designing a grid-connected PV system for a residential design.

Keywords: Residential grid-connected PV system, Grid code, Partial shading effect

1 INTRODUCTION

Renewable energy (RE) sources are good solution to overcome the global energy problem and these sources are becoming after each year more popular in the electric energy market [1]. Among the renewable energy sources, solar energy has a sustained growing due to development in grid integration technologies, decreasing photovoltaic (PV) panels production costs, subventions from the governments, etc. Despite these developments, solar power generation has the high losses in energy conversion in solar cells and the output power is dependent on solar irradiation and temperature. Therefore, the components of the grid connected PV system need to be carefully designed for achieving the purposes of high efficiency, low cost and safety.

Work on grid-connected residential PV systems has recently become popular in the literature. One of these studies a new control system has been developed for a hybrid system that energizes the fuel cell and the PV system [2]. In another study, a hybrid energy system was modeled and analyzed in Matlab / Simulink environment [3]. A real-time analysis of a grid-connected PV system was done in another study [4]. The study in Ref. [5] presents the optimum energy control of a 3 kW residential grid-interactive solar PV system that is planned to be built in Durban, South Africa. This work, in which the optimal energy model has been created, has resulted in high savings. The study in Ref. [6] Matlab/Simulink model is developed for single phase grid-connected photovoltaic inverter for residential application with maximum power point tracking.

In this paper, mathematical models of the components that make up residential grid-connected PV system were obtained and designed for Bursa Technical University MimarSinan Campus environment with Matlab/Simulink. The design criterions of PV modules, MPPT method, filters and single phase inverter are modeled and simulated for residential applications. The proposed system is operated with under different weather conditions. This study makes a contribution to the researchers to design and analyze a grid-connected PV system easily to improve a residential PV plant under different grid and climatical conditions.

2 THE PROPOSED GRID-CONNECTED PV SYSTEM FOR RESIDENTIAL APPLICATIONS

In this section, a Matlab/Simulink model is developed for a single phase grid-connected PV plant for residential applications. Figure 1 shows the developed model has sub-models consisting of a PV array, H-bridge converter, MPPT controller module, load and the grid connection modules. The design steps and the selection criteria of the electrical parameters for each sub-model are introduced in the sub-sections of the paper.

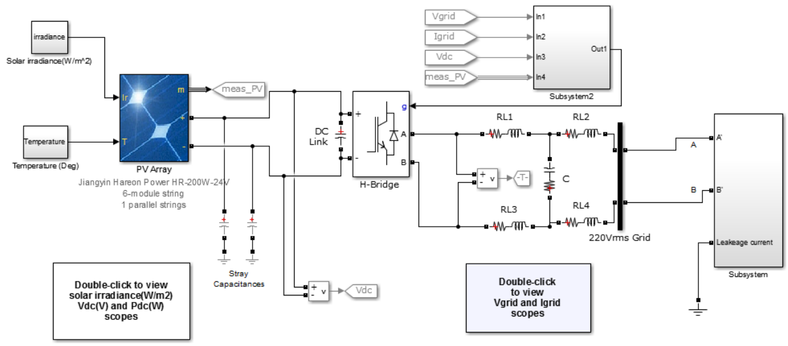

Fig. 1. Developed grid connected PV system for residential power plants

2.1 Model of PV Module

An electrical equivalent circuit of solar cell can be represented single diode model, double diode model, empirical model and vulture model. Among all of these methods, single diode equivalent model has simplicity and sufficient accuracy [7]. Single diode equivalent circuit of a solar cell is shown in Fig 2. I_{ph} represent the PV cell photo-current, R_{sh} represents leakage current and R_s represents the voltage drop at the out-put.

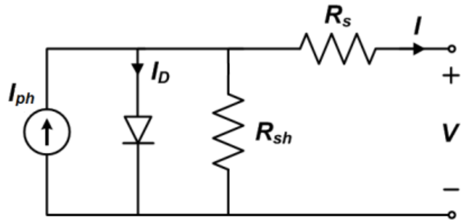

Fig. 2. Single diode equivalent circuit of a solar cell

In the solar cell equivalent circuit given in Figure 2, the Kirchoff voltage law is ap-plied to obtain the source current expression in equation 1 [8]. The relationship be-tween output voltage (V_{pv}) and current can be described by the following relation

$$I = I_{ph} - I_0 \left\{ exp \left[\frac{q(V_{pv} + IR_S}{AkT} \right] - 1 \right\} - \left(\frac{V_{pv} + IR_S}{R_{sh}} \right) \quad (1)$$

where I_{ph} is the PV cell current, I_0 is the PV cell reverse saturation current, q is the electron charge (1.602× 10^{-19} C), A is the ideality factor, k is the Boltzmann constant (1.381× 10^{-23} J/K), T is the absolute temperature in Kelvin.

Output power depending on the efficiency of a single solar cell is relatively low (1-1.5W). So if a large number of solar cells are connected in series and parallel, the required voltage and power can be achieved. Solar cells are combined to form PV modules. The relationship between output voltage and output current of PV module can be described by the following relation

$$I = N_{pc} \left\{ I_{ph} - I_0 \left\{ exp \left[\frac{q(V_{pv} + IR_S}{AkTN_{sc}} \right] - 1 \right\} \right\} - \left(\frac{V_{pv} + IR_S}{R_{sh}} \right) \quad (2)$$

where N_{pc} is the number of cells connected in series, N_{sc} is the number of cells con-nected in parallel.

The output power of the solar panel is a function of the radiation intensity and the ambient temperature. In general, various mathematical calculation methods have been developed in the solar panel to find I-V values. By using the equations 3 and 4, the I-V characteristic of the PV panel can easily be obtained.

$$I_{new} = I_r + \left[\alpha \left(\frac{G}{G_r} \right) (T_m - T_{mr}) + \left(\frac{G}{G_r} - 1 \right) I_{sc} \right] \quad (3)$$

$$\Delta I = \left[\alpha\left(\frac{G}{G_r}\right)(T_m - T_{mr}) + \left(\frac{G}{G_r} - 1\right) I_{sc}\right] \quad (4)$$

$$V_{new} = -\beta(T_m - T_{mr}) - R_s \Delta I + V_r \quad (5)$$

where G and G_r (W/m^2) are the effective and reference radiation intensity, T_m and T_{mr} (Kelvin) are the effective and reference temperature of PV module. In these equations, I_r and V_r are the current and voltage values referenced in I-V curve. α and β coefficients are the temperature coefficients of current and voltage.

3 MODEL OF MPPT METHOD

Inverter control system provides Maximum power point tracking, current and voltage regulation to be achieved and to be synchronized with the grid. Perturb and Observe technique was used to simulate the maximum power point tracking in the simulation. This system in use changes the reference signal of the voltage regulator up or down in the specified direction to obtain a voltage which will extract the maximum power from the PV array.

4 PERFORMANCE ASSESSMENT OF THE DEVELOPED PV SYSTEM FOR DIFFERENT CONDITIONS

The developed model has been tested under different conditions such as temperature and radiation. For this purpose, The Jiangyin HR-200W-24V type solar modules are selected for modeling with Matlab/Simulink and the solar modules are simulated for Bursa Technical University MimarSinan Campus environment. Parameters of selected PV module are shown in Table 1.

Table 1. Technical specifications of The Jiangyin HR-200W-24V

Maximum Power (Pmax)	200 W	Short Circuit Current (Isc)	5.79 A
Voltage at MPP (Vmpp)	37.39 V	Open Circuit Voltage (Voc)	45.5 V
Current at MPP (Impp)	5.35 A	Cells per module	72
β	-0.33	α	0.05

4.1 Operating PV System under Different Weather Conditions

PV module current-voltage (I-V) and power-voltage (P-V) curves of HR-200W-24V solar module obtained at different temperature and radiation values are shown in Fig. 3 and Fig. 4. As can be seen from these figures, the radiation increase increases the PV module output current. So the power received from the panel is also increasing.

The temperature also reduces the output voltage of the PV panel, which adversely affects panel efficiency.

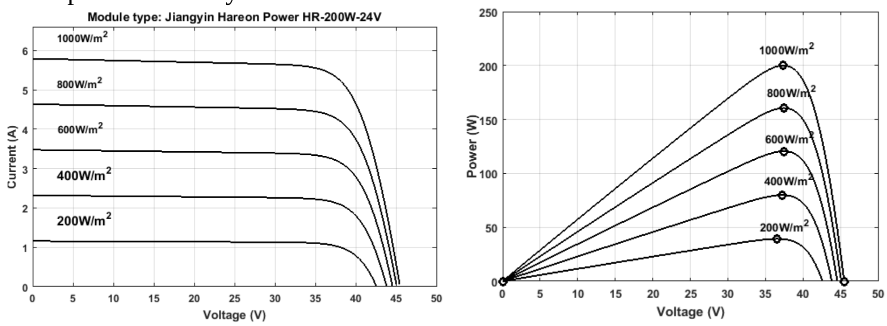

Fig. 3. I-V and P-V curves of selected solar module under different irradiance

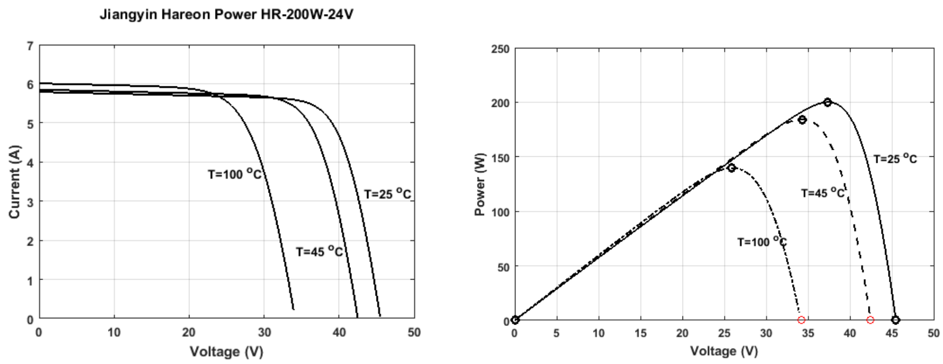

Fig. 4. I-V and P-V curves of selected solar module at different temperatures

4.2 Operating PV System with Partial Shading Effect

In a solar module all cells are not exposed to the same solar radiation due to reasons such as building shadow, sun position and bird dropping [9]. To explain the occurrence of partial shading, 72 cells of the HR-200W-24V solar panel were divided into 3 groups of 24 cells. Irradiance of 1000 W/m^2 applied on the first string of 24 cells while partial shading is applied on strings 2 (cells 25-48) and string 3 (cells 49-72), resulting in respective irradiances of 300 W/m^2 and 600 W/m^2. The global I-V and P-V curves are shown in Fig 5.

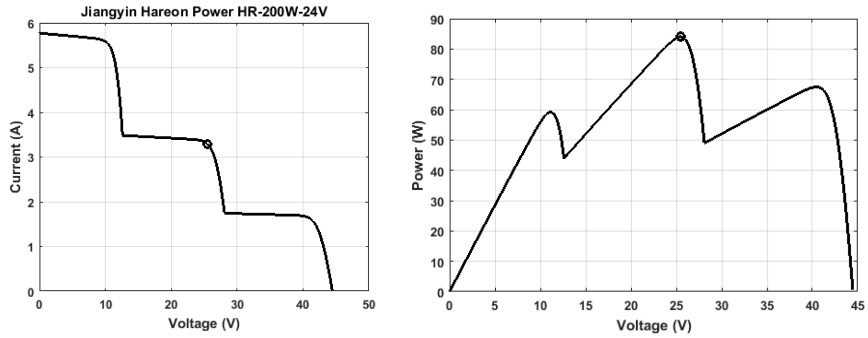

Fig. 5. Global I-V and P-V curves of Jiangyin HR-200W-24V solar panel

4.3 Operating PV System under Different Load Conditions

The 5500 KVA load is connected at system to test the grid-connected PV system model. The active and reactive power of the load is shown in Fig 6 (a). The inverter output voltage and current values of the PV system connected to the 220 V network are shown Fig 6 (b). The rms value of the grids voltage rose to 226 V after the PV system was added to the grid.

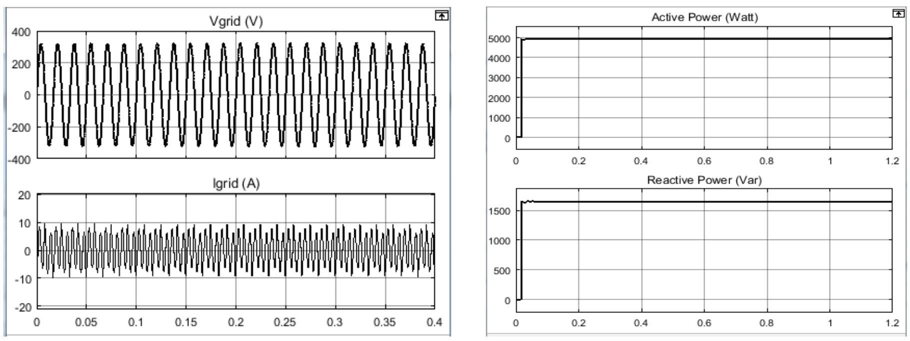

Fig. 6. (a) Current and voltage of the grid (b) Active and reactive power of load

5 DISCUSSION AND CONCLUSION

In this study, a grid-connected PV system consisting of 6 panels on the campus of Bursa Technical University was simulated. The PV generator is connected to the DC line via the inverter and the inverter output is connected to the grid via the LCL filter. The modeled system was tested under partial shading with different irradiations and temperatures under load. It is observed that the load is operating at nominal values. The global Maximum Power Point (GMPP = 84.95 W) value in the case of partial shading was found to be 32% lower than the expected maximum power (125 W). The results verify that the proposed system will also make a contribution to the researchers for selecting the proper electrical and climatical criterions by designing a grid-connected PV system for a residential design.

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Investigation of Drying and Burning Characteristics of Wastes Originated from Paper Mills as a Biomass Source

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ABSTRACT. This study has investigated the drying and burning characteristics of paper mill wastes in order to efficiently convert the wastes to heat energy. Waste biomass products can be converted to heat energy by direct or indirect burning methods in a safe way in small and big industrial ovens; and therefore, waste disposal problems can be resolved by using such wastes for energy purposes. Recently, a rapid increase has been observed in the studies related to the collection of waste papers, and direct or indirect burning for heat energy production. However, certain types of waste such as oil soaked wall paper, adhesive tapes, carbon and fax papers, adhesive and waxed papers, coated papers, toilet papers, paper handkerchiefs, paper towels, and hygiene wipe papers are not fully converted to useful products. Therefore, depending upon the waste source, we experience difficulties in converting paper mill wastes into useful products. For these and other similar wastes (based on paper types), different drying and burning methods must be employed. In this study, the parameters in direct and indirect burning methods, and the corresponding flue gases emitted during the burning processes were investigated and discussed.

Keywords: Paper wastes, Biomass, Drying, Combustion, Flue gases

1 INTRODUCTION

Benefit from waste paper as energy source have become a critical topic for the Turkey's economy. In 2016, Turkish Statistical Institute declared annual population growth rate of Turkey where increased to 13.4% in 2015 from 13.3% in 2014 [1]. Due to Turkey's population growth, the total paper/pulp consumption has increased and expected it will continue to increase in the future.

Eleven million tons of wastes are produced yearly by the European pulp and paper industry, of which 70% originates from the production of non-recycled paper [2]. Due to legislation limits and increased disposal cost, landfills are quickly being eliminated as a final destination for wastes in Europe, and incineration with energy recovery is becoming the main waste recovery method. Therefore, to incinerate these wastes for energy recovery, it has become the main waste recovery method. In Turkey, April 2, 2015 and dated 29 314 numbered published in the Official Newspaper Waste Management and waste regulation ensured compliance with current practices as well as the European Union's Directive 2008/98/EC has been harmonized with the Waste Framework Directive provisions. According to this regulation, it is expected primarily to prevent the formation of waste at the source. Where this is not possible, waste materials should be reused, recycling is not available, it is expressed that re-operation needed to do. After the drying and biopellet process, the paper mill wastes can be used as test fuel in a small scale industrial furnace.

Figure1 shows European paper recycling amounts between 1991 and 2015. The recycling rate in Europe reached 71.5% in 2015, and paper consumption has slightly increased compared to 2014, reaching 82.5 million tonnes. Compared to the base year of the Declaration (2010), collection and recycling of paper has increased by 1.4%, corresponding to 0.8 million tonnes of paper. It is noted that Europe are quite clearly starting to reach maximum potential, since 22% of paper consumption cannot be collected or recycled e.g. wallpaper, hypiene paper [3].

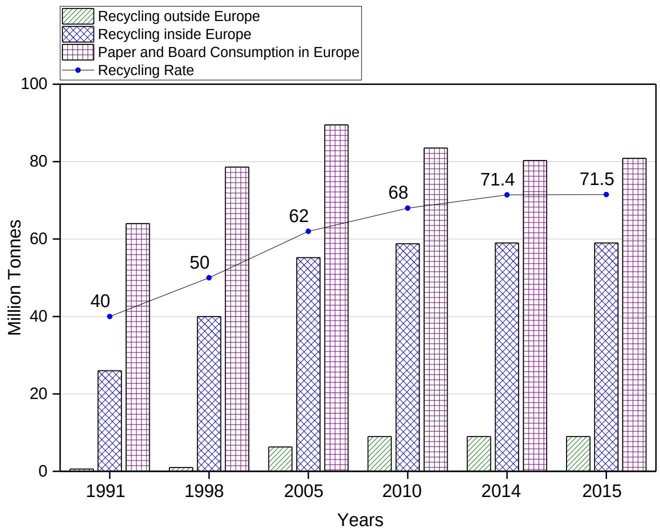

Fig. 1. European Paper Recycling 1991–2015 [3]

SEKA the pulp and paper factories were established on August 18, 1934 in Kocaeli, and also it is the first governmental industrial establishment in history of the Republic of Turkey. The word "SEKA" is a portmanteau of "SEllüloz" (for "cellulose" or "pulp") and "KAğıt" ("paper). The paper industry is one of the fastest growing sectors of the Turkish economy [4]. The steady increase in demand and production of paper and paperboard is expected to continue. In Europa, the total amount of paper collected and recycled in the paper sector has increased by 1.5% to 59 million tonnes, while consumption of paper has increased by 1.5% or 1.2 million tonnes [3]. In Turkey, in the paper sector of Turkey, the difference between production and consumption values is growing. Figure 2 shows Paper industry indicators in Turkey, 2009-2014. Looking at the figure, it can be said that all of the paper/pulp wastes are used in production in Turkey.

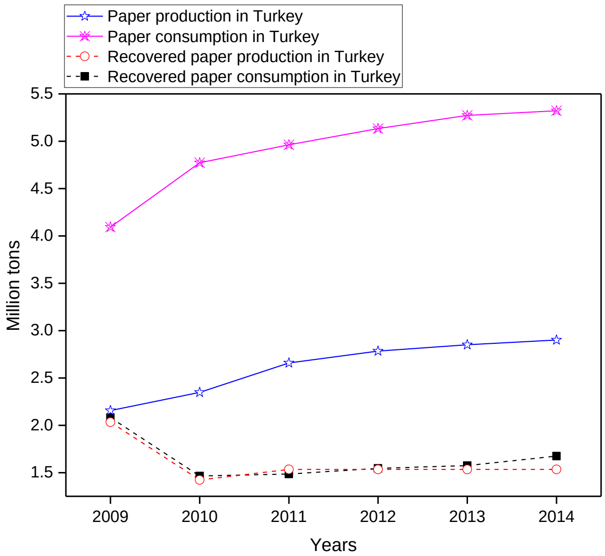

Fig. 2. Paper industry indicators in Turkey, 2009-2014 [5]

With the increasing demand on alternative energy sources, we can compensate to get energy from wastewater treatment sludge and deinking sludge, including combustion technology. Disposing of paper sludge in landfill or by incineration creates environmental problems, and legislative trends in many countries are restricting the amount and types of materials that are permitted to be disposed of by landfill [6]. The production of biomass from paper mills sludge can solve the environmental problems related with paper sludge disposal. In this study, the technologies required for sludge pretreatment before incineration have been discussed.

2 PROPERTIES OF WASTE SLUDGE GENERATED AT PAPER MILLS

Several solid wastes and sludge are generated in the paper mills under different production methods. The solids in sludge fall into two broad categories: the combustibles and the ash. Combustibles include the organic per cell mass and other organic matter (scum, leaves, etc.) [2, 7].

Treatment of wastewater generated at pulping, papermaking, and deinking processes is the main source of Wastewater Treatment Sludge and Deinking sludge. Composition and amount of sludge are strongly influenced by paper grade being produced; raw materials used by the process, the production and wastewater treatment technologies [2, 8].

Primary sludge consists of mostly fines and fillers depending on the recovered paper being processed and it is relatively easy to dewater. Secondary or biological sludge is generated in the clarifier of the biological units of the wastewater treatment, and it is recycled to the product (board industry) or thickened, dewatered and then incinerated or disposed of in landfill. Compared with the primary sludge, the secondary sludge as by-product of the biological treatment is however far more difficult to dewater [9]. Figure 3 shows that the percent distribution of sludge types produced by pulp and paper industry plants in USA and Italy.

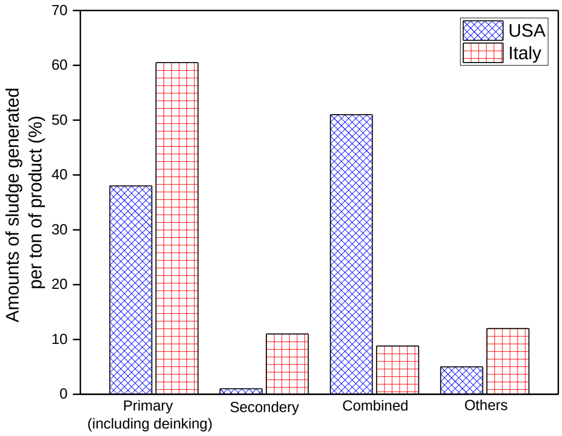

Fig.3. Percent distribution of sludge types produced [10]

The percentage of solid matter is the most important sludge parameter in the design and operation of incineration systems. The dewatering of sludge can be affected by a number of technologies. For most municipal treatment plants, dewatering is seldom able to produce sludge with more than a 25% to 27% solids cake. Thus, the burning of sludge is more the ‘‘burning’’ of water than of organic biomass. Figure 4 shows the composition of wastewater treatment sludge depending upon primary/secondary sludge and deinking sludge.

It should be noted that composition of ash can vary depending on the raw materials used for recycled fibre production [12]. As can be seen in figure 4, the deinking sludge has a lot of ash content. Thus, the deinking sludge has low calorific value on a dry basis and, therefore, it can be expected that combustion of the deinking sludge is not economical. To use the deinking sludge as a biomass source must be applied different fuel conversion methods such as gasification and pyrolysis etc. to burn more effectively.

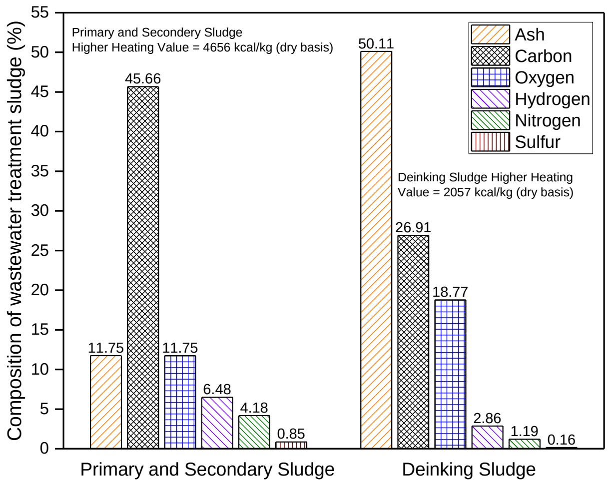

Fig. 4. Chemical composition of primary, secondary and deinking sludge [11]

Table 1 shows that ash analysis for deinking sludge [13]. As can be seen from the table, inorganic part of deinking sludge mainly consists of Si, Al, and Ca oxides. The rest elements are present in smaller concentrations. Si and Al are the main components of kaolin, while Ca is the main element of precipitated calcium carbonate. Demir et al., [14] showed that kraft pulp residues can be utilized in brick-clay as an organic pore-forming agent and by this way it can be utilized in environmentally safe way. Sutcu and Akkurt [15] compressed the granulated powder mixtures in a hydraulic press, and dried the green bodies before firing at 1100 °C. They showed that compressive strengths of the brick samples were higher than that required by the standards. Conversion of this product to a perforated brick may reduce its thermal conductivity to very low values. Successful preliminary tests were conducted on an industrial scale.

Table 1. Deinking sludge ash analysis [13]

Ash analysis (weight %)	No:1	No:2
SiO_2	28.6	40.9
Al_2O_3	43.4	22.9
CaO	4.6	25.8
Others	23.4	10.4

Especially, deinking sludge is generated during recycling of paper (except for packaging production). Separation between ink and fibres is driven by “flotation” process, where foam is collected on the surface of flotation cells. The generated deinking sludge contains minerals, ink and cellulose fibres (that are too small to be withhold by filters) [12]. Table 2 shows the heavy metal percent different paper sludge.

Table 2. Heavy metals content in different sludge types [16]

Source/ Component	Elements content on dry basis (mg/kg - dry basis)						
	Lead (Pb)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Nickel (Ni)	Mercury (Hg)	Zinc (Zn)
Primary sludge	41	<0.7	24	238	6	0.1	141
Secondary sludge	22	<0.7	17	71	8	0.01	135
Deinking sludge	10-210	0.01-0.98	9-903	20-195	<10-31	0.1-0.9	34-1320

3 ENERGY RECOVERY WITH THE FUELS OBTAINED FROM WASTE PAPER/PULP

Routinely, the pulp/paper sludge is disposed for landfilling and incineration which have the significant energy loss in evaporating the sludge-containing water in combustion duration [17]. Sludge incineration is commonly implemented as a co-combustion process with bark at the pulp and paper industry plants. Among all grate types, travelling ones have become the most popular for bark incineration.

Energy recovery by incineration is difficult because of the high water content in paper sludge. Water removal is a crucial part of sludge management, and the most energy efficient way to remove water is by using mechanical dewatering. Hagelqvist [18] suggested the two sludge management strategies that are currently dominating within the industry are mechanical dewatering followed by composting in order to make material for soil amendment or covering material for landfill and mechanical dewatering and incineration with deposition of the ashes on landfill. Chunbao and Lancaster [9] demonstrated that secondary pulp/paper sludge powder, with a higher heating value of 18.3 MJ/kg on a dry basis, could be effectively converted into liquid oil products by direct liquefaction in hot-compressed water with and without catalyst. Ouadi [19] analyzed the composition and characteristics of products obtained from pyrolysis of deinking sludge generated at two different paper mills with a composition similar to deinking sludge generated at the case study paper mill. The results showed that the generated bio-oil had a high heating value of 36-37 MJ/kg.). In past, some researcher [20, 21] stated that the ethanol fuel produced from cellulosic feedstocks offers significant benefits if cost-effective processes can be developed. In Turkey, Yaman et al., [22] converted the olive refuse and paper mill waste to fuel briquettes. That study showed that the mechanical strength of the briquettes produced only from the olive refuse was not high enough. In order to the produce strong briquettes was used paper mill waste. When olive refuse was blended with fibrous paper mill waste, briquettes with sufficiently high mechanical strength could be produced. Burning profiles of the samples were derived applying derivative thermogravimetric technique under dynamic dry air atmosphere up to 1273 K with a heating rate of 40 $K \cdot min^{-1}$.

Paper/pulp wastes has been combusted for many years as a way of reducing waste volume and deactivating many of the potentially harmful elements within it. Combustion can only be used to create an energy source when heat recovery is included. Heat recovered from the combustion process can then be used to either power turbines for electricity generation or to provide direct space and water heating. Some waste streams are also suitable for fueling a combined heat and power system, although quality and reliability of supply are important factors to consider.

4 CONCLUSION

In recent years, the researches has been made to improve the utilization of paper mill rejects as secondary energy sources due to quickly decreasing landfill area and the secondary pollution issues associated with the conventional sludge disposal approaches as well as the increasingly stringent environmental regulations, the disposal of sludge continues to be one of the major challenges for most pulp and paper mills. Due to legislation and increased taxes, landfills are quickly being eliminated as a final destination for wastes in Europe, and incineration with energy recovery is becoming the main waste recovery method. However, deinking sludge, pulping rejects from recovered fibers processing and dewatered sludge from wastewater treatment plants generally have high moisture and sometimes inorganic contents and therefore have poor heating values preventing their energy recovery. Thus, in some cases other methods can be preferred. Other methods such as pyrolysis, gasification, land spreading, composting and reuse as building material are being applied. And also, it is necessary to continue research on different applications of wastes, while taking into account the environmental and economic factors of these waste treatments.

If the deinking sludge utilization systems can be improved at small-scale paper producers in Turkey, numerous benefits can be obtained for the environment, local community, and economy. Undesirable effects on the environment can be reduced basically through the reduction of greenhouse gas emissions generated at a landfill area. It was reviewed in this study that the deinking sludge can be used as an alternative source of raw materials or fuels in other industries. With today's facilities in Turkey, it is proposed converting the paper mills wastes to bio pellets, bioethanol or bio briquettes is an ideal method for using in small-scale industrial furnaces.

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Economic Comparison of Building Heating With Geothermal Energy and Natural Gas

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ABSTRACT. The need for energy is also growing rapidly as countries are increasingly developing economically. For this reason, countries are exploring ways to benefit more from conventional energy sources while at the same time making more extensive use of renewable energy sources. In this study; the first investment for geothermal energy and natural gas and the annual heating costs for heating this area were calculated for geothermal energy located in Simav district of Kutahya and an apartment with an area of 100 m^2 heated by natural gas in Istanbul-Kartal district and the two different energy sources were compared in terms of heating. Accordingly, it has been researched whether it is economical to heat geothermal energy and natural gas in the heating of buildings. In the evaluations made, it was concluded that there was not a significant difference between the average consumption values of the square meters of the two energy classes at the 5% significance level. According to this result, since the geothermal energy is indigenous and renewable and the investment costs are low, providing widespread use in regions where geothermal resources are present will provide positive contributions for both the consumers and the country's economy.

Keywords: Key Words: Geothermal Energy, Natural Gas, Economic Analysis

1 INTRODUCTION

Today, energy is one of the main problems of all countries of the world. The most important reasons for this are; Population growth, industrialization and rising living standards. The energy needs of the countries are increasing parallel to population growth and development. For this reason, more sophisticated ways of exploiting fossil-based energy resources are being explored, while renewable energy sources are being addressed. Increasing use of renewable energy resources such as geothermal energy, which is an important potential for our country, can make a significant contribution to the national economy. Today, housing heating is usually done with natural gas, fuel oil, coal and geothermal energy. The use of natural gas is becoming increasingly widespread as the use of coal, which is common in heating, is gradually diminishing. Geothermal energy is also observed to develop at least.

The need for energy is also growing rapidly as countries are increasingly developing economically. For this reason, countries are looking for ways to benefit more from conventional energy sources while at the same time exploring ways to benefit more from renewable energy sources. Indeed, researchers have been more interested in renewable energy sources such as geothermal, solar, wind and tide in recent years and are exploring more economically to benefit from these sources. In energy production, the biggest cost is the initial investment cost. For this reason, the number of enterprises producing electricity in the energy sector is not large. Consumers want to know what energy source will be economical if they have alternative energy sources. The Simav region is one of the few places with this alternative energy source. Due to economic development and rapid urbanization in our country, the demand for energy is increasing. Significant difficulties are particularly noticed in the heating of cities. The increasing cost of conventional energy sources such as petroleum and coal used in heating, air pollution and, most importantly, concern that the reserves will someday constitute a major problem. From this point of view, the rapid increase in energy demand in the world has led to the search for new sources of energy, beyond traditional energy sources. One of the new sources of energy is geothermal energy. Energy production costs are at the core of the economical availability of energy resources. In this study, the reliable methods used in the appropriate decision making process which is taken as a condition of modern business are examined under economic analysis methods. In this study, based on the data of 2016, a comparative analysis was made by determining the initial investment costs and unit heating costs for the houses with geothermal energy and natural gas heating.

2 LITERATURE RESEARCH

Geothermal energy, which is one of the most important sources of renewable energy resources, can now be used in numerous fields such as electricity generation, medicine, tourism, agriculture, industry. Although geothermal energy resources have many benefits, they are mainly renewable as previously mentioned, that is, it is a kind of energy that cannot be consumed with proper use, easy to detect and produce, low cost, return of investment in a very short time. Also, according to other sources, the damage to the environment is very small (Külekçi, 2009). Geothermal energy; It can be defined as the hot water and steam generated by the accumulated heat at various depths of the earth's crust and containing more dissolved minerals, salts and gases than the normal underground and surface waters whose temperatures are above the regional atmospheric temperatures (Arslan, ve ark., 2001). The energy resources that exist in the world are rapidly depleting. On the other hand, the search for and finding new energy sources and the ways to use it are under investigation. Thus, countries are looking for ways to benefit more from conventional energy sources while at the same time exploring ways to take full advantage of renewable energy sources. Indeed, renewable energy sources (such as geothermal, solar, wind, hydrogen, tidal) have started to be used economically in recent years. Investigations are continuing in order to make more economical use of these resources (Mollahüseyinoğlu ve ark., 2005). The cost of producing geothermal energy is lower than other energy sources. This cost is even lower when it comes to integrated uses (Çerçioğlu ve Şahin, 2016). Geothermal energy is an uninhabitable and renewable energy source. As the waters forming the geothermal fluid are of meteoric origin, the reservoir rocks underground are constantly fed and the depletion of these rocks is not possible unless they are used on the feed (Özkaya ve ark., 2008). The heating of the houses with the central system with geothermal energy is one of the cheapest methods together with the complex investment and operating costs. 1 kwh energy production cost; geothermal energy, 14 for the diesel, 8 for the central heating fuel and 4 times lower than the natural gas (Table 1) (Aydın, 2008).

Table 1. Production Cost of 1 kWh Energy According to Some Energy Sources

Energy Type	Diesel*	Heating fuel	Natural gas	Geothermal energy
Cost of Energy (Cent kwh)	14	8	3-4	0,5-1

Natural gas is a kind of combustible gas mixture of fossil origin in the earth's crust. It's a petroleum derivative. It takes the second order after crude oil in order of importance as fuel. Most of the natural gas (70-90%) consists of the hydrocarbon compound called methane gas (CH_4). Other components include; Ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}) gases. It contains carbon dioxide (CO_2), nitrogen (N_2), helium (He) and hydrogen sulphide (H_2S) in trace amounts. Natural gas is conventional and non-conventional types of natural gas include rock gas, sand gas and coal gas. In Turkey, a limited amount of natural gas is emitted and used. Turkish natural gas is mainly purchased from Russia and Iran via pipelines, from Algeria and Nigeria as liquefied natural gas (LNG) by sea. He has also signed agreements with Azerbaijan and Turkmenistan for natural gas. Turkey's external dependency on natural gas is 98.8%. Of the 49,8 billion m^3 natural gas consumed, only 502 million m^3 (1%) were produced in Turkey. 50% of natural gas is used for electricity generation (Crude Oil and Natural Gas Sector Report, 2014). Turkey has imported natural gas imported in 2014 from the following countries, respectively: Russia 56%, Iran 19%, Azerbaijan 9%, Algeria 9%, Nigeria 7%. Turkey's natural gas reserves are 5 billion m^3. Existing wells have a 10-year production life if no new sources are available (Crude Oil and Natural Gas Sector Report, 2014).

Several studies have been carried out in the literature on geothermal energy, some of which are given below. Şahin ve güntürkün, (2008), the first investment and yearly heating costs for the heating of three different energy sources such as lime coal, fuel oil and geothermal energy were investigated by taking as an example a 4-storey apartment with 100 m2 area in simav district. In addition, it has been researched whether it is economical to utilize geothermal energy to heat the buildings. For this, an economic analysis of the fuels used in the heating of a 100 m2 area has been made. As a result of the economic analysis, it has been found that heating with geothermal energy is more economical than other alternative energy sources. Efe, (2008), by examining each building model designed for erzurum province in six different types, it emphasized the relationship between building layout and heat loss. He compared heating systems in terms of initial investment cost and operating cost. In addition, by calculating the emission values of the fuels, it has been determined which fuel is more environmentally friendly. As a result of this work, natural gas central heating systems are the most economical and environment friendly, and cleanest natural gas is the comparative system. Keçebaş ve ark., (2010), determined the emissions released to the atmosphere according to the fuels used in the flats in the opium center and pointed out the use of geothermal energy and natural gas for heating purposes. In addition, in order to make a sample for our other cities with the resources used in afyonkarahisar, we have presented the contribution of geothermal energy and natural gas usage to the prevention of air pollution with current figures. Kon and yüksel (2013) determined the optimum insulation thicknesses and energy consumption of the outer walls of the rectorate main building and printing house in the campus of balıkesir university. Balbay (2015) conducted an experimental study on natural gas consumption on the ground, first and second floors of an insulated 5-storey building located in siirt province for the heating season. Oguz and kırmacı (2015) concluded that the most environmentally friendly and economical heating system in the study they are doing is the natural gas central heating system. Furthermore, in this study, it is seen that systems should not be evaluated only in terms of initial investment costs, and when the other costs are taken into consideration, it is seen that systems with low initial investment costs lose their economics. It has been understood that the conversion from the coal-fired heating system to the natural gas central heating system is cheaper than the conversion to the natural gas-fired individual heating system. Kozak (2016) investigated the availability of geothermal energy resources for heating houses. It is stated that 55% of the geothermal areas in Turkey are suitable for heating applications, 1200 hectares of greenhouse heating is done by using geothermal energy and 100.000 dwellings are heated by geothermal energy in 15 settlements. Considering the potential of our country in terms of geothermal energy, it has been emphasized that the dissemination of geothermal energy in residential heating will have a very big precaution in terms of country economy. Kon, (2016) calculated the heating and cooling fuel consumption and energy requirement considering the properties such as window type, insulation material and renewable fuel for the sample house in the balıkesir province in the 2nd district according to the turkish standard ts 825 for thermal insulation regulations. In addition, Türkeri, central and individual heating systems are compared. The comparison of individual and central heating systems in a 20 apartment model has resulted in a more economical central heating system for a 20 apartment building in terms of the total cost, which is the sum of the initial investment cost, operating expenses, depreciation costs and other expenses.

3 HOUSING HEATING TECHNIQUES

The basic principle used in modern heating is based on the central heating technique from ancient Romans (Genceli ve Parmaksızoğlu, 2003). Today's heating circuits differ from this technique in terms of the type of hot fluid used and the size of the system. Today, hot water, boiling water, air, hot oil or steam can be used in terms of fluid type. In terms of the size of the systems it is possible to classify them in the forms called individual (floor calorie), center, region or compound (cogeneration). In addition, various heating element applications such as radiator, convector, floor and wall heating can be applied to all these systems. In all these systems, solid, liquid and gaseous fuels can be used as primary energy source. Various advantages and disadvantages can be found depending on the type of systems and fires used. For this reason, it is necessary to carry out an engineering and economic analysis in order to select the most appropriate system, heating fluid and heating element for each different application (Genceli ve Parmaksızoğlu, 2003).

Local Heating: Heat is produced within the environment to be heated. Where these systems are applied, it is necessary to have a heat generator in an environment that needs to be heated. Heating techniques with fireplaces, wood and coal stoves, electric heating devices are considered within this group. Thermal capacity is between 1 and 10 kw (Genceli ve Parmaksızoğlu, 2003).

Individual Heating: Individual heating of volumes between 10 and 40 kw is called floor heating. The system usually uses diesel, natural gas or liquefied petroleum gas (LPG) as fuel. Generally, in our country, fluids in applications are water with a maximum temperature of 900C. Hot water is prepared in a unit called a boiler or combi boiler and sent to the heaters in the places to be heated by means of pipes. Especially in this type of heating technique in the US, the fluid used is heated to about 40 to 50°C. The air prepared in an air heater is sent to the channels to be heated. The use of a certain amount of outside air here also allows forced ventilation in the System (Genceli ve Parmaksızoğlu, 2003). Although the individual heating method is not economical compared to the central heating system, it is the greatest advantage that this system is independent on its own. For this reason, it is preferred by the people of our country who are sitting in an apartment building. Especially when natural gas is used, it is expected that this system will become more widespread in the future (Genceli ve Parmaksızoğlu, 2003).

Central Heating: The most appropriate heating requirement in a block-built building is met by the central system. Hot water prepared in a boiler room on the premises is sent separately for each apartment or unit in the building. While it is possible to burn all types of fire in the road, natural gas and liquid fuel are preferred in terms of environment. Unfortunately, with this technique, a large amount of energy waste can sometimes occur unnecessarily when warming up, as the devices that measure the heat energy are not as widespread as each independent unit in our country. When used consciously, the central heating system is more advantageous than the individual heating system in terms of both investment and operation.

District Heating: In this system, which is also known as city or remote heating technique, the prepared hot fluid is carried to the building a few kilometers away. The fluid, which is usually prepared in the heat center and receives the first fluid name, is boiling water or boiling water. This fluid heats the mains water in the second cycle and at a maximum temperature of 90 ° C with the help of a heat exchanger located under each building. The system in the second cycle is the same as the one used in the central system. In principle, if the buildings in the system are close to one kilometer, it can be done in a single circuit using hot water at 90 ° C directly in the system. In more widespread and dispersed systems, boiling water (steam), which can reach a temperature of 180 ° C in the first cycle, is used. District heating is the most economical system in terms of technology. Particularly in the case of using fuels such as coal or heavy fuel oil, except natural gas, it is only possible to control the temperature of the burner and the fluid precisely in a single center. Hospitals, barracks, residential sites, university campuses are suitable for this heating technique (Genceli ve Parmaksızoğlu, 2003).

4 MATERIALS AND METHODS

4.1 Materiel

In this study, it is examined whether geothermal energy and natural gas heating are economical in the heating of buildings. Today, the heating of the house is usually done with natural gas, heating oil, coal and geothermal energy (Şahin, 2005). However, in recent years, the use of natural gas has become increasingly widespread in residential heating. With the development of geothermal energy use, this situation is limited to the regions where the geothermal energy is present. In this study, economical comparison of the heating methods using natural gas and geothermal energy in building heating is done. Initial investment costs and annual heating costs have been determined in order to heat an average residence with natural gas and geothermal energy resources. In Simav and Kartal districts, 10 houses with geothermal energy and natural gas were taken as material in 2016 and Table 2 gives the data for these dwellings.

Table 2. Total residential areas heated by natural gas and geothermal

Heated housing	1	2	3	4	5	6	7	8	9	10	Mean
Natural gas (m^2)	100	100	135	100	100	135	100	100	135	135	114
Geothermal energy (m^2)	137	105	100	47	73	97	177	46	78	153	101

As shown in Table 2, 10 houses of 2 provinces are heated with about 114 m2 of average natural gas and about 101 m2 of geothermal energy. In addition, monthly mean temperature averages for the two provinces in 2016 are given in Table 3.

Table 3. Monthly temperature averages of Simav and Kartal districts in 2016

District	Temperature	Month

	(°C)	1	2	3	4	5	6	7	8	9	10	11	12
Simav	Mean	2,6	3,6	6,3	10,5	14,9	18,5	20,8	20,8	17,5	12,8	8,4	4,7
	Min	-1,5	-0,6	1,1	4,8	8,4	11,3	13,3	12,8	9,6	6,1	3,0	0,6
	Max	6,7	7,8	11,6	16,3	21,4	25,7	28,4	28,8	25,5	19,6	13,8	8,8
Kartal	Mean	6,3	6,8	8,1	12,5	16,9	21,4	23,9	23,8	20,6	16,0	12,2	8,7
	Min	3,3	3,7	4,4	8,0	12,0	16,2	18,6	18,8	15,8	12,1	8,7	5,7
	Max	9,3	9,9	11,8	17,0	21,9	26,6	29,2	28,8	25,4	20,0	15,7	11,7

4.2 Method

Comparisons of 10 units of samples from two different housing groups heated by geothermal energy and natural gas were made. For this, in case of installing a geothermal energy and natural gas heating system in a residence of 135 m2, the first investment costs of these systems are compared with each other and then the annual square meter heating expenses for each energy type are compared. In making this comparison, the economic life of the heating system for both energy sources is taken as 10 years. Comparisons of energy sources are based on payments made in 2016. The initial investment costs of the heating systems are detailed in Table 2 and Table 3 for both types of energy, based on a 135 square meter residential area.

When Table 4 is examined, it is seen that heating with geothermal energy is 7116 TL / apartment. Total initial investment costs consist of installation and labor costs. Furthermore, according to the terms of subscription of Simav Municipality, 17 TL per square meter, connection fee is 135,70 TL, and also 3 deposits with invoice amount. During the first installation, an average 100 m2 apartment costs 750 TL to the municipality. When Table 5 is examined, it is seen that the installation cost and the labor cost are 8511 TL in the heating of a circle with natural gas. This installation cost consists of necessary material and labor cost.

Table.4. Initial investment cost for heating with geothermal energy for 135 m2 residence (left)

Table.5. Initial investment cost for natural gas heating system (right)

Material	Amount (Piece)	Unit cost (TL)	Material	Amount (Piece)	Unit cost (TL)
80 lt boiler	1	550	Calorimeter	1	100
EM-3 20 Plate exchanger	1	2000	Combi fleksi	3	150

60x180 radia-tors	3	400	Ocak fleksi	1	67
60x160 radia-tors	1	500	Havlupan	1	300
60x12 radia-tors	1	200	Gas alarm device	1	150
60x150 radia-tors	1	300	Natural gas coun-ter	1	120
Havlupan	1	200	Combi	1	1400
Corner radiator valve	14	140	Regulator	2	180
Kloktar 7	1 team	240	Mouth mini valve	3	150
Monometer	3	30	60x3 valve	4	80
Thermometer	3	160	Spherical calo-rimeter	1	161
40 pipe	4 size	160	60x3 pipe	10 m.	250
32 pipe	2 size	60	Spring Clamp	3	95
20 pipe	5 size	50	Natural gas pete-chia	6	2400
16 mobile pipes	2 balls	450	Thermostatic radiator	3	300
1/3 valve	4	200	Yellow flap	1	250
1/3 Conical record	4	40	Pressure reducer	1	140
Other materials	-	250	Other materials	-	800
Labor costs (The total cost is 20%)		1186	Labor costs (The total cost is 20%)		1418
Total		7116	Total		8511

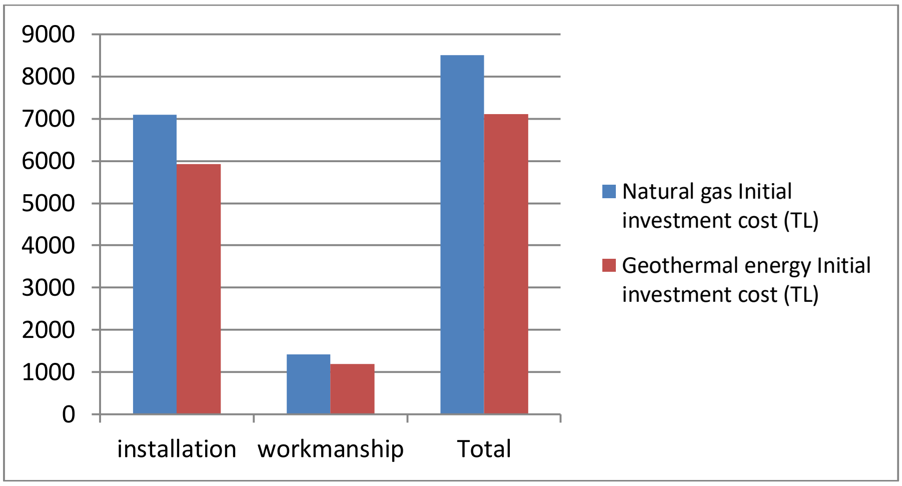

Fig. 1. Initial Investment Costs for Geothermal Energy and Natural Gas

The annual costs for calculating annual costs consist of annual fixed costs and annual variable costs. Annual variable costs; Annual fuel costs, energy costs, labor costs and repair and maintenance costs. In houses heated by geothermal, an average of 5,6 years old tube was used in Simav district. If the cost of a tube is 80 TL, it costs about 450 TL / year tube.

Table 6. Invoice Amounts of Natural Gas Heating in 2016 (left)

Table 7. Billing Amounts of Heating with Geothermal Energy in 2016 (right)

Housing (m^2)		Natural gas (annual) Total	Housing (m^2)		Geothermal energy (annual) Total
1	100	974,5	1	137	1282,3
2	100	522,4	2	105	982,8
3	135	1354,2	3	100	936
4	100	1394	4	47	439,9
5	100	740	5	73	683,3
6	135	652,8	6	97	907,9
7	100	1365	7	177	1656,7
8	100	393,6	8	46	430,6
9	135	916	9	78	730,1
10	135	483	10	153	1432,1
Mean	114	879,9	Mean	101,3	948,2

5 FINDINGS AND DISCUSSION

Table 8 shows the annual consumption costs of m2 of residential area of geothermal energy and natural gas consumption, which are two different energy sources for heating the selected residential buildings.

Table 8. Invoice Amounts for 2016 with Natural Gas and Geothermal Energy (TL/ m^2)

Housing	1	2	3	4	5	6	7	8	9	10	Mean
Natural gas	9,75	5,22	10,03	13,97	7,4	4,84	13,65	3,94	6,79	3,58	7,72
Geothermal energy	9,36	9,36	9,36	9,36	9,36	9,36	9,36	9,36	9,36	9,36	9,36

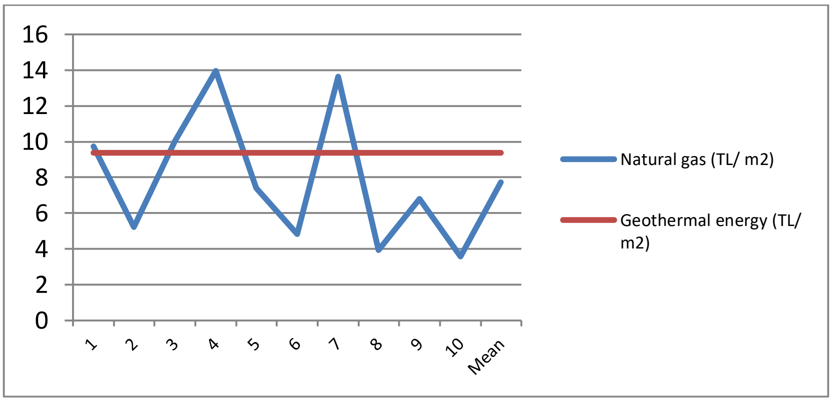

Fig. 2. Change in geothermal energy and natural gas unit prices in selected houses (TL / m2years)

Table 9. t test for natural gas and geothermal energy consumption

Energy		N	Mean	Standard deviation	Equality test of variance			t test		
					F	df	Possibility	t	df	Possibility
Consumption	Geothermal	10	9,36	3,8	28,52	1;18	0,000	-1,2	9	0,261
	Natural gas	10	7,917	0						

The independent samples t test was applied to the consumption values given in Table 8 above and the results in Table 9 below were obtained. As can be seen from Table 9, it is understood that the variances of energy consumption in houses using two types of energy are not homogeneous at the 1% significance level compared to the F test. According to the t test for the difference of average consumption of two energy types, t =-1.2, the probability for 9 degrees of freedom was 0,261. As a result, it is concluded that there is not a significant difference between the average consumption values per square meter of two energy species at the 5% level of statistical significance. According to this result, since the geothermal energy is indigenous and renewable and the investment costs are low, providing widespread use in regions where geothermal resources are present will provide positive contributions for both the consumer and the country's economy. Heating systems also use hot water as well as floor heating. The usage of hot water in geothermal energy is around 60 0C and it is used for 24 hours. In other energy systems, this can be achieved by burning a certain amount of fuel, which can keep the boiler burning at a certain level and the floor heating can protect the temperature. The 12-month heat-up charge includes the hot-water charge for 24 hours as well as the heat-up charge. In other words, although this fee seems to be excessive, it is possible to use hot water for 12 monthsWith other types of energy it is not the case that such a use is provided. This is an advantage of heating with geothermal energy. Heating with geothermal energy is provided by the municipality and the monthly usage fee does not change according to the way it is used. So the monthly heating fee is the price. Since the building is heated every hour of the day, the current temperature of the building is protected. This provides comfort and convenience in use. Thus, when cheap, comfortable and clean warming is achieved, damage to the environment is minimal.

6 CONCLUSION AND RECOMMENDATIONS

In this study, the initial investment costs and the annual operating costs of the natural gas and geothermal energy heating system are separately calculated so that 10 different buildings of 100 m2 can be heated. In terms of initial investment costs, the most economical energy source is the heat with geothermal energy. When annual operating costs are compared, there is no significant difference between the two energy and heating costs. Considering its many advantages, geothermal energy in Turkey should be encouraged in areas with these energy fields of residential heating. In this way, both our own people and the best service will be provided and the natural resources of our country will be evaluated. Turkey is the seventh most important country in the world in terms of geothermal energy richness. Therefore, the development of thermal and electrical use of geothermal energy will provide great benefits. To this end, legal arrangements to accelerate the development of geothermal energy should be brought into force as soon as possible. In Turkey, the total number of wells opened against 170 geothermal fields is 200 and very few compared to world standards. The number of geothermal drilling wells must be increased in order to reveal the geothermal potential in our country. It is of great importance to provide support for research and development, implementation projects and investments to MTA, universities and private organizations for the discovery of new sites, continuation of capacity studies and reintroduction.

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A Review on The Economic Impact of Ice Thermal Energy Storage System

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ABSTRACT. This study presents the effect of ice thermal energy storage (ITES) systems on the cost of electricity consumption. ITES systems provide economical savings by shifting the electricity required for cooling to off-peak hours. There are three types of ITES systems: encapsulated, ice-on-coil and ice slurry. ITES types and ITES utilization strategies have a great impact on the economic effect of ITES. ITES utilization strategies are divided into two sections as partial and full storage. While the entire cooling load of the building is stored in the full storage strategy, Part of entire cooling load of the building is stored in the partial storage strategy. Also, there are many partial storage strategies. These ITES utilization strategies have a significant effect on ITES economic benefit. Better ITES utilization strategy supplies more savings. However, in addition to the amount of savings, the pay-back period of the system is important. Consequently, the utilization strategy of ITES should be set well in order to get maximum benefit from ITES. When setting the ITES strategy, the electricity prices and cooling load changes during the day should be taken into consideration. Although the maximum amount of savings is seen in full storage strategy, the shortest pay-back period is seen when the peak hours for electricity overlap with the peak cooling loads.

Keywords: Ice thermal energy storage, ITES, Off peak cooling, Cooling load, Economic analysis

1 INTRODUCTION

Energy storage is to store energy for later usage. In energy storage systems, energy is charged into a storage medium when energy source is active or cheap and discharged from the storage medium when energy source is not active or expensive. Energy storage systems have many advantages. These advantages can be listed as follows [1]:

- Reduced energy costs

- Reduced energy consumption
- Improved indoor air quality
- Increased flexibility of operation
- Reduced initial and maintenance costs
- Reduced equipment size and capacity
- More efficient and effective utilization of equipment
- Conservation of fossil fuels
- Reduced pollutant emissions

Thermal energy storage (TES) is one of the most advanced and mature types of energy storage types. TES has two types as sensible and latent. Sensible TES is based on changing the temperature of the materials. Latent TES is based on phase change of materials. Although these systems have advantages and disadvantages according to each other, the following criteria are important for which one of these systems will be preferred.

- Storage capacity
- Storage period
- Storage medium or material
- Type of energy source (solar, wind, electricity etc.)
- Physical conditions of the environment
- Operation conditions

Generally, sensible TES requires larger volume than latent TES. The energy content of sensible and latent TES for equal 1 kg water is seen in Fig. 1. As can be seen from Fig.1, while 20.9 kJ energy is required to change the temperature of 1 kg water 5 °C, 334.4 kJ energy is required to 1 kg ice melting. Hence, latent TES systems are generally preferred for higher storage capacity.

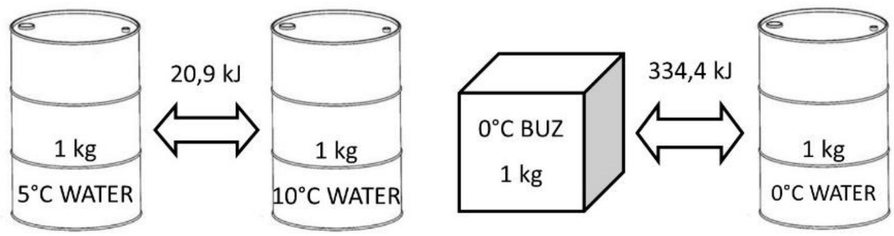


Fig. 1. The energy contents of sensible and latent TES for 1 kg water

The cooling capacity can be stored by chilling or solidifying the water or other materials such as glycol and eutectic salts. The working principle of cold energy storage is as follows: First, energy is charged in storage medium at off-peak hours when the electricity is cheap, then stored energy is discharged at peak hours when the electricity is more expensive. In addition, if it is necessary to wait between charging and discharging period, the storage medium is kept in the insulated storage tank. Thus, utilizing the change in electricity tariffs during the day, cooling costs can be reduced by

CTES. There are a number of storage materials for cold energy storage systems such as chilled water, ice, eutectic salts etc. Water and ice are widely used as storage materials due to its practical and thermodynamic properties in sensible and latent TES systems. Ice thermal energy storage (ITES) system is used for cooling capacity for residential building. ITES systems require much less volume than chilled water systems (Fig.1). Therefore, ITES systems are used to reduce cooling costs in many commercial building. Ice storage systems are divided into static or dynamic systems according to the way ice is delivered to the storage tank. In static ITES systems, ice is produce inside of the storage tank. These systems are the ice-on-coil, ice-in-coil, encapsulated ITES systems. In dynamics systems, ice is produce outside of the storage tank (ice slurry). Static ITES systems are more common than dynamics systems. Because, dynamics systems have more complex structure. Static ITES systems require just an additional storage tank for a normal cooling system.

2 ITES utılızatoın strategıes

ITES systems reduce cooling costs by using costs by utilizing the change in electricity tariffs during the day. On the other hand, ITES systems is need to additional equipment compared to normal cooling systems. So, the initial investment cost increases for the cooling system. The operating conditions of the system must be adjusted very well to reduce the payback period of cooling system. After the completion of payback period, ITES system will saves on the cooling costs. ITES utilization strategies have great impact on system payback period and saving on the cooling cost. Common ITES utilization strategies are below:

- Full storage
- Load levelling
- Partial storage

In full storage strategy, all cooling load is stored by ITES. In load levelling strategy, a part of the total cooling load is stored for equal chiller utilization during the day. In partial storage strategy, a part of total cooling load is stored for different purposes. Stored energy in partial storage strategy is used for pre-cooling before chiller, peak-hours storage and reduced reducing peak cooling load. In Fig. 2, some ITES utilization strategies for encapsulated ITES is shown [2].

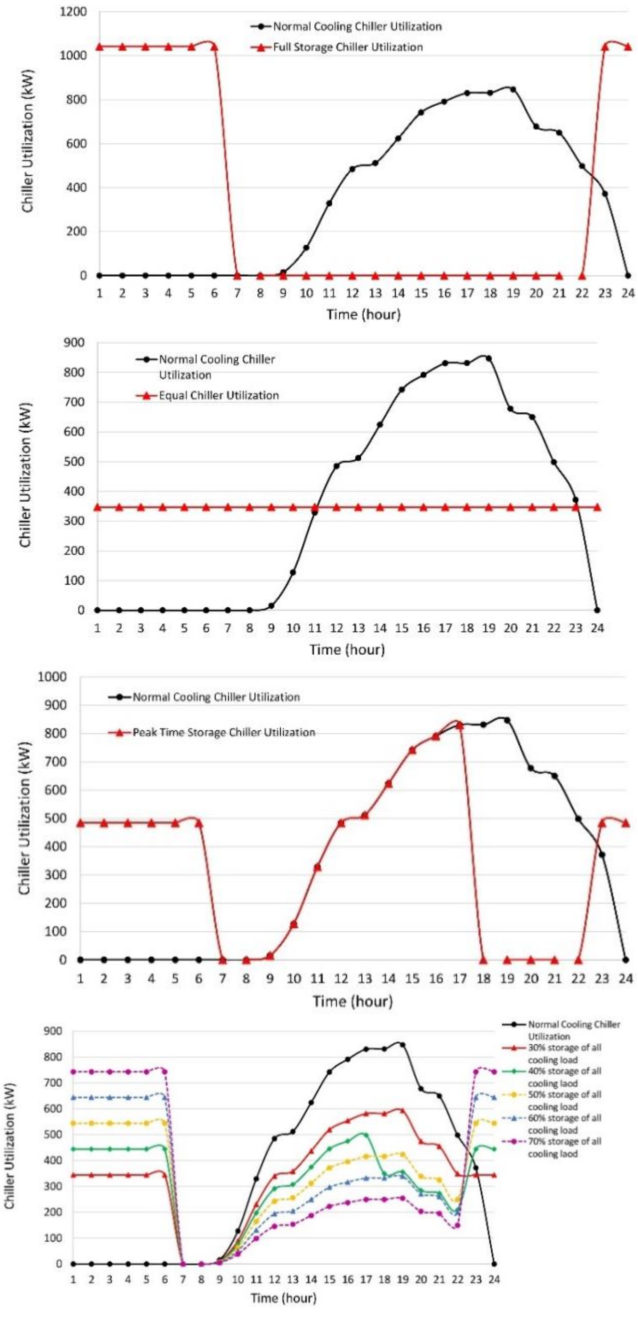


Fig. 2. Figure 2. ITES utilization strategies, full storage, load leveling, partial load for peak hours, partial load for decreasing cooling load (top to bottom)

The chiller is just used at off-peak time in the full storage strategy (Fig.2 a). The chiller is operated at the same load during the day in the load levelling strategy (Fig.2 b). In peak-hour storage strategy (Fig.2 c), the cooling load at peak hours is stored and the chiller doesn't operate during peak hours. A percentage of the total cooling load is stored in partial storage strategy (Fig.2 d). As can be seen from Fig. 2 a-d, ITES utilization strategies affected to the chiller capacity and electricity consumption saving. Increased storage capacity increases both the chiller capacity and storage volume. This situation causes to increasing in the initial investment cost. Increasing initial investment cost increases payback period. Therefore, ITES utilization strategies should be adjusted carefully.

3 THE APPLICATIONS OF ICE THERMAL ENERGY STORAGE SYSTEM

The schematic view of the typical ITES system is seen in Fig. 3. As can be seen from Fig. 3, the system contains the chiller, the storage tank, pump, valve and heat exchanger. The system shown in Fig. 3 is the encapsulated ITES. For other types of ITES, the structure of the storage tank varies. In ITES systems, system periods (charging, discharging and storing) are controlled with valves.

There are many studies in the open literature related to ITES and its economic effects. This section summarizes some of the economic evaluation of ice storage systems.

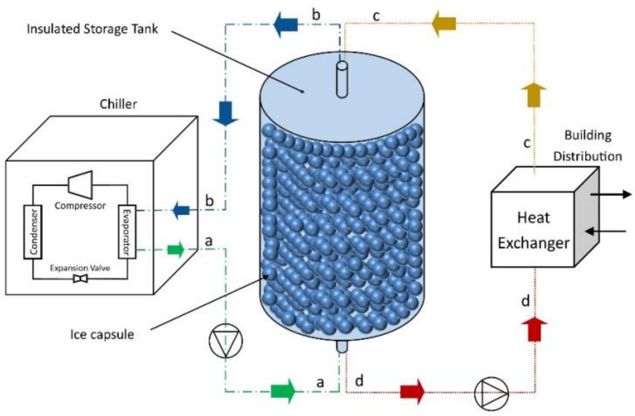


Fig. 3. The schematic view of the encapsulated ITES

Beggs [3] has investigated the economics of ice thermal storage. It has been determined from the study ITES is an economically viable energy conserving technology. It has been emphasized that, in the USA, the peak summer time demand experienced by utility companies can be as much as 40% of their total generating capacity. This summer time peak is solely due to the additional load imposed by air-conditioned buildings. This over load can be reduced by ITES. With increased storage capacity, the amount of savings obtained from the system has increased. Also, with increased storage capacity, the cost per kWh has reduced.

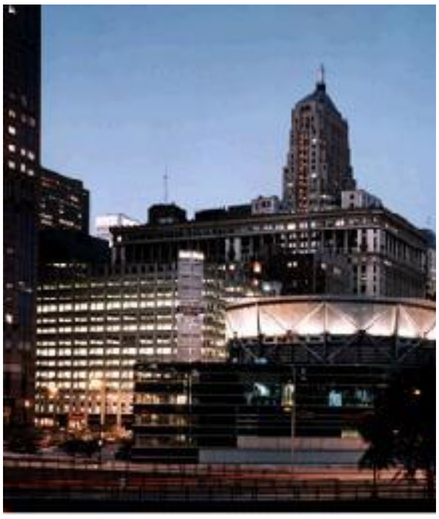
Rismanchi et al. [4] have studied to predict the potential cost savings of employing ice thermal storage (ITS) systems in the office buildings cooling application in Malaysia over the next 20 years. They have conducted for three different scenarios of retrofitting 10%, 25% and 50% of the existing conventional air conditioning systems with new ITES systems. Results have shown that the full storage strategy can reduce the annual costs of the air conditioning system up to 35% while this reduction is limited to around 8% for load levelling strategy.

Erdemir and Altuntop [5] have investigated to calculate the electricity consumption cost saving for shopping center, which is integrated ITES. There is an encapsulated ITES system in shopping center. The cooling load at peak hours has been stored by ITES. As a result of this study, it was found that daily savings can be 394$ during peak load usage. They also emphasized that the amount of savings from the system would be maximum if the peak of the cooling load coincided with the peak times of the power usage.

Chaichana et al. [6] have developed a computer model for comparing energy use in conventional air conditioning systems and ice thermal storage systems. Under Thailand electricity tariffs, the results from the present computer model show that the full storage can save up to 55% cooling cost for a per month. And full storage strategy can increase the total electricity consumption by 5%.

Wu et al. [7] have investigated to application of an ITES as ways of energy management in a multi-functional building. They have considered a commercial office building in Taipei, Taiwan. The system uses partial storage approach to satisfy off-peak cooling demand while peak-hour cooling burden is relieved by chilled water built the previous night. They have calculated saving amount by Using Carrier HAP 4.8, simulation rendered an estimated annual cooling consumption of 715,641 kWh for the building. By a simplified estimation of only time-dependent differential of the electricity tariff schemes in Taiwan, NT$3.89 and NT$1.99 per kW h for on-peak and off-peak rates, it is estimated that cooling cost saving of NT$1.35 million (or roughly 43 thousand US dollars) may be achieved annually.

Ehyaei et al [8] have reviewed potential use of cold thermal energy storage systems for better efficiencies and cost effectiveness. Habeebullah [9] has investigated economic feasibility of thermal energy storage systems. Nassif et al. [10] have investigated the impact of ITES on cooling energy cost for commercial HVAC systems. Rismanchi et al [11] have modelled and simulated to cold thermal energy storage system in office buildings in order to determine the potential energy savings.



Thermal Chicago
314,400 ton-hours – 1,110 MWh [14]

Midway Airport, Chicago
14,000 ton-hours – 49,4 MWh
528,988 kg ice [14]

Cosmo Square, Osaka, Japan
29,300 ton-hours – 103.4 MWh
1,107,097 kg ice [14]

University of Pennsylvania, Philadelphia
22,000 ton-hours – 77,7 MWh
831,267 kg ice [14]

Admiral Fell Inn, Baltimore
1,200 ton-hours – 4,3 MWh
45,342 kg ice [14]

Wachovia Sports Center, Philadelphia
9,500 ton-hours – 33,4 MWh
358,956 kg ice [14]

GIMSA Hypermarket, Ankara, Turkey
2,136 ton-hours – 8,3 MWh
54,386 kg ice [5]

Baltimore Convection Centre
89,665 ton-hours – 317 MWh
1,853,537 kg ice [14]

Fig. 4. The views of some buildings where ITES systems are applied and their capacities.

Sanaye and Shirazi [12] have performed thermo-economic optimization of an ice thermal energy storage system for air-conditioning applications. Vetterli and Benz [13] have done cost-optimal design on an ITES system using mixed-integer linear programming techniques under various electricity tariff schemes. The views of some buildings where ITES systems are applied are shown in Fig. 3. As seen from Fig.3, ITES systems have a wide range of utilization

4 RESULTS

ITES systems have an important effect in reducing the cost of electricity required for cooling. This situation is true for all types of ITES. The biggest impact of ITES types on the system economy is the initial investment cost. While there is no big difference between the amount of savings provided by the ITES types, the greatest impact of ITES types on the system economy is the initial investment cost. Increased investment costs increase the payback period for additional costs incurred for the system. Therefore, in ITES systems, the system types and its initial investment cost should be taken into account in the preference of the system. The shorter payback period will increase the amount of profit that can be gained by saving electricity consumption.

ITES is applicable in all large, medium and small scale buildings. ITES systems reduce the cost of electrical consumption in all the buildings where they are installed. As the size of the buildings is directly proportional to the heat gains, the increasing building capacity increases the amount of electricity saved by the cooling load. However, increased storage capacity increases the initial investment cost of the system. In addition, increased storage capacity increases the initial investment costs of the system. However, with the increased storage capacity, the unit electricity costs for whole system decreases.

The two most important factors affecting the economic performance of the ITES systems are the hourly cooling load and electricity tariff. If the peak times of the electric tariff coincide with the peak times of the cooling load, the economic benefit from the system is highest. This coincide usually does not occur. Because the hours when the cooling load is peak correspond to the hours of lunch and afternoon, and the peak hours of electricity consumption usually coincide with the evening hours. To overcome this situation, electric distribution companies can give special tariffs to the users. Governments can also make laws in this respect.

ITES systems operate in three different periods: charging, discharging and storing. Ice storage tanks are generally very well insulated, so the heat gains are negligible. When this is considered, the most important period charging period in terms of system economy. This is because shortening the charging period will reduce the amount of energy and electricity consumption required to produce ice. In addition, the enhanced charging period will allow to produce more ice on the same charge run. Thus, the economic performance of the ITES system will increase.

The most important problem for the installation of ITES systems is the space required for the storage tank. Because this space may require very large volumes according to cooling capacities. This problem is less in new buildings. Because the storage space required for ITES can be included in the plan, during the design of the building. However, this case is not available in old buildings. Therefore, creating the necessary space for the storage tank is a significant problem in old buildings. In such buildings, the storage capacity can be adjusted according to available physical conditions. If possible, the necessary space can be created by amending the building. If there are indoor car parks, it is quite handy for these places. Also, if there is adequate space next to the building, the storage tank can be placed underground.

ITES systems can be used in all buildings such as hospitals, universities, schools, sports complexes, shopping centers, hotels, supermarkets, airports, railway stations etc. All types of ITES systems reduce cooling costs at all the buildings they use. The features described above are called ITES utilization strategies. In order to maximize the economic benefit of the system, the ITES utilization strategy should be adjusted very well. A poorly adjusted ITES utilization strategy can increase the initial investment cost of the system and extend the payback period.

5 ACKNOWLEDGMENT

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The Assesment of Polywell: The Cost –Effective Electricity Producer Device

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ABSTRACT. The polywell concept is a new method for inertial electrostatic confinement (IEC) by using electrostatic and magnetic fields. This system can confine energetic ions in a small volume and increase their densities up to threshold value necessary for thermonuclear reactions. Ions are accelerated in this system up to several tens of Kev which is needed for fusion reactions. Accelerated ions are attracted by electron clouds and therefore collision occur. Some of these collisions can cause fusion reactions at the center of region. As the ions move back and forth (returning to the central focus), the reaction rate build up around the electron cloud. In this paper, we studied the dynamics of ion and computed the density of confined electron clouds in multi-cusp magnetic fields then we estimate possible energy losses. The results of our calculation demonstrated that the two significant energy losses are: losses due to electron transport across the point-cusp field region and bremsstrahlung losses. Here we have neglected synchrotron radiation losses. By determining power gain (the ratio of fusion power production) to total losses, we conclude that a polywell device can be considered as a system for producing energy (power reactor).

Keywords: Polywell, Electrostatic, Multy-cusp, Energy loss

1 INTRODUCTION

There are different methods for plasma confinement and performing nuclear fusion reactions. The most important of these methods are the magnetic confinement fusion (MCF) and inertial confinement fusion (ICF). MCF uses convenient magnetic fields in relatively sophisticated devices as tokamaks, stellarators and spheromaks [1-2-3]. Different devices of these kinds with different sizes and cross section are designed and used for researches since 1960's. The well-known joint international program will explore ITER tokamak for possible reactor design. On the other hand, the compression of solid D-T fuel to a very high density using high power lasers [4] now has been possible. National ignition facility (NIF) in USA is an example for this method [5]. Meanwhile it seems to exist simpler way for plasma confinement, notably inertial electrostatic confinement (IEC)[6] where a negative spherical grid placed in the center of a spherical chamber can accelerate incident ions towards the center of the grid. The incident ions are accelerated symmetrically in the radial direction. Ions in this process can squire sufficient energies, so that by colliding with each other they can participate in nuclear fusion reaction and produce energy. Polywell system [7] is a spherical case of IEC devices in which instead of the negatively charged grid, a very dense and condensed electron cloud confined by multi-cusp magnetic field is replaced. This dense electron cloud attracts and accelerate ions to itself and by increasing their density and energy in the electrostatic field of the electron cloud provide the required condition for the verification of nuclear reactions. As will show in this paper, the accelerated ions will oscillate around the center and hence increase the collision probability. In fact, the idea of Polywell is based on the use of electrostatic and magnetic field for confinement purposes. In this paper we calculate the velocity of the accelerated ions when they arrive at the center and show that they can acquire tens of Kev energies by this way. The frequency of ion oscillation around the center of the negative cloud is estimated. Since the fusion reaction rate depends on the number of collisions in the center, we find a relation for the oscillation frequency and finally we numerically estimate the energy of ions and the oscillation frequency around the negative cloud sphere.

2 DETERMINATION OF ION VELOCITY

In order to find ion velocities in the center of negative cloud, we assume that electrons are confined in a sphere of radius R. we designated the ion charge by q, by Q the total negative charge. Using simple electrostatics formula, we first calculate the ion velocity in a point located at distance (r_1>R) outside the negative sphere

$$mr_1'' = \frac{-kqQ}{r_1^2} = -kqQr_1^{-2} \tag{1}$$

Where m is ion mass and $k = \frac{1}{4\pi\varepsilon_\circ}$ is a constant.

Multiplying the both sides of equation (1) by r_1' and integrating it, we arrived at:

$$\frac{1}{2}mr_1'^2 = +\frac{kqQ}{r_1} + C_1 \tag{2}$$

Here r_1' is the ion velocity at the distance of r_1 from the negative sphere. The integration constant C_1 can be determined by considering the initial condition that is $r_1' = V_\circ = \circ$, $r_1 = \infty$ (or very close to zero). By this condition the integration constant is find as $C_1 = \circ$. If the initial velocity of ions is assumed V_0 (not zero), the integration constant would be then equal to $C_1 = V_0$. Thus the velocity in any point outside the negative cloud sphere would be:

$V_1^2 = \frac{2KqQ}{mr_1}$ (3)

Especially it will be equal to $V_1^2 = \frac{2kqQ}{mR}$ at the surface of the negative sphere.
It is evident that inside the negative cloud sphere at any distance $r_2 < R$ from the center, the effective negative charge on the ion will be Q' which is smaller than the total cloud charge Q. So the equation of motion will be:

$$mr_2'' = -\frac{kqQ'}{r_2^2} \quad (4)$$

Where $Q' = \frac{4}{3}\pi r_2^3 \delta$, with δ being the charge per unit volume of the negative cloud determined from the total charge $Q = \frac{4}{3}\pi R^3 \delta$ as function of Q and R. Thus we have

$$r_2'' = \frac{-kq \times \frac{4}{3}\pi r_2^3 \delta}{mr_2^2} = \frac{-kqQr_2}{mR^3} \quad (5)$$

Again by multiplying both sides of the equation by r_2' and integrating it, we get

$$r_2' = -\frac{KqQ}{mR_2} r_2^2 + C_2 \quad (6)$$

It is clear that at $r_1 = r_2 = R$, both velocities (3) and (6) should be equal, that is:

So, we get $C_2 = \frac{3kqQ}{mR}$. Thus the velocities at any part inside the negative cloud sphere will be given by:

$$V_2^2 = \frac{-kqQ}{mR^3} r_2^2 + \frac{3kqQ}{mR}$$

According to this equation the velocity at the center of the sphere, i.e., $r_2 = \circ$ would be:

$$V_2 = \sqrt{\frac{3kqQ}{mR}} \quad (7)$$

3 NUMERICAL APPLICATION

Assuming the radius of the negative sphere as R=1 m, and inserting the values of $k = \frac{1}{4\pi\varepsilon_\circ} = 8.99 \times 10^9$ we can find the ion energy $E = \frac{1}{2}mV_2^2$ at the cloud center as a function of electron density n_e;

$E \cong \frac{1}{2}mV_2^2 = \frac{3}{2}\frac{KqQ}{R}$

$Q = \frac{4}{3}\pi R^3 n_e e$ is the total negative charge. Using the numerical practical formula is found as:

$$E(eV) = 1.45 \times 10^{-8} n_e (m^{-3}) \quad (8)$$

We can see from equation () that when electron density exceeds $n_{e\approx}7\times 10^{-12}m^{-3}$the energy of ion will be around the fusion cross section peak (i.e. 100KeV).

4 CONCLUSION

Taking into account the D-T fusion cross section peaks at energies around 100KeV, we conclude that by proper electron cloud confinement, the symmetrically injected ions can be accelerated to several tens of Kev and by oscillating around the cloud center they can make sufficient fusion collision with each other. Electron radial diffusion toward the wall and their run-over through the magnetic field cusp are not take into account in this paper.

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Estimating Greenhouse Gas Emission and Energy Potential of Eskişehir Landfill Area

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ABSTRACT. Landfilling is the most widely used waste disposal method in Turkey and its usage is increasing day by day. Landfill gas (LFG) that is consist of %50 methane (CH_4), %45 carbon dioxide (CO_2) and %5 non-methane organic carbon (NMOC) is formed by anaerobic decomposition of buried waste in the landfill area. Landfills are the largest anthropogenic emitters of greenhouse gas such as CH_4 and CO_2. Although methane concentration in the atmosphere is lower than that of carbon dioxide, it is 21–25 times more harmful than CO_2 and account for 20% of global greenhouse gas effect. On the other hand, with a calorific value of 3.5-5 kWh/Nm^3, landfill gas contained methane can be used as high-value renewable fuel in gas engines that can be effectively used for heat and power. Thus, by oxidized the methane both power and heat can be produced and greenhouse effect can be reduced. In this study, by using LandGEM 3.2 landfill gas estimating model, CH_4, CO_2 and NMOC emissions were estimated for Eskişehir landfill area that has been started to operate in 2010. In addition, the energy potential was calculated for this landfill area. Using data obtained from the Turkish Statistical Institute, the population and quantity of solid waste was estimated by using arithmetic increase method for the next years. Methane generation rate (k) and potential methane generation capacity (L_o) for Eskişehir were calculated as 0.02287 year-1, 110.4802 m3/Mg, respectively. According to the model result, the amount of landfill gas was 1,12x106 m^3/year in 2011 and the maximum landfill gas formation was found 2,28x107 m^3/year in 2032. In this study, the reciprocal internal combustion engine that fueled biogas is used as power generator. Project life time was selected as 133 years (2017 to 2150). Total electricity production was calculated as 1542.594 GWh duration of considered life time.

Keywords: Landfill gas estimation, LandGEM, Greenhouse gas emission, Energy potential from landfill

1 INTRODUCTION

The population growth, the acceleration of migration from villages to cities and the improvement of economic conditions, together with the increasing amount of MSW, becomes a major problem and this also leads to an appropriate MSW management requirement [1]. Landfilling is the most common disposal method in developing countries nowadays [2]. Landfilling is the disposal method in which landfill gas and leachate water formed by resulting in the anaerobic decomposition of solid wastes buried are controlled. Landfill gas is composed of approximately 50% of the CH_4, 45% of CO_2 and 5% of other non-carbon organic compounds (nitrogen compounds, hydrogen sulfide, and non-methane organic compounds) [3]. Moreover, CO_2 accounts for about 9-26% of total greenhouse gas and CH_4 about 4-9% [4]. Although methane concentration in the atmosphere is lower than that of carbon dioxide, it is 21–25 times more harmful than CO_2 and account for 20% of global greenhouse gas effect [5,6]. For this reason, the greenhouse effect of landfill gas is inevitable. Landfill gas also is considered as a renewable energy source because about %50 of this gas composed of methane having approximately 16-22 MJ/Nm^3 lower heating value (LHV) depending on methane content [7].

By collecting and using of landfill gas, both the energy can be obtained to contribute to the economy and the greenhouse effect can be reduced directly and indirectly with the conversion of CH_4 into CO_2 [8,9]. The determining of landfill gas amount emitted is the most barrier in order to calculate the energy that can be obtained from landfill areas and to determine the greenhouse effect. Landfill gas can be estimated by field measurements, experimental processes or mathematical modeling approaches [10]. Numerous mathematical models have been developed for predicting the amount of landfill gas for many years based on the zero, first and second order decomposition equations [11]. However, models based on second order decomposition are not widely used because of not being precisely determined of the required parameters [12]. In addition, zero order models do not reflect the biological landfill gas generation processes. Therefore, the first order models are widely used by industry, state regulators, the Intergovernmental Panel on Climate Change (IPCC), and the US Environmental Protection Agency (US EPA) to estimate landfill gas generation [13]. The Landfill Gas Emissions Model, LandGEM, which is develop by US EPA based on the first-order decomposition equation is an automated estimation tool with a Microsoft Excel interface that can be used to estimate emission rates for total landfill gas methane, carbon dioxide, non-methane organic compounds (NMOC), and individual air pollutants from municipal solid waste landfills [14]. To be able to use this model, parameters such as the amount of annual waste stored or the total amount of waste in the storage area, the methane generation rate, the potential methane generation capacity, initial and final year of waste acceptance is required. In this study, it was aimed to estimate the amount of landfill gas to be generated in the landfill area of Eskişehir in Turkey and to determine the energy potential of this gas.

2 METHODOLOGY

In the present study, for the long term, the landfill gas amount in Eskişehir landfill area was estimated by using LandGEM 3.02 model and the energy potential of estimated gas was determined in the case of using an internal combustion reciprocal gas engine. To achieve this study, the amount of solid waste for the future was obtained by population estimation using the arithmetic increase method. In addition, methane generation rate and potential methane generation capacity values required for model were obtained using IPCC methodology. The amount of stored solid waste, waste composition, population and meteorological data for the past years were obtained by the TURKSTAT, Turkish State Meteorological Service and Eskişehir Governorship Provincial Directorate of Environment and Urban Planning.

2.1 Case-Study Landfill

In this study, Eskişehir landfill area in Turkey was selected as study area. Eskisehir is a city with a total of 14 districts, 2 of which are central districts. The municipal solid waste (MSW) of the two central districts, Odunpazari and Tepebaşı are disposed of the landfill area, whereas MSW of 12 districts are disposed of open dumping [15]. This landfill site began to accepting of the MSW in 2010. TURKSTAT shares the knowledge of the amount of annual waste accepted into the area in each two years. The annual amount of solid waste needs to know to estimating landfill gas, the data of solid waste amount buried in unshared years has been determined to be based on following year data. The amount of MSW disposed in this area and the total populations of central districts data according to years are shown in Table 1.

Table 1. Population and amount of MSW buried for Eskişehir

Years	Total Population Of Central Districts	Accepting MSW Amount (Tonne/year)
2007	595157	-
2008	614247	-
2009	631905	-
2010	643640	233971
2011	662468	203919
2012	674221	203919
2013	685727	223889
2014	700281	223889
2015	717076	

The composition of MSW disposal in the landfill area in 2014 is shown in Fig. 2 [15]. As seen in Fig. 2., the amount of organic solid waste is quite high and the amount of ash is fairly low. It is mean that Eskişehir MSW has a very good waste composition in point of potential methane generation capacity.

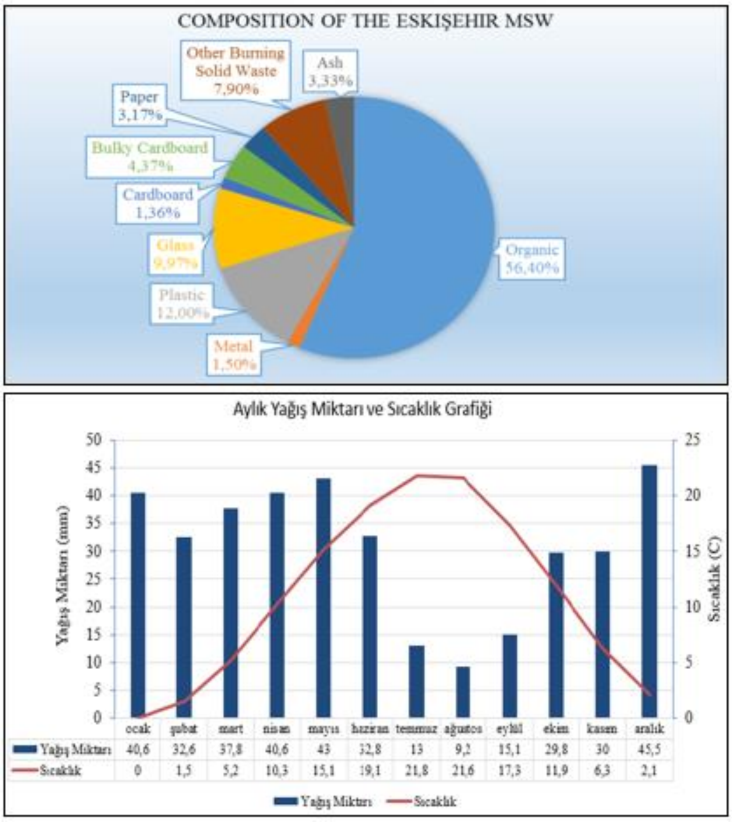

Fig. 1. Composition of the Eskişehir MSW and annual precipitation and temperate according to months

The annual average rainfall and temperature values according to months for the considered area in 2015 are shown in the Fig. 1. According to Fig. 1., the annual average rainfall is 370 mm for Eskişehir.

2.2 Determining the parameters to be used for the landfill

The amount of the solid waste, methane generation rate (k) and potential methane generation capacity are needed to know to estimating landfill gas by using LanGEM model for the considered site. This model has standard k and Lo values created by United States Energy Production Agency and also enable to entering values determined by the user. However, the standard k and Lo values were found out by using solid waste composition and meteorology values of United States. It is mean that these standard values may not proper for the considered site if this site is not in the United States. The k and Lo are needed to determining for considered site to calculating more accurate landfill gas estimation.

2.3 Estimating the amount of solid waste

The amount of being buried solid waste is calculated by Eq. 1[16].

$$A = N_t \times \frac{A_k}{1000} \times 365 \quad (1)$$

where A is to be buried annual solid waste amount (tonne/year), Nt is the population of the considered year and Ak is the amount of the solid waste produced a day per a person (kg-person/day). In this study, the future population was calculated by using arithmetic increase method as seen Eq. 2 [17].

$$N_t = N_y + k_a \left(t_g - t_y\right) \quad (2)$$

where Ny is the, tg is the ty is the and ka is the arithmetic increase coefficient which is calculated by using Eq. 3.

$$k_a = \left(\frac{N_y - N_e}{t_y - t_e}\right) \quad (3)$$

where Ne and te is the the first population and the year in which first population census was carried out respectively.

Determining methane generation rate.

The methane generation rate, k, determines the rate of methane generation for the mass of waste in the landfill [14]. The methane generation rate is calculated by using Eq. 4 [2,18]. According to this equation, the methane generation rate was determined as 0.02184 for Eskişehir landfill area.

$$k = 3,2 \times 10^{-5} \times R + 0,01 \quad (4)$$

where R is the annual precipitation amount for considered site.

Determining potential methane generation capacity

The potential methane generation capacity, Lo, depends only on the type and composition of waste placed in the landfill [14]. According to International Panel on Climate Change (IPCC) methodology, Lo value is calculated as seen in Eq. 5 [19].

$$L_o = MCF \times DOC \times DOC_f \times F \times 16/12 \quad (5)$$

where Lo is a potential methane generation capacity (kg/tonne), MCF is a methane correction factor (default =1.0), DOC is a degradable organic carbon (kg/tonne), DOCf is a fraction of assimilated DOC (default = 0.77), F is a fraction of methane in landfill gas (default = 0.5), and 16/12 is a stoichiometric factor. DOC is calculated by using Eq. 6 [19].

$$DOC = A \times 0.15 + B \times 0.4 + C \times 0.24 + D \times 0.43 + E \times 0.2 + F \times 0.24 + G \times 0.39 \quad (6)$$

where where DOC is degradable organic carbon, A, B, C, D, E, F, G are fraction of municipal solid waste (MSW) that is the food waste, the paper or cartoon waste, the textile waste, the wood or straw waste, the garden or park waste, the nappy waste, the rubber or leather waste respectively.

2.4 Calculating of the power generation

The amount of power could be computed using the electrical conversion efficiency as seen Eq. 7.

$$E_{el}(kWh) = \dot{m}_{lg} \times LHV_{lg} \times \Re \times \eta_{el} \qquad (7)$$

where $\dot{m}_{lg}$ is the flow rate of landfill gas (m3/h), LHV is the lower heating value of landfill gas (MJ/m3), $\Re$ is the recovery rate (75%) and η_{el} is the electrical efficiency of the gas engine (38.7%). LHV of the landfill gas varies from 3.5 to 5.5 kWh/Nm3 [7]. In the present study, LHV of the landfill gas is specified as to be 5 kWh/Nm3.

2.5 Results

A projection of the LFG generation up to 2150 was done for the Eskişehir landfill. Fig. 4. shows estimated total landfill gas, methane, carbon dioxide and NMOC gas up to the year 2150. The graph shows that the amounts of gas would keep on increasing until it reaches a maximum in 2032 where total landfill gas is 22.79 Mm3, methane and carbon dioxide is 11.39 Mm3 and NMOC is 0.09 Mm3. After 2032, the amounts of gas would continue to produce but a lower rate because of not accepting waste.

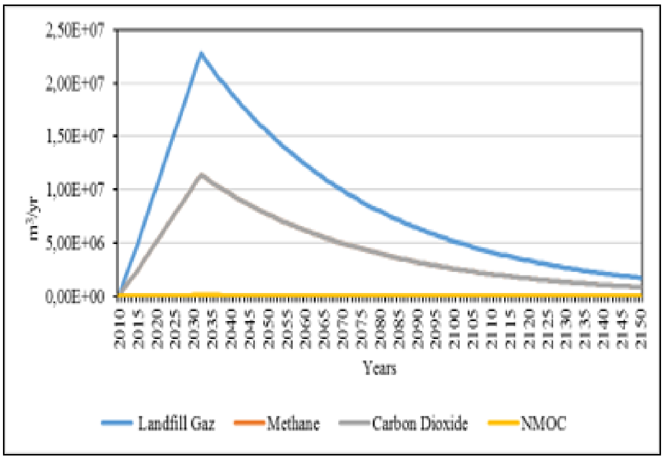

Fig. 2. Estimated landfill, methane, carbon dioxide and NMOC gas

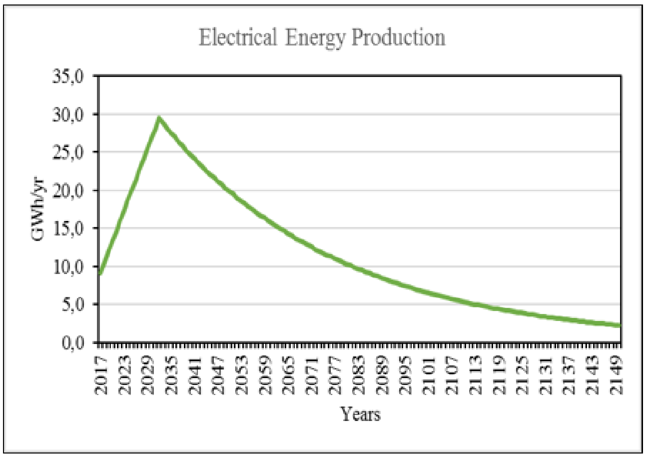

Fig. 3. Electrical energy production for Eskişehir Landfill

Fig. 3. shows electrical energy production for according to estimated landfill gas. The amount of power produced in 2017 would be 9.2 GWh and it could be seen from the graph that it would reach a peak power in 2032 with 29.5 GWh.

3 CONCLUSION

The use of landfill gas to produce electricity is a promising approach both in terms of conserving energy and also to reduce greenhouse gas emission. the maximum landfill gas formation and electrical energy production was found as 22.79 Mm3 and 29.5 GWh respectively. Total electricity production was calculated as 1542.594 GWh duration of considered life time (2017-2150). It can be concluded that landfill gas as a renewable energy source is a good for power generation and it can be used as an alternative to fossil resources.

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Overview of Future for Offshore Wind Energy In Turkey

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ABSTRACT. Energy, in its basic definition, is the ability of a system to perform work. If it is thought that world is the biggest combined closed system, the most significant relation between world and energy is appeared easily. All investment projects should be handled with their most significant parameter as energy. Over the previous decades, twist control, as a critical innovation of renewable vitality era, encountered a maintained and fast improvement in the globe. Contrasting and coastal wind control, seaward winds tend to stream at higher paces than coastal winds, in this manner it permits turbines to deliver more power. Not with standing, the improvement has concentrated altogether on offshore wind control. The major concern while using renewable vitality assets is their discontinuity and inconstancy. One approach to manage this inadequacy is to reap vitality from correlative sources. Turkey, despite having excellent climatic conditions does not have nearly enough offshore wind projects to capitalize on the regions wind potential this article means to demonstrate that offshore wind vitality asset isn't effectively utilized as a part of Turkey and how the utilizing of offshore wind vitality potential is enhanced is examined. Turkey is a nation which has wind vitality potential ashore and sea more than numerous European nations however the estimation of introduced wind control plants is not exactly these nations. There is no power era from seaward twist turbines in Turkey while it is encompassed on three sides via seas. This paper manages a brief modification of the cutting edge of seaward wind control, trailed by a basic examination about the reasons for the as of late development that is as of now incident. The dialog depends on the examination of seaward twist vitality with other renewable energies and even with routine power.

Keywords: Key words: Renewable energy, Offshore, Energy utilization, Wind

1 INTRODUCTION

Energy, in its basic definition, is the ability of a system to perform work. If it is thought that world is the biggest combined closed system, the most significant relation between world and energy is appeared easily. The International Environmental Agency predicts at least 37% growth in global energy demands by 2040 [1]. In addition to these, according to United Nations, the population of the world is predicted 8.7

billion by 2035; energy demand will increase within parallel to population over that period 8 [2]. The increase in oil prices in the fall of 2000 has once again placed energy among the primary concerns of the industrial world, which seemed to have forgotten the impact of skyrocketing oil prices in the early 1970s. The crisis was a reminder of the volatility of oil prices, the exhaustibility of fossil fuels, and the importance of stable, reliable, and non-polluting energy resources for the generation of electrical power [3].

Energy is available in two different alternatives, i. e., non-renewable, e. g., coal, fuel oil, and natural gas, and renewable, e. g., solar, wind, hydro, and wave sources. Since the industrial revolution in the nineteenth century, firstly coal and then fuel oil have been used as primary energy sources for the needs of modern communities. However, in Turkey, modern technological and industrial developments were started at the beginning of the 20th century. Unfortunately, despite its eastern and southern neighboring countries, Turkey has very limited fuel oil reserves and most of its high quality coal reserves have already been used. It is known that fossil fuels have limited potential and at the current rate of exploitation, are expected to be depleted within the next few centuries worldwide. This is one of the reasons why clean, sustainable and environmentally friendly alternative energy resources are currently sought [4].

The wind energy potential on the Earth is huge and enough, in principle, to meet allthe world’s electricity needs [5]. Wind energy has overtaken hydro as the third largest source of power generation in the EU with a 15.6% share of total power capacity [6]. Wind energy in Europe potentially stands to benefit greatly as one of the most efficient renewable energy technologies and the extensive expertise of European companies investing in global markets [7]. As the most promising renewable power in technology and economy currently, wind power generation has gradually become a major alternative form [8-9].

There are two options in order to implement wind energy such as onshore and offshore. From the beginning of using wind energy all the installations for power generation were onshore. Besides, offshore wind power installations are fairly recent. Regarding low space usage, more wind speeds, more generation capacity and low cost in accordance with onshore the wind power sector is shifting to offshore installations [10-11]. Offshore wind energy today seems all the more feasible as technology development has pushed the size of wind turbines well beyond the megawatt level [10].

In this paper, the current status of both onshore and offshore wind power installations globally is reviewed and discussed first, and then the current status and development of Turkey's future offshore wind power market is investigated in detail.

2 OFFSHORE WIND ENERGY IN THE WORLD

Wind energy is the fastest growing energy source in the world and wind power is one of the most widely used alternative sources of energy today [13]. The global offshore wind industry took a big step forward in 2015, installing more than 3.4 GW across five markets globally, bringing total offshore wind capacity to over 12 GW.

Globally, the UK is the largest offshore wind market today and accounts for over 40% of the installed capacity, followed by Germany in the second spot with 27%. Denmark accounts for 10.5%, Belgium for almost 6%, Netherlands for 3.5% and Sweden for 1.6%. Other European markets including Finland, Ireland, Norway, Spain and Portugal make up about 0.5% of the market. The largest market outside of the European waters is China, which accounts for approximately 8.4% of the global market. However, other countries are setting ambitious targets for offshore wind and development is starting to take off in some of these markets [14].

The European Wind Initiative (EWI) targets competitive land-based wind by 2020 and offshore by 2030, as well as reducing the average cost of wind energy by 20% by 2020.The cost competitiveness will depend on costs of other technologies as well, and assumes that externalities of fossil fuels are incorporated [15].

- 1,100,000 jobs created by the global wind industry at the end of 2015.
- The record number of 63.5 GW of wind power installed in 2015, bringing the total installed global capacity to 433 GW at the end of 2015.
- 637 In 2015, wind power avoided over 637 million tonnes of CO_2 emissions globally [16].

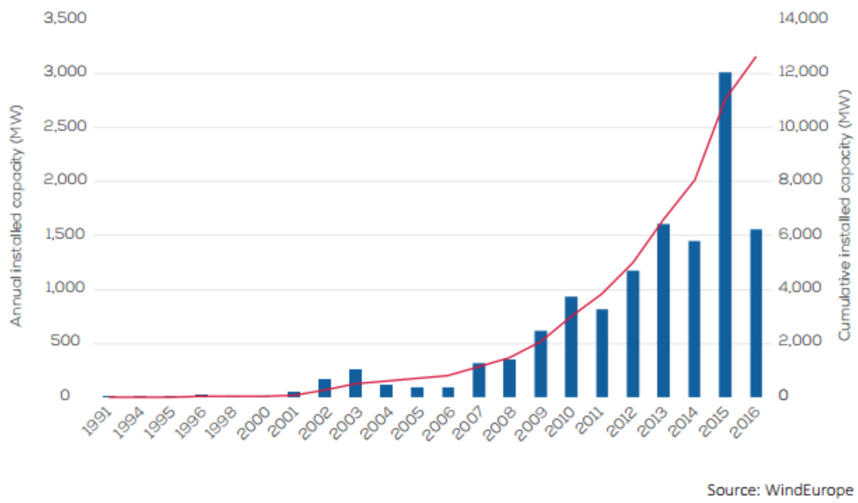

Fig. 1. Cumulative and annual offshore wind installations (MW)

Europe's cumulative installed offshore wind capacity at the end of 2016 reached 12,631 MW, across a total of 3,589 wind turbines. Including sites with partial grid-connection, there are now 81 offshore wind farms in 10 European countries [17]. Offshore wind is generally said to be 10-15 years behind onshore wind, but under the right conditions, the success of onshore wind power can be mirrored offshore. The industry has displayed one of the fastest growth rates of all renewable energy sources, with a 5-year compound annual growth rate of 31%. At the end of 2014 [18].

In the coming years, the offshore wind industry could triple its capacity, from 8GW today to 23.5GW in 2020 [19]. The development of the industry in the coming years is expected to create major growth opportunities for Europe, if long-term visibility and stable regulatory frameworks are in place. The cost of offshore technologies also needs to become more competitive – and considerable investment in research and development into turbines, supply chain optimization, transmission, operations and maintenance is likely to be needed to help achieve cost reduction targets. Many of the solutions lie in the industry's own hands, and the industry is already working hard to make progress in cost reduction. The pace of growth in the industry now needs to be matched by an equal pace in lowering costs [20].

For the ideal place for wind farms constructions on the sea there is a "Double Ten" standard written by National Energy Management at 2010. According to that standart if the overseas area for the wind turbine installation is more than 10 km away from the land, the water depth should not be less than 10 m" [12].

3 OFFSHORE WIND ENERGY IN TURKEY

It was specified by Turkey Wind Energy Potential Atlas (REPA) that there is an 114,173 MW of wind energy potential in regions where wind speed is higher than 7,0 m/s at 50 m height (Table 1). The country's wind power capacity is estimated to 10,000MW is in offshore wind and the major part of potential holds onshore wind.

In international law, territorial waters are defined as the area of the sea immediately adjacent to the shores of a state and subject to the territorial jurisdiction of that state [16]. The standard width of territorial waters has gradually increased from initially 3 nautical miles (5,6 km), to 6 nautical miles (11 km), and currently 12 nautical miles (22 km). The current value has been protected in treaty law by the United Nations Convention on the Law of the Sea of 1982 (Art.3). [17]. The suitability of shores for offshore wind generation in terms of territorial waters of Turkey is not an issue at Black Sea and Mediterranean Sea, but it could be an issue at Aegean Sea due to close proximity to Greek islands.

Table 1 Wind power potential of Turkey by regions where wind speed is higher than 7.0 m/s at 50 m height. The raw data was obtained from EIE [4] for each of the cities located in the region and the wind power potential of the regions was calculated by the authors.

Table 1. Wind power potential of the Turkey.

Region	Wind power potential (MW)	Percentage
Aegean	26,150	22.9
Marmara	43,917	38.5
Mediterranean	11,214	9.8
Black Sea	14,312	12.5
Eastern Anatolia	2974	2.6
Central Anatolia	10,904	9.6
Southeastern Anatolia	4703	4.1

4 RESULT

Cost reductions, both in magnitude and timeliness, should be achieved to secure widespread acceptance by consumers, investors and politicians in the long run. While the clock is ticking, industry is giving signs that it is ready to deliver, but it requires a long-term stable regulatory framework that ensures its efforts are not stalled. As a young industry in its quest for cost-competitiveness, the offshore wind market is still policy-driven, depending on public support schemes. Perhaps more than other renewables, it depends to a great extent on the reliability of regulation and the stability of political support. There is a blank page in the book of opportunities to 2030. While it is clear that there is no appetite for national binding targets for renewables, Turkey should encourage ambitious national pledges secured by a clear governance, with strong incentives that signal long-term certainty and promote regional approaches. Nowhere more than in a shared sea, working with neighboring countries is this essential [20].

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Design Principles of Wind Turbine Installation Vessels

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ABSTRACT. Wind turbine installation vessels (WTIVs) are specifically designed for the installation of offshore wind turbines since the offshore wind industry is maturing and wind farm developments have to be constructed in the most economical way possible. WTIVs have specific needs, different from traditional oil and gas-focused offshore operations. As is the nature of wind turbine installation vessels, they go through frequent repositioning. This proves to be challenging for the jacking systems if not properly taken into account. In addition, there is a need to make a balanced judgement when selecting an operational profile – taking into account operations in more extreme weather conditions. This paper aims to address principles, technical requirements and guidance for the design and construction of the units to satisfy Classification Society rules, Coastal State and Statutory regulations.

Keywords: Windfarm, Wind turbine installation vessel, Self-elevating unit, Jacking system

1 INTRODUCTION

Various natural disasters caused by global warming and lack of energy due to the depletion of fossil fuels are accelerating deep-sea oil exploration and development of shale gas which emerges from concerns of the environmental problem. In addition, the nuclear accident in Japan amplified anxiety about the nuclear energy. The world is putting multilateral efforts to secure renewable energy industry, and to move away from carbon-dependent economy paradigm by developing green energy technologies.

Oil majors are moving into multi-billion-dollar offshore wind farms in the North Sea and beyond. The oil companies have many reasons to move into the industry. They have spent decades building oil projects offshore, and that business is winding down in some areas where older fields have drained. Returns from wind farms are predictable and underpinned by government-regulated electricity prices.

The wind power industry, the best economical option among the renewable industries, is growing 30% annually. However, onshore wind power is already reached saturation and the development is only rising moderately. As an alternative, development of offshore wind power farm has led to a lot of attention and investment. A typical offshore windfarm is shown in Figure 1.

Large numbers of offshore wind turbines have been installed offshore recently. The vast majority of these turbines is founded on monopile foundations in water depths up to 30 m. For deeper waters, tripod and jacket foundations are being applied.

Bereznitski [3] developed a new type of the wind turbine installation vessel. The concept utilizes the Small Waterplane Area Twin Hull (SWATH) vessel. High transit speed, excellent seakeeping, and quick installation sequence allow placing a large number of wind turbines within short time minimizing the time of offshore construction works.

Yao et.al [4] established finite element model of a newtype of offshore wind turbine installation vessel with propelled, jack-up, carriage and lifting functions. After analyzing different operating conditions of transportation and installation, calculation situations were determined and kinds of loads were analysed.

Fig. 1. Offshore Windfarm

Bo and Xue [5] analysed an offshore wind turbine installation vessel under the survival condition, its loading feature was analyzed, the FEM model was built up, the structural strength of its main hull and legs were analyzed, and the stress distribution and deformation were obtained.

Qui et.al [6] performed a three dimensional finite element analysis of new Jack-up ships using a coupled Eulerian-Lagrangian method (CEL) were carried out to simulate penetration and extraction process. A hypoplastic constitutive model and the Mohr-Coulomb constitutive model were used to describe the filling. The studies of influences of geometry of foundations as well as the soil parameters on the bearing capacity of stilts and failure mechanism in foundations were carried out as the design basis of the foundations.

Ouyang et.al [7] performed nonlinear fine finite element model established by MPC and contact algorithm. Based on the results of parameter optimization, strength analyses of the jack-up system were carried out under the conditions of different types and operating conditions. Results showed that in a certain range, the strength of main part (leg and pin) of the jack-up system increase when the distance between the active line of jacking force and the center of the leg become smaller or the height of the fix leg area become higher.

Lv et.al [8] investigated the stability mechanism of the offshore wind turbine installation jack-up vessel considering the impact of environmental loads and lifting operation. The stability performances of jack-up vessel under lifting operation were analyzed, which include buckling stability of leg, overturning stability and foundation stability.

The WTI vessels will in general be used to carry out repeated weather restricted operations, and therefore it has been established practice to allow for limited design conditions as an alternative to the design and regulatory requirements for vessels used for more continuous operations in the offshore oil and gas sector [1].

Both design philosophies are applicable for wind turbine installation vessels; “mobile units” are assumed to be designed for quick demobilisation and escape to protected waters; “stationary units” are assumed to be appropriately designed to sustain the expected extreme design conditions at location. Offshore wind turbine installation jack-up vessels are shown in Figure 2.

When restricted environmental design conditions are used in the design of vessel, it is emphasized that the design requirements need to be consistent in order to ensure a robust design that is capable to withstand the relevant design loads for all design and operational conditions. Special attention is paid to the ability to demobilize and escape. This paper attempts to address principles, technical requirements and guidance for the design and construction of the units to satisfy Classification Society rules, Coastal State and Statutory regulations [2].

Fig. 2. Offshore Wind Turbine Installation Jack-up Vessel

2 GLOBAL STRUCTURAL MODEL

A global structural model of WTIVs should represent the global stiffness and behaviour of the unit. The hull may either be represented by a detailed plate and shell model or a model using grillage beams. The legs may be modelled by detailed structural models or equivalent beam, or a combination such. See Figure 3.

A detailed finite element model as a local structural modelling should be applied to calculate the transfer of leg axial forces, bending moments, and shears between upper and lower guide structures and the jacking and fixation system. The analysis model should include a detailed model of the leg in the hull interface area, the guides together with the main jackhouse structure.

The vessel should be designed with sufficient ULS capacity for the maximum 100 years storm at location. The elevated condition and jacking conditions are normally governing for legs, jacking system and key parts of the hull / leg interface structure.

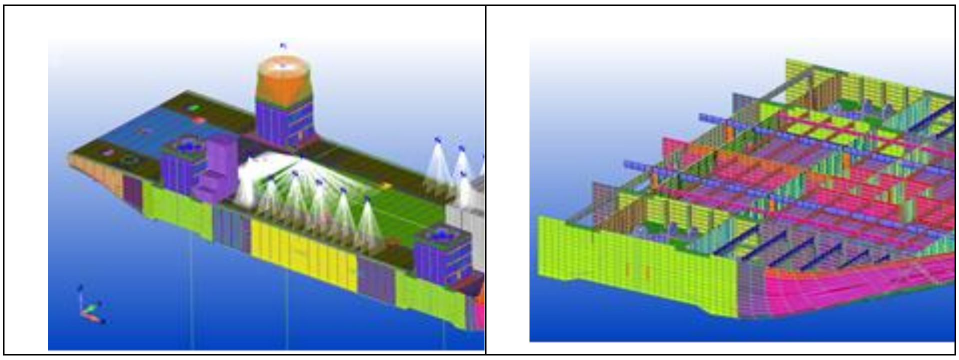

Fig. 3. A Global and Local Structural Finite Element Model, respectively

Ultimate strength capacity check shall be performed for all structural members contributing to the global and local strength of the WTIVs. The structures to be checked include, but not limited to, all plates and continuous stiffeners in the followings such as main load bearing plating in mat and spudcan type footings, all leg members in truss type legs, outer plating in column type legs, jack-house and supporting structure, main bearing bulkheads, frameworks and decks in the hull structure, girders in the hull structure.

It should be noted that the structural strength should be documented for the maximum crane loading for all relevant crane positions in combination with the environmental loading and other functional loads. For the vessels where the crane foundation is built up around one of the leg wells, special attention should be paid to the combine effect of the leg and crane loading at the interfacing structure. Detailed local models are required to document sufficient structural strength in accordance with recognized Class Codes, where dynamic factors and load factors applied to crane pedestals and the supporting structure should be accounted for.

Partially submerged hull position which is reached during installation and retrieval may represent a governing design condition for the legs. A simplified design check should be performed to evaluate the leg utilization during this condition. The results of the analysis such as maximum leg bending moment and maximum vertical reactions will define the directional limiting sea state for the installation phase. The analysis needs to take into account the dynamics effects of the environmental loads, added mass and hydrodynamics forces on the hull and legs.

Corrosion allowance is not required provided that a corrosion protection system is installed and maintained. In other words, given a corrosion protection is implemented, gross scantling may be used in the calculation of hull structural strength.

Buckling strength analysis shall be based on the characteristic buckling strength for the most unfavourable buckling mode. Initial imperfections in the structural members shall be accounted for [1-2].

3 LEG STRENGTH

The boundary conditions for the legs at the seabed shall be varied within realistic upper and lower limits when the scantlings of the legs are determined. The variation in boundary conditions shall take into account uncertainties in the estimation of soil properties, non-linear soil-structure interaction, effects due to repeated loadings, possible scouring, etc.

When determining the forces and moments in the legs, different positions of the hull supports along the legs shall be considered. Lattice-type legs shall be checked against overall buckling, buckling of single elements and punching strength of the nodes. A cylindrical type of leg under construction is shown in Figure 4.

Bottom impact forces occurring during installation and retrieval conditions should also be accounted in the design. Special attention shall be paid to the means for the leg support, the jackhouses, the support of the jackhouse to the main hull, and the main load transfer girders between the jackhouses.

A Failure Mode, Effect, and Criticality Assessment (FMECA) should be carried out to define the control of the jacking system and shall form the basis for the risk assessment. Elements with a low utilization factor imply that the likelihood of failure is reduced.

Fig. 4. A Cylindrical Type Leg Structure

4 FATIGUE ASSESSMENT

Fatigue assessment for the WTIVs should account for all relevant loading conditions such as transit, jacking, and elevated. A sufficient number of load cycles for each condition should be assumed based on the planned operation of the vessel.

Fatigue safety factors applied for wind turbine installation vessels shall be given dependent on the criticality of the detail and accessibility for inspection and repair. Special considerations should be made for the leg in the splash zone, submerged parts legs and spudcan, and possible inaccessible of the spudcans.

The fatigue analysis should focus on members that are essential to the overall structural integrity of the unit. Fatigue susceptible areas may cover such as the leg to hull holding system, the leg members and joints in the vicinity of the upper and lower guides, the leg members and joints in the splash zone, the leg members and joints in the lower part of the leg near the spudcan, the spudcan to leg connection.

The fatigue damage contributions from the operational phases shall be based on an assessment of the expected area of operation and the configuration of the operation with regards to time spent in the various phases such as elevated, transit and jacking. The structure shall be designed for a minimum of 20 years fatigue life based on this assessment.

If an estimation of the operational phase distribution is not made, the minimum requirement for hull fatigue calculations shall be made with the assumption that 50% of operational time is made in worldwide unrestricted sailing. Fatigue effects to the hull resulting from repeated loading during elevated condition should also be considered and accounted for.

5 CONCLUSION

This study focused on the principle design aspects for wind turbine installation jack up vessels. Structural categorization, selection of steel materials and inspection principles in areas of the hull which is not governed by the elevated mode should follow up maritime regime rules. The remaining areas specific to jack-up units should follow up self-elevation regime rules. Fabrication and testing of jacking and supporting system should comply with offshore production standard. The requirements are based on the consideration of the fatigue damage and assessment of general fabrication quality. The inspection categories are related to the structural categories. The inspection category for elements of the jacking and supporting system should be considered separately from any downgrade of the structural category. The level of inspection should be based on the consequence of failure independent of the utilization of the system. It is recommended that assignment of primary and special categories are verified against an overall risk assessment of possible failures of the different components of the hydraulic jacking systems. Failure in one structural element may result in excessive utilization of other parts of the structure or in the hydraulic system, leading to an unacceptable load scenario. All phases such as transit, jacking up / down, and elevated should be accounted for.

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Kinetic Modelling on Catalytic Dehydrogenation of NaBH4 by Hydrogel Based CoF2 Catalyst

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ABSTRACT. In this paper, the dehydrogenation reaction of sodium borohydride ($NaBH_4$) was performed in the presence of hydrogel catalyst. CoF_2 was used as the source of metal to prepare Co-ion loaded poly (acrylamide-co-acrylic acid) hydrogel. Dehydrogenation reactions were performed under three different reaction temperatures, 25, 35 and 45 °C. It was determined that the dehydrogenation reaction time decreased significantly with an increase in temperature. The reactions took place within 27, 18 and 9 hours at 25, 35 and 45 °C, respectively. On the other hand, the yield of the dehydrogenation reaction did not change with temperature and was calculated as 90%. In addition, the relation between the initial concentration of $NaBH_4$ and released hydrogen was investigated at 45°C. The rate constants and activation energy of the reaction were determined by means of related differential equations and graph of lnk versus 1/T, respectively. The activation energy was found as 43,82 kJ/mol and seen compatibility with literature. Furthermore, the pre-exponential factor (A) presented in Arrhenius equation was calculated as $5.38x10^{-3}$ mol L^{-} min^{-}. Dehydrogenation index of $NaBH_4$ was calculated as 2526.31 ml H_2/g $NaBH_4$ according to the amount of $NaBH_4$ in the aqueous solution. Additionally, dried and swollen Co-ion loaded poly(acrylamide-co-acrylic acid) hydrogel catalyst was used to produce hydrogen from $NaBH_4$. The effect of this was investigated to determined reaction time and amount of released hydrogen. It was demonstrated that dehydrogenation of $NaBH_4$ could be controllable according to the reaction temperature and state of the catalyst as mentioned.

Keywords: Sodium borohydride, Dehydrogenation, Hydrogel catalyst, Activation energy, Arrhenius equation.

1 INTRODUCTION

Renewable and alternative energy resources have attracted great attention owing to the fact that fossil fuels will not exist forever. As the demand of the energy and population increase, novel energy resources will be needed. Global warming is also an unwanted situation as a result of consumption of them. It is known that hydrogen is a promising candidate as an environment-friendly energy carrier. Hydrogen can be stored using physical and chemical methods. Chemical bonds (covalent or ionic interactions) between hydrogen and a host compound form relatively safe storage option [1]. Metal borohydrides are the best hydrogen carrier materials due to their non-flammable feature, easy transportation capability of them and producing emission free and high amounts of energy [2]. Recently, most of the studies have been carried out to find out a perfect hydrogen release method from $NaBH_4$. By this way, an uninterrupted energy will be provided feasible for the fuel cells [3]. Principally two techniques are performed to release the hydrogen of $NaBH_4$; thermal dehydrogenation and catalytic dehydrogenation. As hydrogen and water can be recovered, catalytic technique is advantageous. Also, operation cost coming from high-temperature requirement and low yield cause not to prefer thermal dehydrogenation [4,5]. It is seen that investigations have been performed predominantly by using $NaBH_4$ among metal borohydrides to produce hydrogen. Hydrogen can be produced by the reaction between the water and $NaBH_4$ in the presence of a catalyst. In order to obtain hydrogen, an alkaline borohydride solution in water is prepared with its metal hydroxide to prevent sudden hydrogen release. High storage capacities could be achieved on a material basis via metal hydrides because the hydrogen from the hydride besides the hydrogen from the water is liberated [6]. According to the reaction given Eq.(1), theoretically four mol hydrogen was generated from the two of them coming from water and the other from $NaBH_4$.

$$NaBH_4 + 2H_2O \quad Na \xrightarrow[\text{lyst}]{\text{cata-}} + \text{heat} \uparrow \qquad (1)$$

The reaction, dehydrogenation of NaBH4, is exothermic and no heat supply is required. In recent years, researchers prepared a catalyst using a polymeric material as support of metal active sites. These polymers are considerable to make progress the efficiency of the catalyst [7]. Functional groups in the hydrogel networks, such as –COOH, –OH, –SO3H, –SH and –NH2, differ according to used monomers and among them, carboxylic acid groups have been shown to be highly effective. Pt, Pd, Rh, Ru, Co, Ni and their compounds can be used as a metal source to prepare catalyst but Co and Ni have been widely chosen because of their low cost [8, 9].

Previously, we reported for the first time the synthesis of Co-ion loaded poly(acrylamide-co-acrylic acid) (p(AAm-co-AAc)) hydrogel catalyst. According to amounts of cobalt ion, the catalyst was selected and used in the dehydrogenation of $NaBH_4$ reaction. The experimental and theoretical ratio of released hydrogen from 0.0965 g $NaBH_4$ at 25 ºC was found to be 90%. This hydrogel catalyst just had ppm level Co metal active sites and the ratio was pretty satisfactory [9]. In the current study, synthesised and selected p(AAm-co-AAc)-Co ion loaded hydrogel catalyst was employed in the $NaBH_4$ dehydrogenation reactions at three different temperatures to investigate reaction kinetic. The behaviours of the catalyst and the kinetic parameters were studied in details. Also, the effect of dried and swollen hydrogel catalyst usage on catalytic dehydrogenation was observed.

2 MATERIALS and method

2.1 Catalytic Dehydrogenation of $NaBH_4$

Dehydrogenation reactions were performed by using 50 ml 50 mM (0.0965 g) $NaBH_4$ (Merck, purity ≥ 98%) aqueous solution with 0.5 g NaOH (Merck, purity ≥ 98%). It is known that self-hydrolysis of borohydrides must be prevented by using its metal hydroxide. Here, the amount of NaOH is important as mentioned in the literature. Because the hydrogen generation rate increases for lower NaOH concentrations in the alkaline $NaBH_4$ solution and decreases after reaching a maximum value. During the process, pH value remains between 12 and 14 because of the presence of NaOH [10]. It can be inferred that amount of NaOH is arranged according to pH. The aqueous solution was poured into the reactor and then 0.1 g of p(AAm-co-AAc)-Co hydrogel catalyst was added to it. The reactor lid was closed tightly whenever catalyst was placed in the dehydrogenation reactor containing the solution. Released hydrogen was measured with the inverse burette system, as seen in Fig. 1.

Dehydrogenation reaction of $NaBH_4$ occurs according to the Eq. (1) given above. P(AAm-co-AAc)-Co hydrogel catalyst should be washed with water at the end of the reaction. It can help removing borate compounds probably remained on the pores of the catalyst [11].

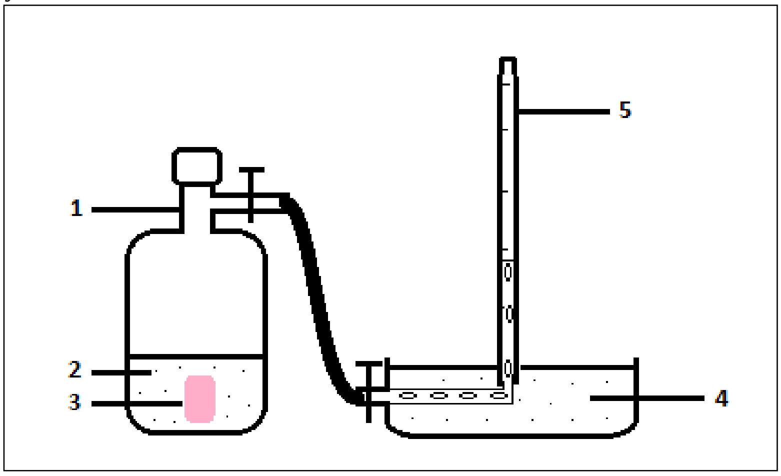

Fig. 1. Inverse burette system: (1) Reactor, (2) $NaBH_4$ and NaOH solution (3) catalyst, (4) water reservoir, and (5) burette.

Theoretically, the amount of released hydrogen is nearly two times more than the stored hydrogen due to hydrolysis in the water. Dehydrogenation reactions were carried out both dried and swollen p(AAm-co-AAc)-Co catalysts to clarify its effect at 45°C. In addition, the effect of the catalyst's surface area was investigated according to measured hydrogen volume. For this purpose, two catalysts which have the same weight and the different surface area were prepared and the amounts of their released hydrogen were compared.

2.2 Kinetic studies

Dehydrogenation reactions of $NaBH_4$ were performed to clarify catalyst's kinetic properties at 25, 35, 45 °C. All of these experiments were performed to find out the reaction rate order and the activation energy (Ea) of the related hydrolysis reaction. P(AAm-co-AAc)-Co hydrogel catalyst was used in each experiment and the amount of hydrogen released was continuously recorded. Furthermore, the pre-exponential factor (A) presented in Arrhenius equation was calculated according to the related equation given below.

$$k = A.e^{-Ea/RT} \qquad (2)$$

While the reactions were occurring at selected temperature, a water bath was used to maintain the constant temperature. Thus, the reaction temperature did not change by the exothermic nature of the hydrolysis reaction. The amounts of released hydrogen of the dehydrogenation reactions catalysed by p(AAm-co-AAc)-Co hydrogel catalyst were calculated for different NaBH4 initial concentrations. Hence, the relation between the initial concentration of the reactant and the amount of released hydrogen was clarified.

3 RESULTS AND dISCUSSION

Recently, studies demonstrate that metal ion loaded hydrogel catalysts have had a pleasant performance in dehydrogenation reactions of metal borohydrides because of their high capabilities to load metal active sites and high catalytic activities [7, 9, 12].

Released hydrogen amounts and reaction times were measured as 225, 230, 240 mL and 27, 18, 9 hours at 25, 35, 45 °C, respectively. When the dehydrogenation reaction of $NaBH_4$ temperature was increased, the reaction time decreased as seen in Fig. (2).

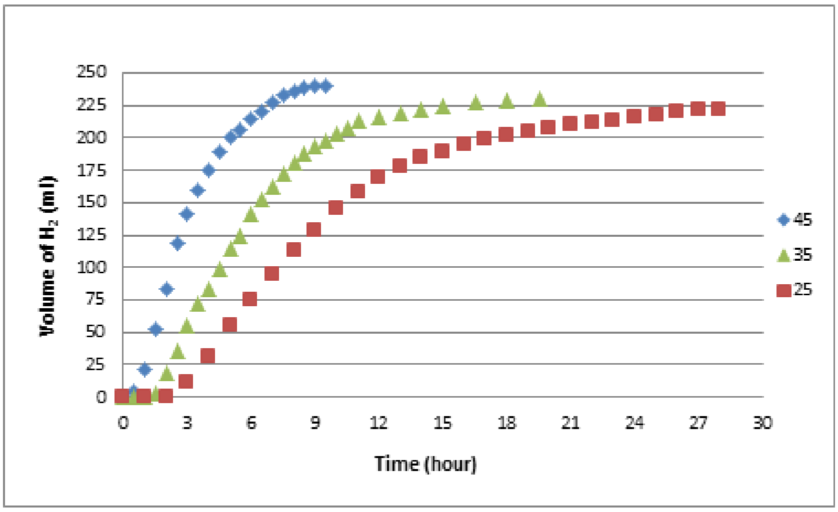

Fig. 2. The effect of temperature on dehydrogenation reaction of $NaBH_4$ (T= 25, 35, 45 °C, 0.0965 g $NaBH_4$, 0.5 g NaOH)

When amounts of theoretically and experimentally released hydrogen were compared, the ratio was found by 90%. $NaBH_4$ was weighted at the inert atmosphere in GLOVE-BOX, so there was an experimental error nearly 5% because of changing in pressure. As a result of this, the yield could be taken by 95%.

In addition, dehydrogenation reaction of $NaBH_4$ was carried out at 45 °C to clarify the effect of surface area of p(AAm-co-AAc)-Co hydrogel catalyst on the production of hydrogen. When two catalysts having 125 and 150 mm^2 surface area but in different size were used, hydrogen was released by 91.0% and 91.2% yield, respectively. It can be inferred that released hydrogen does not depend on their surface area. Besides, hydrogel catalyst was used as dried and swollen, and reaction time was determined as 9 and 25 hours, respectively. Thus, the option of using dried or swollen state of the catalyst can be done by the expectation of its place of use.

It was found that initial amount of $NaBH_4$ and amounts of released hydrogen increased linearly. Specific dehydrogenation rate does not change according to initial amount of $NaBH_4$ so it can be inferred that the reaction rate order is zero. Hence, the differential equation is arranged as given Eq. (3) and (4).

$$-\frac{\mathrm{d}C_A}{\mathrm{dt}} = kC_A^n \text{ , n=0} \qquad (3)$$

$$(C_{A_0} - C_A) = kt \qquad (4)$$

Reaction rate constants were calculated by using Eq.(4). and given in Table 1 at 25, 35, 45 °C. lnk versus 1/T graph as seen Fig. (3) was plotted by using these constant.

Table 1. Data for lnk versus 1/T graphs

T(K)	1/T	k	lnk
298	0.003356	0.000112160	-9.100
308	0.003247	0.000154994	-8.692
318	0.003145	0.000340884	-7.984

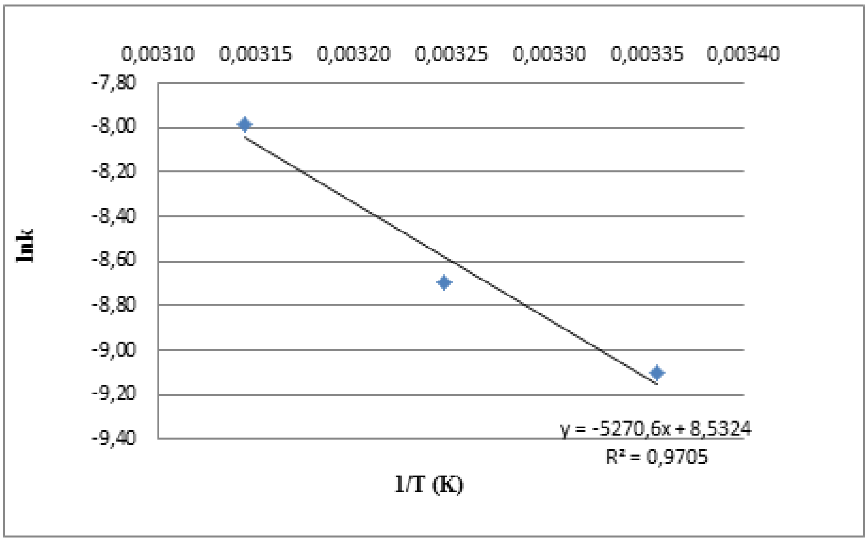

Fig. 3 The effect of temperature on dehydrogenation reaction of $NaBH_4$ (T= 25, 35, 45 °C, 0,0965 g $NaBH_4$, 0,5 g NaOH)

The activation energy was calculated as 43,82 kJ/mol by using the slope of lnk versus 1/T graph. Activation energy is under 50 kJ/mol as it is demanded and compatible with the literature [13].

$$lnk = lnA - \frac{Ea}{R.T} \quad (5)$$

Arrhenius equation was rearranged as given Eq.(5) and pre-exponential factor (A) presented inthis equation was calculated as 5.38x10-3 mol L- min-.

4 CONCLUSION

In this study, dehydrogenation reactions of $NaBH_4$ were carried out at three different temperatures for investigation of kinetic parameters. Here, we reported for the first time hydrogen release characteristic of p(AAm-co-AAc)-Co hydrogel catalyst synthesised and prepared by our previous study via CoF_2 metal source. Dehydrogenation index of $NaBH_4$ was calculated as 2526.31 ml H_2/g $NaBH_4$ according to the amount of $NaBH_4$ in the aqueous solution. As it was informed that reaction rate order was found as zero and activation energy of the reaction calculated as 43,82 kJ/mol. Cobalt metal active sites can be taken away from hydrogel support material in an acidic solution so reusability of these sites is possible. To sum up, this novel catalyst has great potential especially for the generation of hydrogen from metal borohydrides.

5 ACKNOWLEDGEMENTS

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Environmental Effects of the Using Diesohol & Hydrogen in C.I Engine

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Abstract. In recent years, the whole world has begun to understand much more the importance of using alternative fuels. The alternative fuels that are produced from renewable energy source called as green energy. These green energy sources have positive contribution potential to solve current important global problems which are global warming, ozone layer etc. There are wide variety type of alternative fuels, biodiesel, bioalcohol (bioethanol, biomethanol), biomass, hydrogen and natural gas. In this study, diesohol fuel enriched with hydrogen was used in a compression ignition engine. Diesohol consists of 15% ethanol and 85% diesel fuel blend. The simulations were conducted by AVL BOOST program. The effects of hydrogen enriched diesohol fuel on engine emissions were investigated in detail. It is observed that the thermal efficiency was increased with diesohol usage. The results showed that using of this fuel blend was provided significant improvements of exhaust emissions such as CO, CO_2, NO_x, smoke and particulate matter. On the other hand all these improvements were obtained without any reduction in performance values dramatically.

Keywords: Diesohol, Alternative Fuels, Emissions, AVL Boost, C.I. Engine.

1 INTRODUCTION

In recent years, many researchers have investigated alternative fuels that can be used alone or in combination with diesel fuel in compression ignition engines in order to reduce the emission of the diesel engine due to its negative effects on the environment. Along with the fact that the use of ethanol is effective in reducing emissions, it has used just as a fuel additive because of the high production cost of ethanol. In 1970s, the ethanol-diesel fuel blends usage was started to try in South Africa [1]. After a decade, the United States and Germany had continued to investigate ethanol-diesel blends as a fuel in internal combustion engines [2, 3]. The aim of these investigations was about smoke and particle levels in the exhaust [4].

The popularity of hydrogen as an alternative fuel in compression ignition engines is increasing day by day. Because of high self-ignition temperature, hydrogen cannot be used directly as a fuel in diesel engine [5]. On the other hand, hydrogen is the one of the most promising alternative fuels for using with air enrichment method in a non-modified C.I. engine. Because of its gaseous form, hydrogen can be mixed with air homogeneously and this enrichment method provides better combustion with pilot diesel injection. When compared to diesel engines operating with this fuel enrichment and standard diesel fueled engine operations, the hydrogen enriched engine operations were provided the same brake power and higher thermal efficiency [6].

Simulation can be defined as a modeling a proposed or real dynamical system and observing behavior over time. A simulation study is carried out with the aim of examining the behavior of any system and investigating the effects of different parameters on working conditions. In this study, AVL BOOST simulation program was used to model diesel engine and to investigate the effects of hydrogen enriched diesohol fuel blends in modelled engine. The emission results were examined in detailed and given by graphs in the next sections.

2 MATERIALS AND METHOD

The AVL BOOST simulation program is a powerful, one-dimensional consistent simulation program that allows to perform detailed engine modelling in real time. It allows the precise calculations make with the help of the possibility to define the various elements to the finest detail. In this present work, all fuels and elements which are seen in the Figure 1, were defined in detail. Also, all abbreviations and numbers were explained in table 1 [7].

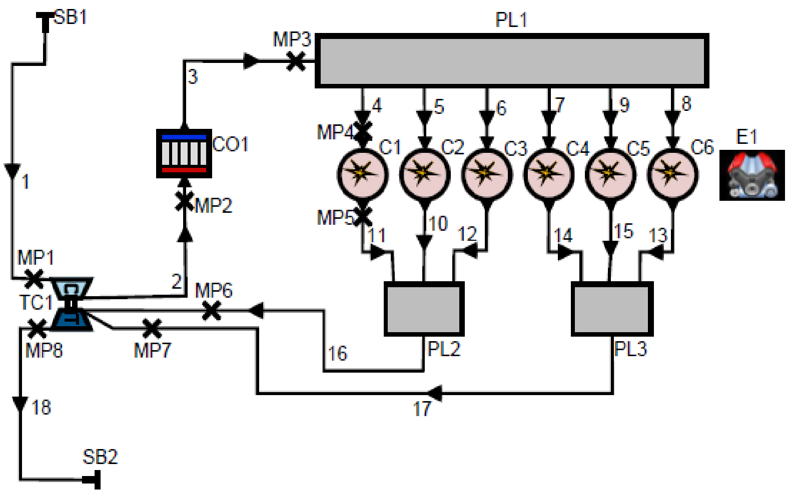

Fig. 1. Diesel Engine Modelled with AVL BOOST

Table 1. Definitions of System

No	Abbreviations	Explanation
1	SB1	System boundary (the beginning of the model conditions were defined in this point)
2	E1	Engine (used for defining of engine specification such as engine speed, stroke type and friction)
3	TC1	Turbocharger (used for conditioning of intake air)
4	CO1	Cooler (used for conditioning of intake air to prepare for combustion process)
5	P1	Plenum 1 (collects enough conditioned air for all cylinders and it was used for intake manifold)
6	C1,C2,..,C6	The engine consists of six cylinders. Cylinders were numbered in the figure 1
7	PL2, PL3	Plenum 2 and 3 (used for exhaust manifold after cylinders)
8	MP1,MP2,..,MP8	Measuring Points (used to see the stability of the system)
9	1,2,..,18	Pipes (used as the connection elements are also numbered from 1 to 18)

In the simulations carried out, the emission values obtained by using diesel fuel were compared with the emission values obtained by hydrogen enriched the diesohol fuel blend without any change to the same engine. In this simulation study, Diesohol fuel blends have consisted of 85% diesel and 15% ethanol fuel mixture. The volumetric ratios of fuel contents are given in table 2 in order to be clearly understood.

Table 2. Volumetric Contents of Fuels

	Diesel (%)	Ethanol (%)	Hydrogen (%)
Standard diesel	100%	-	-
Hydrogenated Diesohol	76,50%	13,50%	10%

3 RESULTS AND DISCUSSION

In this section, all emission results were illustrated in graphs and discussed in detail. This present study, the comparison between standard diesel fuel and diesohol fuel blend included only exhaust emissions. Also, the effects of fuel blends characteristics on the exhaust emissions were explained briefly.

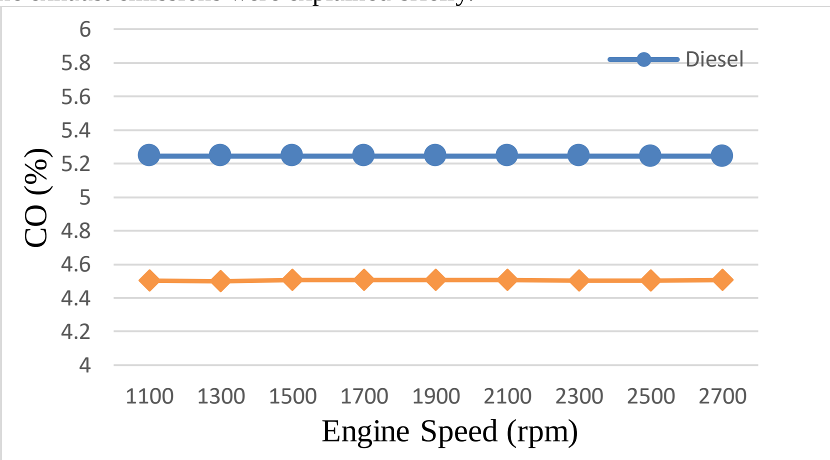

Fig. 2. CO - Engine Speed

Figure 2 is Engine Speed – CO graph. It is clearly seen that the hydrogen enriched diesohol fuel blend caused considerable reduction of CO values. The CO reduction value is 16.42% with respect to standard diesel operation. This result is similar to many studies in the literature. Kumar A.A. mentioned that, the extra "oxygen" content of ethanol provides better combustion characteristic in internal combustion engines [8]. In other studies, the reduction of CO up to 30% can be provided depending on the physical conditions of the engine used [9, 10].

Engine Speed vs. CO_2 graph is shown in figure 3. When compared with standard diesel operation, diesohol fuel blend with hydrogen enrichment has caused slightly less CO_2 release in exhaust emission. It is also supported by many studies in literature. He, B.Q. et al., studied effects of different ethanol blended diesel fuel in compression ignition engine. They reported that the amount of carbon dioxide is decreased by increasing the amount of ethanol. Decreasing of the C/H ratio was shown as the cause of this reduction [11].

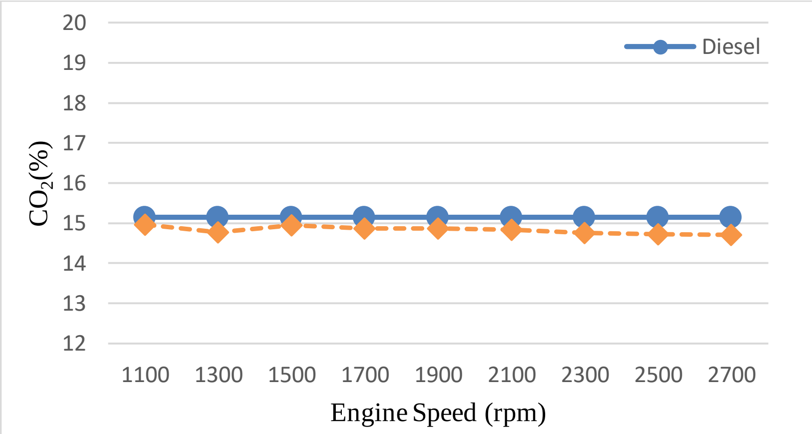

Fig. 3. CO2 - Engine Speed

NOx – Engine Speed graph was illustrated in figure 4. Although NOx emissions have decreased with the increasing of ethanol concentration in diesel fuel, in this study, there was no significant change in NOx level due to the increasing combustion temperature with hydrogen enrichment.

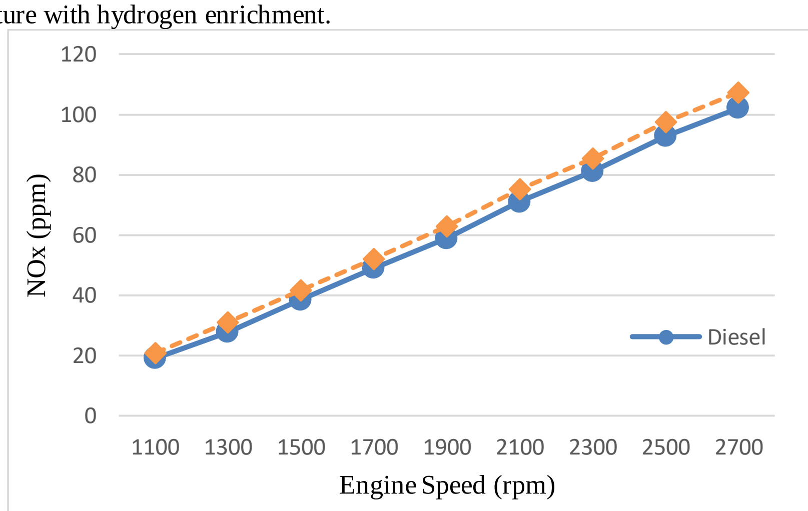

Fig. 4. NOx - Engine Speed

4 CONCLUSIONS

This paper presented an overview of using ethanol with %15 volumetric ratio with diesel fuel (diesohol), meanwhile hydrogen gas fuel has supplied to the combustion through the intake manifold. AVL-BOOST simulation software was used for this theoretical study. Overall results of this study indicate that hydrogen enriched diesohol usage has very promising exhaust gas emissions. Also experimental study may be conduct to provide comparison between theoretical and practical results.

Hydrogen enriched diesohol fuel mixture improved the engine emission characteristics such as CO, CO2 except NOx. It is believed that hydrogen caused higher combustion temperatures which lead higher NO emission. Beside, overall improvements were 16.42% and 2.01% for CO and CO2, respectively. Using ethanol blends in biodiesel fuels can be subject for future studies.

5 ACKNOWLEDGEMENTS

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Assessing the Energy Management Performance of Turkey: An Integrated MCDM Approach

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Abstract. Energy is a major input for national economies. Using energy efficiently gains importance because of the diminishing resources. Therefore, efficiency in energy utilization is a hot topic and the researchers are focusing on alternative fuels and various technology options for conversion, distribution, and end user's operating environment processes. Energy utilization by more efficient technologies and processes is growing in importance in many countries. While the societies are continuously searching for alternative pathways for the "sustainable economy" idea, the management factor is getting considerably important within each phase of energy related activities. Using energy efficiently requires good management and this is particularly important for Turkey.

In this paper, the energy management performance of Turkey is analyzed using a integrated multi-criteria decision making approach and compared with the performances of a panel of OECD countries. Four major indicators, i.e. GDP per capita, total primary energy consumption and total primary energy production per Dollar of GDP, and total CO_2 emissions are considered. Our results show that, Turkey displays a low performance compared to the other countries in analysis scope. The results can be encompassed by in-depth analyses and long-term plans to shift the country's energy technology selection strategies to more efficient, cost-effective and cleaner options.

Keywords: Energy management, Multi-criteria decision making, AHP, TOPSIS.

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1 INTRODUCTION

Energy is an essential part of daily life, and issues related with energy concern many people around the world. In specific, changing global trends, rapidly rising energy consumption rates, and fluctuating high energy prices have been the main concerns for societies and stakeholders. As discussed by Ayres et al [1], energy has a significant role in economic growth, and there is plenty of evidence that supports the view that energy will severely constrain future economic development. In industrialized countries, efficient management of energy supplies and rational use of energy and energy-related products are key requirements for economic growth. Therefore, management of energy and energy-related issues is of high interest at both strategic and operation levels for all stakeholders.[2]

In this study, we consider the energy management performance of nine OECD (Organization for Economic Co-operation and Development) countries, viz. Canada, France, Germany, Greece, Italy, Japan, Spain, Turkey and the United Kingdom, who constitute the world's major greenhouse gasses (GHG) emitters. Among those countries, Turkey has a strategic geographical position, which offers an energy bridge between the rich natural resources of the Middle East and Central Asia and the suppliers of the Western world. Turkey also has strong ties to rest of the world through its OECD membership. However, having an energy intensity level twice that of the OECD countries, and an energy consumption per capita one-fifth that in OECD countries [3], Turkey has to undertake a number of tough tasks and has to apply effective energy policies to attain energy conservation targets and improve energy efficiency. For those reasons, we focus on Turkey and build the structure of our performance analysis on an analytic basis, which incorporates a number of key indicators and parameters [4].

It turns out that, the relationship between the health of a country's economy and her energy management performance is strongly related to a number of key indicators and parameters. Among those, the Gross Domestic Product (GDP) is one of the primary parameters, and it represents the monetary value of all commodities produced over a specific period of time. Hence, in economic analysis studies, GDP is mostly used for comparing the economic growth of a particular period of time within previous timelines.

Economic production and growth affects the GDP and creates a remarkable impact on every sector in national economies. In countries with healthy economies, it is expected to observe low unemployment levels and relatively higher or lower wage increases as businesses demand labour to meet the growing economy. A significant change in GDP to a negative or positive direction has also a significant effect on the energy sector, including the prospective decisions about new investments and fixed or variable operation and maintenance costs. The established country or community targets should play a leading role in the complex economic process of energy consumption, and the emerging economies have to consider their implications while forming the energy policies at the national level [5].

On the other hand, climate change and global warming have been other main trending topics in late decades originated by GHGs emitted during energy producing and consuming processes. Countries are now developing their energy policies under these primary constraints of power generation, consumption, and GHG mitigation, as well. The emissions of the ten OECD counties who constitute the world's major GHG emitters account for nearly two-thirds of total emissions. This proves their significant and direct effects on global energy expenditure and the global environment. Relevantly, Turkey has recorded GHG emissions in an increasing trend simultaneously with her economic growth and expanding industry [6].

To assess the energy management performance of Turkey with respect to other OECD countries, we considered four major indicators:

6. GDP per capita,
7. Total Primary Energy Consumption per Dollar of GDP,
8. Total Primary Energy Production per Dollar of GDP,
9. Total CO_2 Emissions.

We further categorized the criteria under three major domains as:

10. Economic Performance (GDP),
11. Energy Performance (energy consumption and production),
12. Environmental Performance (CO_2 emissions).

An increase in the numbers of alternatives and criteria makes it difficult to assess the alternatives and make a rational decision. Thus, in this study, we applied an integrated Multi-Criteria Decision Making (MCDM) methodology.

MCDM is a discipline that explicitly considers multiple criteria in decision-making environments. They are used to assess alternatives versus selected criteria through a group of decision makers, where the suitability of alternatives versus criteria and the importance weights of criteria can be evaluated. They are frequently used to solve real-world problems in the presence of multiple, conflicting, implicit or explicit and incommensurate criteria [7,8]. Our hybrid methodology incorporates two widely-used MCDM techniques, Analytic Hierarchy Process (AHP) and TOPSIS, to determine the energy management efficiency rankings of the selected ten OECD countries. Our analyses utilize related data ranging from 2001 to 2014.

The organization of the paper is as follows: A literature review is provided in Section 2. The integrated MCDM methodology and numerical results obtained are given in Section 3. Sections 4 and 5 include a discussion and conclusion of our work, respectively.

2 LITERATURE REVIEW

Applications of MCDM techniques are popular in the energy domain. For example, Yan et al. use TOPSIS to evaluate the performance of coal enterprises in terms of energy conservation and reduction of pollutant emissions [9]. In a recent study, Shirazi et al. utilize TOPSIS to determine the best solution among a set of Pareto-optimal solutions with respect to the design parameters of an ice thermal energy storage system [10]. Guo et al. use Data Envelopment Analysis (DEA) for evaluating the carbon emission performance in Chinese provinces [11]. Some other examples include; the use of AHP for an assessment of energy source policy [12], VIKOR for selection of energy resources [13], Goal Programming for the optimal location of renewable energy facilities [14]. An extensive literature review of MCDM applications in the energy domain can be found in [15].

In our analysis, we use AHP to create the weights for each criterion, and use TOPSIS to determine the relative rankings of the countries in scope. Among the MCDM techniques in the literature, AHP is the most popular technique used for prioritization purposes. It is applied to a wide range of problems especially in engineering, education and manufacturing fields. The technique basically allows decision-makers to evaluate alternatives with respect to several criteria by pairwise comparisons. Using matrix operations, it provides the decision-maker with a weight vector for alternatives that represents their relative importance.

On the other hand, TOPSIS distinguishes the best alternative among a finite set of alternatives by a series of mathematical operations. TOPSIS first introduces two “reference” points named as the negative and positive ideal solutions. Next, it selects the alternative that is the farthest from the negative and closest to the positive as the best decision. It performs normalization to degrade all data into same scale. The closeness values among alternatives are measured with linear metric (Euclid distance) values of their criteria.

3 PROPOSED METHODOLOGY AND RESULTS

3.1 Integrated MCDM

In this paper, we integrate two well-known MCDM techniques; viz. AHP and TOPSIS, into a single application to attain a higher level of confidence in our decision problem. Our methodology comprises of three steps. First, we define the problem and develop the framework. For this reason, we (1) state the available alternatives to be evaluated, (2) determine the assessment criteria with the help of expert opinions, and (3) state the objective of our decision problem.

Next, we establish the hierarchy between the goal, alternatives, and criteria. Then we implement AHP to determine the criteria weights. These weights form a basis to our solutions in the next stage. Although AHP may be employed to solve the entire decision-making problem, in this study we integrate this method to TOPSIS to provide the criteria weights.

Finally, using the criteria weights, we solve the decision problem with TOPSIS. After evaluating the model results, the alternatives are ranked with respect to expert opinions.

3.2 NUMERICAL RESULTS

Step-1.
Our indicators are briefly described as follows:

GDP (Economy Domain): GDP estimates are mostly used to measure the economic performance of a country. GDP stands for the monetary value of the final commodities, namely goods and services, produced in a country and bought by the end user. GDP counts all of the output generated within the borders of a country, including some non-market productions, such as defence or education services provided by the government.

Total primary energy production and consumption per Dollar of GDP (Energy Domain): Primary energy (non-renewable or renewable) is a form of energy found in nature that has not been subjected to any transformation process. As an important indicator, per capita energy use is the efficiency of energy use. A commonly used indicator of energy efficiency is the energy produced and used per GDP produced by an economy. The large difference in energy efficiency of high-and low-income countries reflects the large difference in access to technology. It is however encouraging to see the trend of increasing efficiency of low-income countries in the past decade.

Total CO2 emissions (Environment Domain): CO2 is the primary greenhouse gas emitted through human activities. The environmental effects of CO2 are of significant interest. While CO2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution (NRC, 2010). Many countries have attempted to reduce CO2 emissions by using a direct and an indirect method because CO2 emission may lead to climate changes. Climate change negatively affects economic growth.

Step-2

In this step, we carried out pairwise comparisons to determine the relative importance of each criterion toward the others. For this purpose, three experts expressed their preferences by assigning a numerical value from the AHP intensity table used in pairwise comparisons presented in [17]. The results indicate that the criterion “economy” is the most important one with a weight of 0.58. It is followed by “energy” and “environment” with a weight of 0.23 and 0.19, respectively. Hence, “economy” should be the main concern in ranking the performances of the countries. “Primary Energy Production” and “Primary Energy Consumption” end up with equal weights of 0.50, which mean that have equal importance.

Step-3

We now apply TOPSIS techniques to compare and rank the selected countries. Using the weights obtained in Step 2 as an input, the final energy management performance weights of the countries computed for each year between 2001-2014 are displayed graphically in Figure 1.

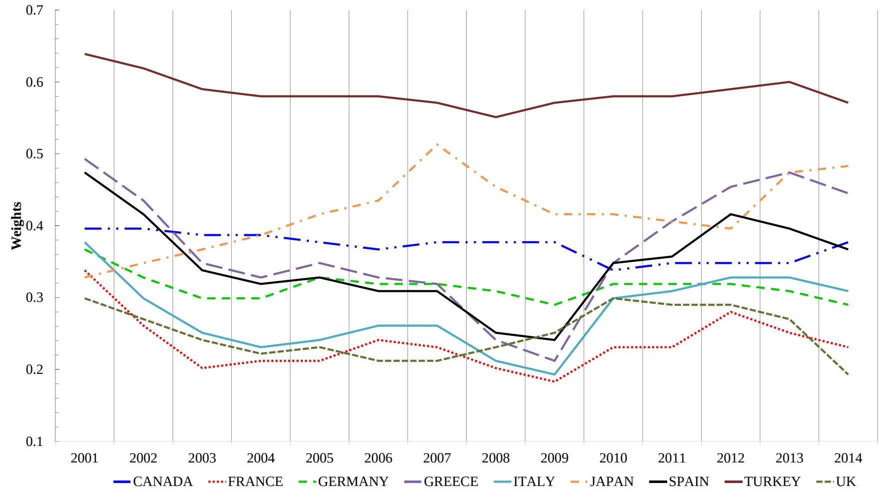

Fig. 1. Relative weights of the countries with respect to their overall energy management performances for years 2001-2014 computed by TOPSIS.

Based on the relative weights displayed in Figure 1, Figure 2 illustrates the rankings of the countries in the selected time domain computed by TOPSIS.

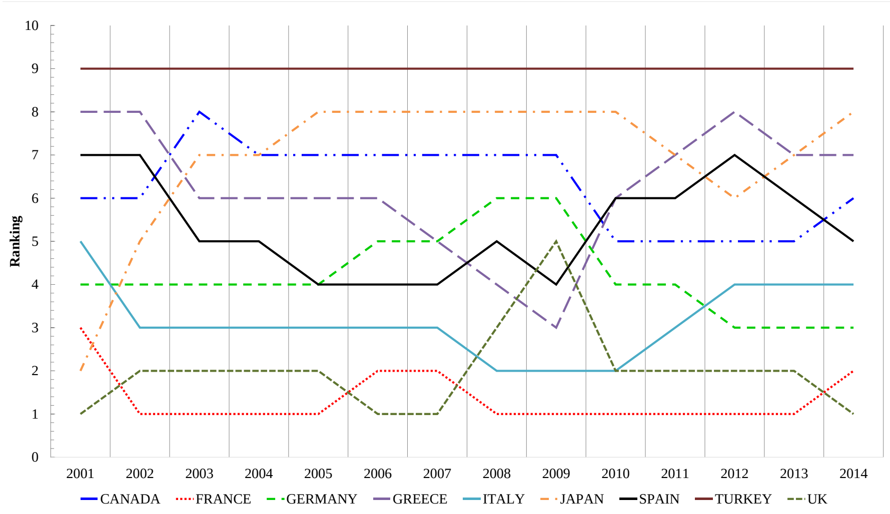

Fig. 2. Relative rankings of the countries with respect to their overall energy management performances for years 2001-2014 computed by TOPSIS.

4 DISCUSSION

Figure 1 illustrates the TOPSIS weights of these countries. Smaller weights indicate better performances. UK has the highest performance in weights with the smallest final weight. A similar result came out for France, with a decline starting from the year 2012. Figure 2 illustrates the relative ranking of the countries in the selected time period in the order as: UK, France, Germany, Italy, Spain, Canada, Greece, Japan and Turkey. This ranking can be taken as; these countries have managed their energy production-consumption levels in this order depending on their total income and CO_2 emission levels.

As noted, Turkey is positioned at the bottom-line of the figure among these countries regarding the performance, which should be evaluated in economic, environmental and energy-related aspects. Turkey; with the world's 17th largest nominal GDP; which changed from 196 B USD (2001) to 798.8 B USD (2014); and 15th largest GDP per capita; which changed from 3053.9 USD (2001) to 10303.7 USD (2014) is defined as one of the world's newly industrialized countries by economists and political scientists. While many economies have been unable to recover from the recent global financial recession, the Turkish economy expanded by 8.5 percent in 2011, thus standing out as the fastest growing economy in Europe and one of the fastest growing economies in the world.

According to data taken from Turkish Statistical Institute, total power installed capacity has evolved from 28.3 (2001) to 69.52 GW; gross energy production has evolved from 122725 (2001) to 251963 (2014) GWh and net consumption has changed from 97070 (2001) to 207375 (2014) GWh in Turkey. These numbers mean that, Turkish energy system has recorded 145.65% growth in total installed energy production capacity, 105.31% growth in gross energy production and 113.63% increase in net energy consumption within thirteen years, while the gap between energy production and consumption has accelerated the energy imports in this period. Turkey’s energy demand growth has increased along foreign energy dependency in analyzed time domain. However, this composition of energy consumption and the economic growth is highly coupled.

Over the past decade, Turkey's economy expanded, and its petroleum and other liquids consumption have increased. With limited domestic reserves, Turkey imports nearly all of its oil supplies. Turkey, which imports the majority of its oil, natural gas, and hard coal supplies, is reportedly expected to double energy demand over the next decade.

From energy-related environmental point of view, CO_2 emissions changed from 217 to 317 million metric tons in 2001 and 2014, respectively. This significant amount of increase in CO_2 emissions is a result of growing energy consumption; but still needs in-depth analyses and long-term plans to shift the country’s energy technology selections to more efficient, cost-effective and cleaner options.

5 CONCLUSION

In this paper, an integrated MCDM methodology is applied to evaluate Turkey's energy management performance while seeking the interrelation in terms of energy, economy, and environmental pollution concerns. To evaluate the energy management performance of Turkey, four major indicators are considered: GDP per capita, total primary energy consumption with total primary energy production per Dollar of GDP, and total CO_2 emissions. The criteria is categorized under three major domains: economic performance (GDP), energy performance (energy consumption and production), and environmental performance. When the combined MCDM methodology is applied, the results give a low profile for Turkey in terms of economy, energy production/consumption and contribution to climate change combat air pollution.

While realizing its recent growth in the last decade, in particular between the years 2010 and 2011, more than 8% annually, Turkey's oil consumption grew with this economic expansion. However, then, economic growth slowed in 2012 and Turkey's economy only grew at just over 2% from the previous year, total consumption of liquid fuels in Turkey increased by 6% in 2012. Turkey's economy grew by 4% over 2013, and total consumption of liquid fuels in Turkey grew by another 6% in that year. Its domestic production, however, shows no signs of any significant growth in the short term. More than 90% of crude oil consumption and substantial quantities of petroleum products came from imports in 2013. In addition to crude oil imports, Turkey is a net importer of oil products.

With this highly import-dependent energy sector profile, Turkey needs to encompass her future moves with a more domestic-oriented energy supply strategies in order to decrease the import share. Alternatively, while energy demand increases, new investments should be preferred by the cleaner options, both in fuel types and the process or conversion technologies. Renewable energy supply options can support the base load and contribute the total CO_2 emission reduction efforts in a positive manner.

Recent big investments in wind and solar industries trigger the promotions on renewables in Turkey, and encourage the investors for future projects, while legal subsidies on domestic technology contribution to renewable energy systems and technologies will positively affect the research and development efforts and budgets in the country.

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Achieving A 100% Renewable Energy Economy, A Multidımensional Approach to Renewable Energy Financing

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ABSTRACT.A successful transition from a Fossil Fuel to a Renewable Energy economy requires a high level of investment from governments and other stakeholders. However, the situation becomes challenging when administrations have limited resources that have to compete with different programmes.

When these decisions are left to governments, due to the nature of the problem, those in office usually consider time inconsistent policies (policies that serve the population in the short term but miss long term goals).

Our approach to the issue, addresses the problem of competing resources and how governments can achieve the transition without causing a heavy burdened to their treasuries. The solution encompasses a combination of different financial platforms, where the risk associated with an investment of this magnitude is spread among all stakeholders.

We achieve this, by combining such platforms as Enhanced Revolving Funds, together with a Grid Tied Utility Assisted Model, Public Private Partnerships, Community Solar, Diaspora Bonds and third party ownership in all its different formats.

We believe that by addressing the problem from different fronts, using a portfolio management approach combined with an optimization process when putting together these different platforms, governments can make this transition without the trauma caused by allowing simply taking the full load.

Keywords: Public Private Partnerships, Diaspora Bonds, Gross Domestic Product.

1 INTRODUCTION

For decades’ governments have been faced with the question of how making their economies grow. In their work Finn E. Kydland and Edward C. Prescott, depict what governments tend to engage in, when trying to serve the needs of the population in the short and long term.

Case in point, when faced with limited resources, governments tend to engage in **"Time Inconsistent Policies"**[4], policies that serve the needs of the population in the short term. Creating a cycle that only serves their political needs; creating situation that expose their economies to boom and bust scenarios.

So what can governments do to break the cycle? The answer is not simple, for over thirty years, economies around the world through the use local and continental trade agreements expanded their Gross Domestic Products. However, this did not improve the distribution of wealth.

This raises the question, why the deterioration of the GINI Index? Our response, as indicated by **Joseph Stiglitz**[5], is that the wealth created did not trickle down to rest of the population as originally thought. Understanding that the element necessary to creating wealth in all sectors of the population and allowing sustainable growth comes from increasing aggregate demand.

One way of creating and increasing aggregate demand is establishing a Renewable Energy industry in the Distributed Energy Resources format. However, governments must understand that the transition from having an economy powered by fossil fuels to different forms of renewable energy is a costly exercise. Having said this, putting together a program to allow a smooth transition, requires the input of all members of society and addition to having a multidimensional approach.

In developing a program with such scope, requires the incorporation of different financial platforms which we will describe in the following sections.

1.1 Grid Tied Utility Assisted

Over the years research has shown that the development of a strong Solar Electric Generation Industry is tied three basic elements[6]:

- Disposable Income,
- Having a Legislation to Support the Industry,
- Levelized Cost of Electricity that will allow the penetration of Photovoltaic.

Grid Tied Utility Assisted Model, due to its nature, offers a co-generation alternative to utilities. In this co-generation arrangement, the Utility offers the PV systems in the form of a rental or lease at the current tariff. The subscriber provides the space for the unit or units; the Utility provides the installation and sale of electricity power by leasing the power generating system where the homeowner pays the Utility the rate currently applied.

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[4] Kydland, Finn., and. Prescott, Edward C. 1977. "Rules Rather than Discretion: The Inconsistency of Optimal Plans." Journal of Political Economy 87, pp. 473-492.

[5] Source: Inequality and Economic Growth, Joseph E. Stiglitz, Version of Record online: 22 JUL 2016. DOI: 10.1111/1467-923X.12237. © The Author 2016, 1.

[6] Ignacio R. Smith and Sherry McMillan, 2011, "Paradigm Shift, The Utility Assisted Model, Bridging the Gap for Renewables in the Caribbean and Latin America", Symposium Small PV - Applications, June 2015.

Because the equipment is leased to the property holder, the excess power goes back to the grid at no benefit to the homeowner. This cogeneration arrangement permits the gradual adjustment of rates, while reducing inflationary fears7.

1.2 Enhanced Revolving Fund[8]

An Enhanced Revolving Fund is a mandatory contribution imposed on the industries that account for at least seventy percent (70%) of the GHG emissions released, in the form of pigovian tax. The program mirrors a trust fund that will use these contributions to finance small distributed generation projects.

1.3 Diaspora Bonds[9]

As the name implies, "these are debt instruments to raise financing from the overseas Diaspora." Diaspora financing and/or Diaspora bonds are a very creative way to structure a deal for any country with a not so favourable credit rating, or macroeconomic structural problems and other hurdles.

1.4 Community Solar

Another model that has gained a lot of acceptance in recent years has been the creation of co-operative by communities with the purpose of using their pooled resources to provide electricity to their community members.

1.5 Public Private Partnerships

This is an arrangement between a government or government agency and a private enterprise to undertake an infrastructural project. The most commonly types of Public Private Partnerships are: Design Build Operate, Design Build Operate, Design Build Finance Maintain Operate.

1.6 Mobile Money Financing

It is a financial platform adopted in different parts of the world, where a great part of the population does not have access to banking products. This form of banking is structured around the use of cell phones as a vehicle for making payments and money transferring.

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[7] Ignacio R. Smith and Sherry McMillan, 2011, "Paradigm Shift, The Utility Assisted Model, Bridging the Gap for Renewables in the Caribbean and Latin America", Symposium Small PV - Applications, June 2015.

[8] Ignacio R. Smith and Sherry McMillan, 2014, "Enhanced Revolving Funds, Developing a Solar Energy Industry in the Caribbean and Latin America" IRENEC, Istanbul Turkey.

[9] Diaspora Bonds - Dilip Ratha www.dilipratha.com/index_files/DiasporaBonds-JICEP.pdf

2 METHODOLOGY

We begin by developing a linear programming model to establish different points in the optimal frontier (Figure 1.)

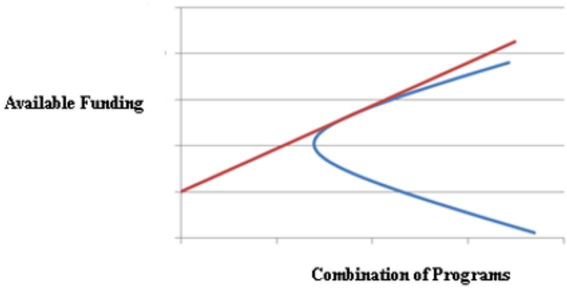

Figure 2.

Where maximum penetration can be expressed as (equation (1) and equation (2):

Max Total PV Penetration: Max: $\sum$ cixi = c1x1 + c2x2 + ………………+ cnxn (1)

Subject to: c1x1 + …………………………………… + cnxn < m1 (2)

. .

. .

. .

Cmxm + ……………………………………+ cnxn < mn

Once an optimal frontier is established, we then look at the time frame in which the program is to be executed. We expressed the deployment of these resources as a function of the countries resources in US$ per global hectares per capita per time (equation 3 and equation 4).

F(G,t) is: X (3)

$\iint_0^\infty f(g,t)dxdt$ (4)

3 CONCLUSIONS

The deployment of resources to allow maximum penetration of Distributed Energy Resources in the form of Solar, must be planned in a manner, that allows the incorporation of all stakeholders in an effort that will let a smooth transition, while at the same time providing a platform that permits sustainable growth.

The establishment of an optimal frontier provides stakeholders with the menu of options which allows decision makers to select the best options available. This will increase aggregate demand, creating new jobs and allowing the expansion of the country's Gross Domestic Product.

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The Affecting Factors of PV Efficiency and Applying FMEA Method

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ABSTRACT. Solar panels have rapidly become a vital part of the global renewable energy for added electric capacity worldwide. The most important stage of the operation management is the determination of the operation risks of the solar panels. This study can offer be spoke risk analysis evaluation cover for operational phase the solar project for an installer, investor or funder or PV project manager. Operational all risks are typically written of an all risks of physical loss or damage basis on either an annual or per project basis. This study is tailored the risk analysis evaluation to meet the specific needs of the PV panels' operation. There are several methods of risk analysis. In this study, Failure Mode and Effect Analysis (FMEA) is used to define the errors and dangers in the system. Also, this study can detect the accidents formerly different from the other risk analysis methods. Questions were to be asked in order to understand the risk for operation of the PV panels.

Risk management was made with the FMEA method which errors and measures have been identified and risk priority numbers are listed in this study. It has been carried out to determine the risk priority number via the values of emergence, weight and determining the values of detection. With the implementation of identified priority measures new risk calculation of the value of the number reviewed in this study results. All of the results and definitions are given by the tables. The analysis of all the results represent that FMEA method is a suitable technique to define the errors and dangers in the system without causing any accidents and to make them better by starting from the top priority of them.

Keywords: Solar PV Panel, Risk Analysis, Failure Mode and Effect Analysis (FMEA) Method

Nomenclature

FMEA : failure mode and effects analysis

PHA: Preliminary Risk Analysis and Risk Matrices

HAZOP: Hazard and Operability Studies

FTA: Fault Tree Analysis	
ETA: Event Tree Analysis	
CCA: Cause-Consequence Analysis	
MORT: The Management Oversight and Risk Tree	
RPN	: Risk Priority Number
S	: Severity
O	: Occurrence
D	: Detection

1 INTRODUCTION

The statistical approach provides the solution that the exact solution to be found to allow when the degrees of freedom (factors and parameter dependency of solar panels) creates a stack as big or not in a classical system. In physics, entropy is a thermodynamic term that represents the thermal energy it cannot be turned into mechanical work of a system. In physics, entropy of a system is a thermodynamic term that represents the thermal energy it cannot be turned into mechanical work. This is often defined as irregularity and randomness in a system. The disorder in the system increases as entropy increases. So, this reduces the amount of useful energy of the system. Hence the randomness and disorder concept in the system exhibit the concept of error that have to be taken into consideration. Several error analysis methods have been developed for improvement of the systems' quality [1].

The focus of identifying and analyzing the risks may be due to a variety of such as customer requests, warranty and service costs, and requirements, as shown in the Figure 1. Definition of risk accommodates uncertainties. Objectives of risk management; risk measures to evaluate and ensure the implementation of these measures to identify and find their focus [2].

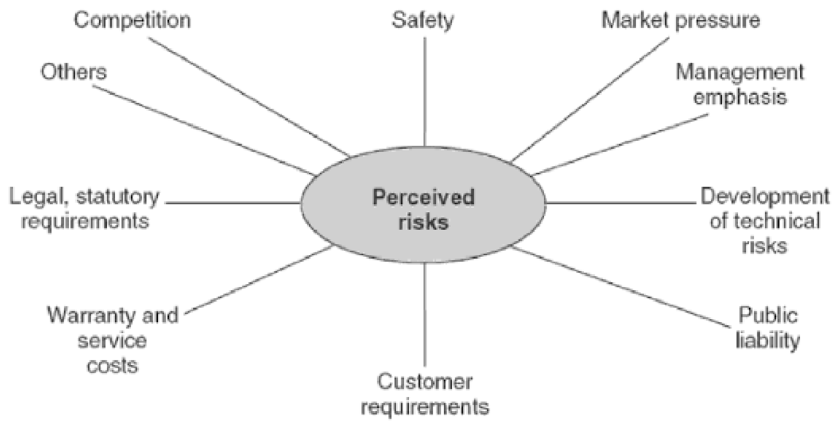


Fig. 1. Leading parameters of risk perception

The risk analysis has a fundamental purpose of answering two questions which are listed such as what can go wrong? and If something does go wrong, what is the probability of happening? and what is(are) the consequence(s)?. This study concentrates on the issue of risk elimination by focusing on the failure mode and effect analysis (FMEA). FMEA is a specific methodology to evaluate performance and efficiency of the system with respect to the failures (problems, errors, risks, etc.) can occur. Risk analysis methods can be classified in two categories such as qualitative (nontechnical) and quantitative (technical) [3, 4, 5, 6].

13. Qualitative Risk Analysis:

- PHA: Preliminary Risk Analysis and Risk Matrices
- HAZOP: Hazard and Operability Studies
- FMEA: Failure Mode and Effect Analysis

14. Quantitative Risk Analysis:

- Static Analysis: FTA: Fault Tree Analysis, ETA: Event Tree Analysis, CCA: Cause-Consequence Analysis, MORT: The Management Oversight and Risk Tree,
- Dynamic Analysis: Diagraph/Fault Graph, Markov Modeling, Monte-Carlo Modeling, Dynamic Event Logic Analytical Methodology, Dynamic Event Tree Analysis Method, “What If” Analysis, TOR: Technique of Operations Review

To evaluate the risk for solar panels, four main questions will be answered with the flow diagram as shown in the Figure 2. These four questions are listed below:

i- What is the dangerous/hazard sources in the PV panel?

ii- What is the probability of occurrence of the hazards? Is it the most serious of all failures effect for the PV panel?

iii- Is hazard result acceptable level, or not for the PV panel? It must be handled with hazard analysis, failure and critical analysis. What problems are affected yield?

iv- How can reduce the risk parameters? What type of testing is available for PV panel? Is the testing appropriate for PV panel? Is corrective action actively pursued?

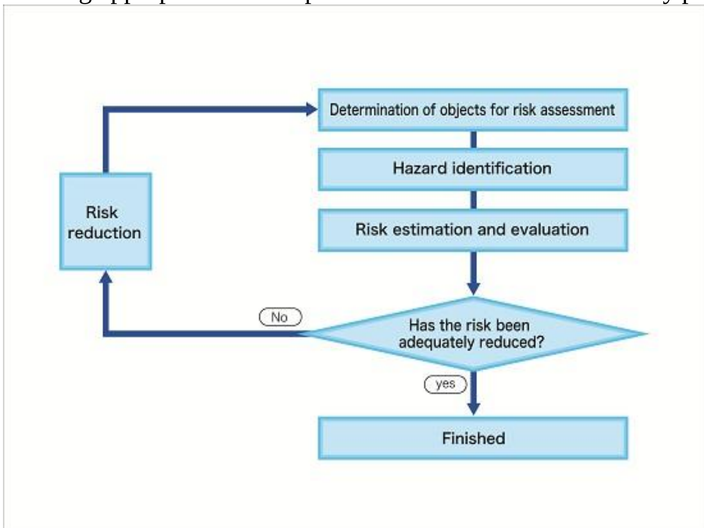
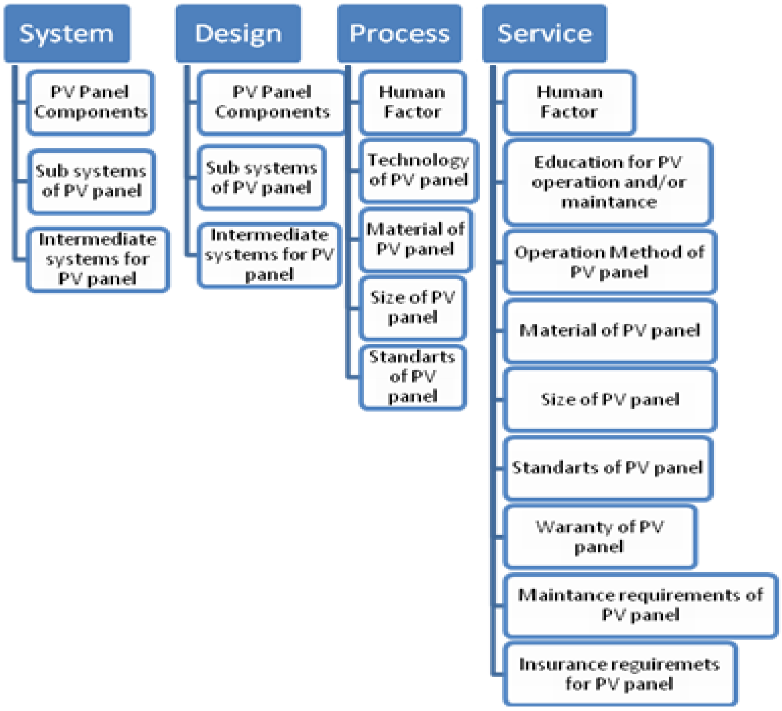


Fig. 2. Risk evaluation diagram [7]

2 FAILURE MODES EFFECTS ANALYSIS (FMEA)

By definition, FMEA becomes a systematic technique using engineering knowledge, reliability and organizational development methods. For solar collector performance / efficiency evaluation, FMEA teams to optimize the system, design, process, product, and/or service. Table 1 represents the relationships of FMEA types.

Table 1. FMEA types and their relations



FMEA application is started by first step of definition of failures and their probabilistic effects and also their priorities. There are three main factors in determining the priorities error in definition of RPN value, where, the risk factors occurrence (O), severity (S) and detection of a failure mode (D) [7]. As all as, each of the three risk factors is evaluated by FMEA team members using a 1 to 10 numeric scale, as expressed in Table 2.

Table 2. Traditional FMEA scale

	Traditional FMEA scale for occurrence (O)		**Traditional FMEA scale for severity (S)**		**Traditional FMEA scale for detection (D)**	
Rating	Probability of failure	Possible failure rate	Effect	Severity of effect	Detection	Likelihood of detection
10	Extremely high: Failure almost inevitable	≥1/2 (≥316)	Hazard-ous without warning	Highest severity ranking of a failure mode, occurring without warn-	Absolute uncertainty	Potential occurring of failure mode cannot be detected in concept, design and process FMEA / mechanism and ubsequent failure mode

				ing and consequence is hazardous		
9	Very high	1/3 (316)	Hazardous with warning	Higher severity ranking of a failure mode, occurring with warning, consequence is hazardous	Very remote	The possibility of detecting the potential occurring of failure mode is very remote / mechanism and subsequent failure mode
8	Repeated failures	1/8 (134)	Extreme	Operation of system or product is broken down without compromising safe	Remote	The possibility of detecting the potential occurring of failure mode is remote, subsequent failure mode
7	High	1/20 (46)	Major	Operation of system or product may be continued but performance of system or product is affected	Very Low	The possibility of the detecting is very low / mechanism and subsequent failure mode
6	Moderately high	1/80 (12.4)	Significant	Operation of system or product is continued and performance of system or product is degraded	Low	The possibility of detecting the potential occurring of failure mode is low /mechanism and subsequent failure mode
5	Moderate	1/400 (2.7)	Moderate	Performance of system or product is affected seriously and the maintenance is needed	Moderate	The possibility of detecting the potential occurring of failure mode is moderate / mechanism and subsequent failure mode

4	Relatively low	1/2000 (0.46)	Low	Performance of system or product is small affected and the maintenance may not be needed	Moderately high	The possibility of detecting the potential occurring of failure mode is moderately high/mechanism and subsequent failure mode
3	Low	1/15000 (0.063)	Minor	System performance and satisfaction with minor effect	High	The possibility of the detecting is high / mechanism and subsequentfailure mode
2	Remote	1/15000 (0.0068)	Very minor	System performance and satisfaction with slight effect	Very high	The possibility of the detecting is very high/mechanism and subsequent failure mode
1	Nearly impossible	≤1/1500000 (≤0.00058)	None	No effect	Almost certain	No known techniques available

The traditional FMEA uses the risk priority number (RPN) to determine the risk priorities of failure modes that it is for the purpose of ranking the risk of potential failure modes. The RPN is in mathematic product equation as Eq.1.

$$RPN = OxSxD \qquad (1)$$

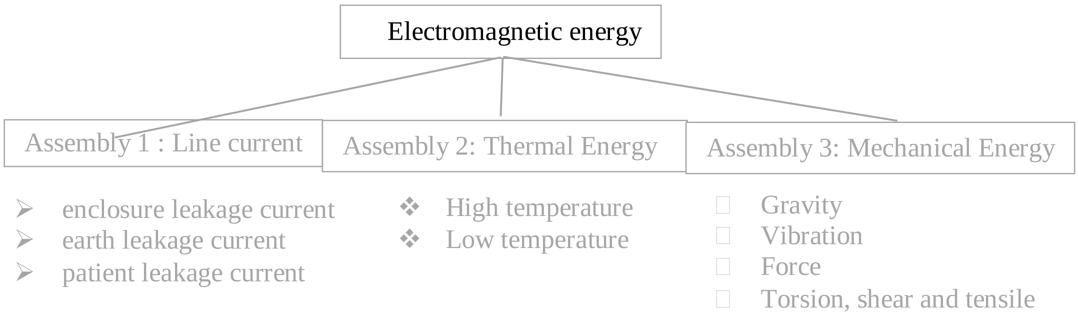
Traditionally, the way for FMEA to improve the system reliability is made by addressing problems in an order from the largest RPN to the smallest ones versa verse. Different combinations of risk factors may produce an identical value of RPN, however, this method ignores the fact that three factors (S, O, and D) may have different weights in system. Therefore, the factor (O) is a key factor in RPN analysis, especially for the non-repairable system [6,7].

Each risk / failure for PV panel are listed in the “Detailed Risk Analysis” below. The failure and possible resulting effects, rate the probability of its occurrence, the severity, and the probability to detect the failure are described. Preventing measures and rate the failure are described again.

3 RESULTS and DISCUSSIONS

Individual assemblies and components for PV panel risk analysis are firstly described in this study, suggested format with this study as follows the Table 3.

Table 3. Using by the FMEA methods, an example to define the individual parameters for PV panel risk



As above mentioned Detailed Risk Analysis is evaluated with suggested format in Table4 for only one assembly of Line Current for PV panel.

Preparing of the Detailed Risk Analysis of PV panel as shown in the Table 5 had produced definition of the factors influencing PV performance. It wouldn't be wrong to say that these factors will have been prepared the list of individual assemblies and components for PV panel risk analysis. These obtained factors due to PV panel component via FMEA method are given by the Table 4.

Table 4. Factors influencing of PV panel performance

Factor	**Cell**	**Module**	**Array**	**System**
Solar irradiance	*	♦	•	♥
Cell temperature	*	♦	•	♥
Module materials		♦	•	♥
Ambient temperature		♦	•	♥
Wind speed		♦	•	♥
Surroundings		♦	•	♥
Wiring			•	♥
Shading			•	♥
Inverter efficiency				♥

Table 5. An example application of detailed risk analysis of PV panel

Assembly	Failure & Effect	S1	O1	D1	RPN before	Preventing measures	S2	O2	D2	RPN after
enclosure leakage current	High/ damage possible for PV panel	10	1	9	**90**	Using megohmme-ter and prepared good electrical isolation between the current wire and case	10	1	1	**10**
	Low/ PV panel operation will be continue	1	7	3	**21**	Using megohmrme-ter to test of good electrical isolation between the current wire and case	1	1	1	**1**
earth leakage current	Very high/ damage possible for PV panel	10	1	9	**90**	Using megohmme-ter and prepared good electrical isolation between the current wire and the Earth	10	1	1	**10**
	High / PV panel will be broken	9	7	3	**189**	Device wil be seperated the sys-tem and its ground-ing case will be checked	1	2	1	**2**
	Low / PV panel operation will be continue	1	7	3	**21**	Using megohmrme-ter to test of good electrical isolation with grounding circuit	1	1	1	**1**
patient leakage current	High/ damage possible for PV panel	10	10	9	**900**	It will be checked over load current statement. Using megohmmeter and prepared good electrical isolation between the current wire due to the each other.	10	4	4	**160**

It is clear that identify failure modes and their effects are related with 3rd column, identify causes of the failure modes and controls are related with 4th and 5th columns, and also determine and assess actions are in the last 5 columns. RPN before deals with prioritize.

This type of detail analysis is prepared with those views of definition of relationship between the failure cause and failure effects. In this point Figure 3 represents an example for flow diagram of failure definitions due to two different case scenario which one of is named double micro inverter (single failure) and the other is string inverter (double failure).

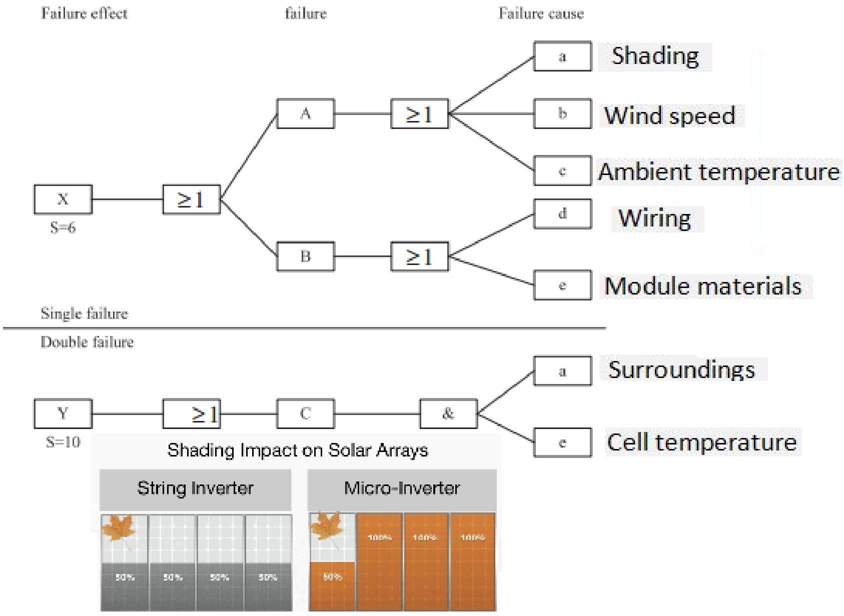


Fig. 3. Relationship diagrams between the failure effect, failure and failure cause.

4 CONCLUSION

FMEA methods were discussed in the application of PV performance evaluations of this study. It represents that FMEA method is remarkable. The agreement between the evaluated and tested values is recommended for use in PV performance risks. According to aims of this study, the issue of risk factors for PV performance is considered by aspects as investigation of solar energy sector and establishment of Turkey profile. For evaluation of the defined results of risk factors on PV panel, the method results are analyzed the risk priority number (RPN).

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Design and Analysis of Grid-Tied PV Panels with Cascaded H-Bridge Multilevel Inverters

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ABSTRACT. This paper presents cascaded H-bridge multilevel photovoltaic (PV) inverters for single-phase transformerless grid-connected applications. The cascaded multilevel inverter topology helps to improve the efficiency and flexibility of PV systems. To realize better utilization of PV modules and maximize the solar energy extraction, Maximum Power Point Tracking (MPPT) algorithm is implemented based on the inverter output power to assure optimal operation of the inverters. Grid-tied inverters are synchronized with power grid using Phase Locked Loop (PLL) for phase and frequency match.

In this study, a single-phase 11 level cascaded H-bridge inverter has been implemented by 5 H-bridge modules. Each inverter is supplied by 5 identical 1.2kW powered PV arrays and transfers the output power (6kW) to the grid by 96% efficiency. PLL provides synchronization of the inverter with the grid in 50ms. The isolation level between inverter and grid can be compatible with standard limits using high efficient reliable inverter control (HERIC) and H-5 topologies. The inverter supplies current with 3% total harmonic distortion (THD), which is below 5% compatible with standard limitations. In order to achieve power balancing of the solar arrays and improve MPPT performance, a code is written to sort solar arrays and define pulse durations of currents. Designed inverter can achieve reactive power sharing with the grid, between +1000 / -1000 VAr, by adapted droop control method (DCM), if required. Simulation results are examined under different temperature and solar irradiance cases.

Keywords: Cascaded H-Bridge, Multilevel Inverters, MPPT, SPWM, DCM.

1 INTRODUCTION

Due to the shortage of fossil fuels and environmental problems caused by conventional power generation, renewable energy, particularly solar energy, has become very popular. Solar-electric-energy demand has grown consistently by 20%–25% per annum over the past 20 years and the growth is mostly in grid-connected applications. With the extraordinary market growth in grid-connected photovoltaic (PV) systems, there are increasing interests in grid-connected PV configurations.

In a solar array system, solar cells can be connected series or in parallel related to the required voltage and current levels. In this study, five independent solar arrays are connected parallelly to generate aimed 6kW active power while every solar array groups powered by 4 pieces of 300W power solar panels. In control systems, individual maximum power point tracker is adapted to achieve maximum energy transfer. Cascaded h-bridge inverter topology is selected because of its several advantages such as replaceability of the modules, power electronic circuit similarity and simple control system design.

Electrical isolation of the inverters is usually achieved by transformers between grid and inverter. Many of the recent researches have shown that the increasing demand and focusing on transformerless inverter concepts are favorable due to its efficiency, low-weight and cheaper price. In this paper, each solar panel h-bridges are configured related to H-5 topology which adds an additional switch to the bridge circuit that is patented by SMA Solar. Leakage current measurements are simulated and controlled related to the standards. A 10mH coil is used to filter the current harmonics.

Grid tied inverter are normally required to transfer active power to the grid. In case the need of reactive power requirement, designed inverter can transfer reactive power to the grid with implemented droop control method(DCM). The inverter can serve +/- 1000 VAr in 1.3 sec while maintaining maximum active power transfer simultaneously.

2 CASCADED GRID TIED INVERTER AND CONTROL TOPOLOGY

Overview of the system is shown in Fig 1. In cascaded multilevel inverter topology, DC source by PV modules connects serially to create AC voltage form. Each PV module generates +Vpv, -Vpv or 0V outputs related to the different combinations of the S1, S2, S3, S4 and S5 switches. The number of PV module groups generate 2N+1 level AC voltage. In this paper, five identical solar array modules generate 11-level AC output.

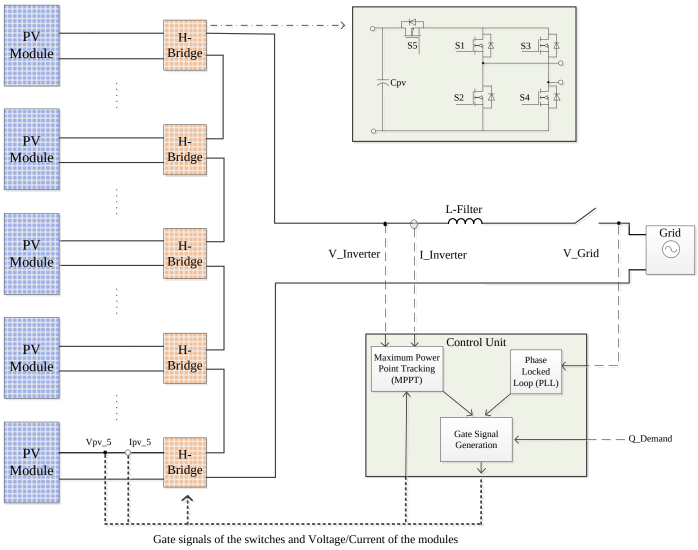

Fig. 1. Overview of the grid tied cascaded multilevel inverter

The proposed inverter is designed in MATLAB. All the controller parameters, solar panels, h-bridge and grid model are selected. In solar panel groups; 2 series and 2 parallel Sharp ND-F4Q300 model solar panels are simulated to generate 1200W. The panel specifications can be seen in Table 1.

Table 1. Solar Panel Parameters

SharpND-F4Q300 Solar Panel Parameters	
Voc	45.1 V
Isc	8.94 A
Vmpp	35.2 V
Impp	8.52 A
Pmpp	300 W

For each level of the inverter, two series and two parallel solar arrays are used to achieve total 6kW power. The main control unit is defined in Fig 2. In control system, MPPT Tracking, solar array sorting, synchronization with grid, reactive power control and gate signal generation are being performed.

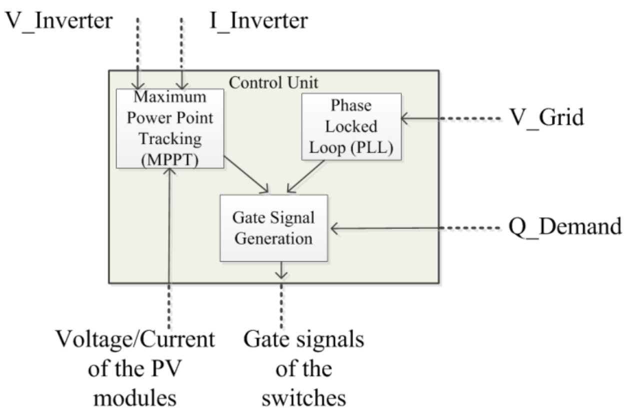

Fig.2. Control Unit

In this study, five independent maximum power point trackers are used to increase the efficiency of the inverter. Thanks to the advantages of the Pesturb&Observation method, it is designed and used in this paper. Related to the current and voltage of the solar panel, Maximum Power Point(MPP) value is calculated and used in the internal control loops [1].

In grid tied inverters, it is required to know the phase angle and amplitude and frequency of the grid voltage. In this study, PLL technique is used to be synchronized with the grid. This study uses transport delay method because of its easy implementation [2]. Grid voltage and phase shifted grid voltage are used as inputs, the controller calculates the required phase shift approximately in 50ms.

There are many control techniques of the inverters. In this paper, the sinusoidal SPWM method is selected. Gate signals are generated while controlling the required phase difference for the active power and amplitude for the reactive power(DCM) [3-4]. Active and reactive power controller block diagram is given in Fig 3.

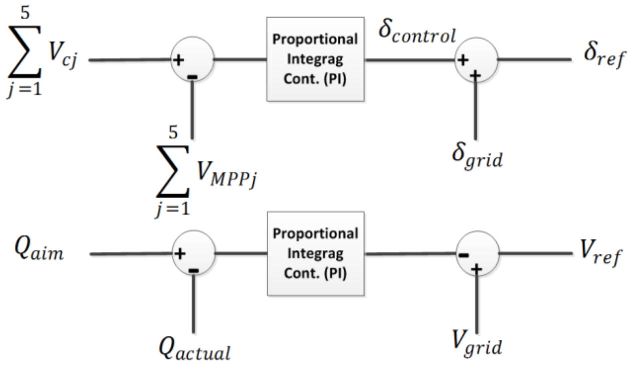

Fig. 3. Phase angle and reference voltage control

H-bridges are modified related to the H-5 topology. With the help of added S5 leakage current of the solar panel is decreased to the compatible limits with standards [5].

In this study, in order to increase the efficiency of the solar arrays, gate signals are sorted to load solar arrays similarly by adapted code, while achieving maximum power point transfer.

Simulation results of proposed inverter are shown in Fig 4, Fig 5, Fig 6, Fig 7 and Fig 8 respectively.

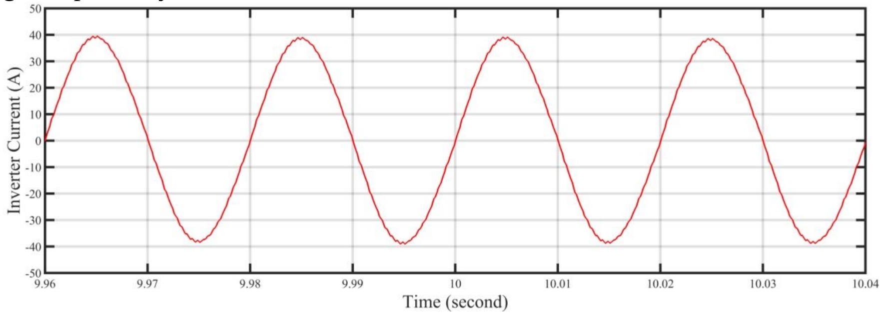

Fig. 4. Inverter Current

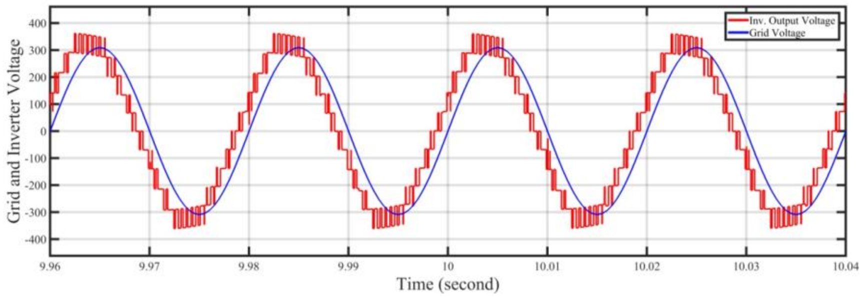

Fig. 5. Grid and Inverter Voltage

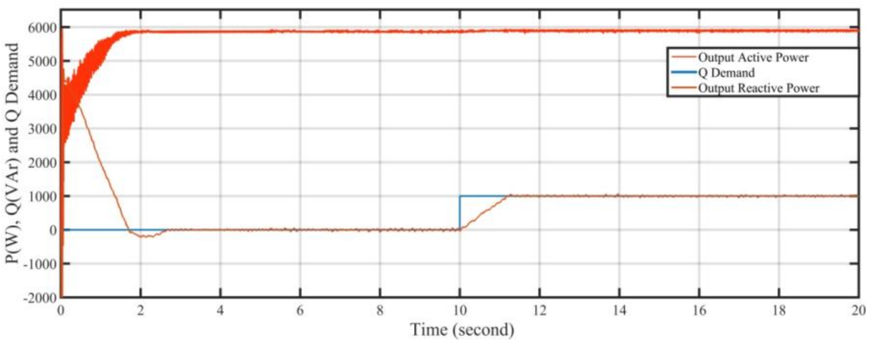

Fig. 6. Output power, reactive power and Q demand (Qset=1000VAR, t>10sec)

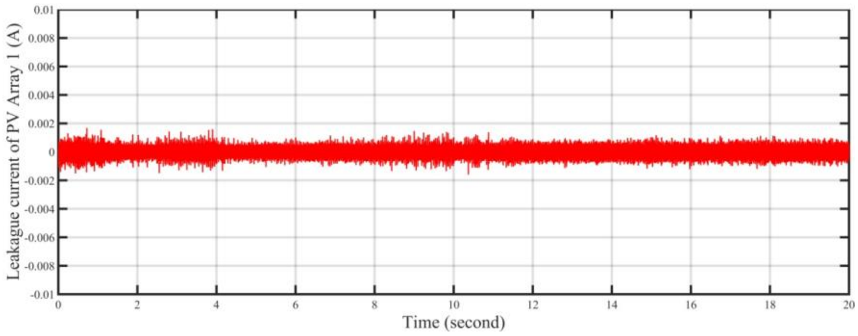

Fig. 7. Leakage current of PV array 1

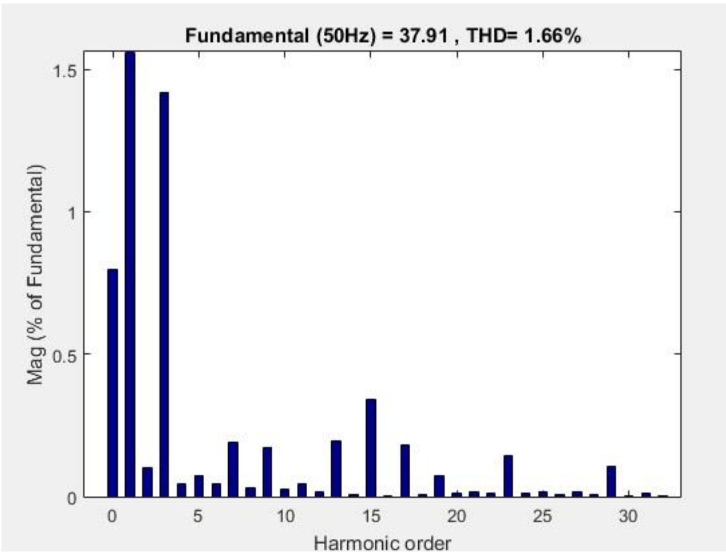

Fig. 8. Inverter Current THD

3 CONCLUSION

This paper presented 11 level cascaded H-bridge inverters. The implemented and simulated circuit of the grid tied cascaded multilevel inverter includes PLL, MPPT and H-5 topology. Gate signals generated are related to the demanded reactive power and maximum power transfer. The simulation results of the proposed inverter are also presented. Inverter's total efficiency is measured as approximately 96% while achieving 2% THD, well below compatible with IEEE 1547 and IEC 61727. Designed PLL model synchronizes the inverter to the grid system in 50ms. Inverter's H-bridge circuits are upgraded to the H-5 topology that patented by SMA solar, and gate signals are generated according to this topology. On behalf of H-5 topology, solar panel's leakage current is obtained well below 2mA. Simulation results are also examined under different temperature and solar irradiance cases.

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Development of Solar Energy Market, Industry and Utilization in Turkey

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ABSTRACT. This study presents investigations on solar energy market, industry and utilization in Turkey. Current developments and situations in solar energy sector are discussed. Turkey is located in a convenient region in terms of solar energy. Solar energy and its application did not see enough interest by industrialists, investors and users until the Renewable Energy Law (REL). Solar energy applications, which are limited only by thermal applications, have increased significantly with REL and PV applications have begun to be used and widespread. Because, Republic of Turkey State has supported to renewable energy sources and their applications with the REL. Besides these positive developments, some negative developments have affected the progress of the sector in the negative direction. Substantial increase in foreign exchange has affected the industrialists and investors. Some important companies have finished their production operations. This paper consists and investigates two main sections of solar energy. These are solar thermal and Pv applications. The number of solar collectors, which are sold in Turkey, is investigated for solar thermal applications. Domestic and imported solar collectors are considered. Also, installed solar Pv capacities are researched for solar PV applications. Also, some updated news from solar energy market and sector has been given in the paper.

Keywords: Solar energy, Solar thermal application, Solar collector, PV, Solar energy sector in Turkey

1 INTRODUCTION

Solar energy is the oldest species used by people among renewable energy sources. There are many different types of solar energy utilization. Among these utilization types, solar domestic hot water heating systems (SDHWS) and Photovoltaic (PV) are the most common types. SDHWS is the old and matured sector in Turkey. Because, there are many manufacturers and users of the SDHWS. In fact, the one of these manufacturers is rank among the top companies in the world with production capacity. Compared to SDHWS, PV application is a newer sector in Turkey. There was almost no activity in PV application until 2005 in Turkey. Because, there was no legislation concerning solar power until 2005. After 2005, there was an increase in utilization of solar energy and other renewable energy sources. This increase has caused to the emergence of a serious industry and market.

Both SDHWS applications and PV applications have shown a fluctuation evolution over time. These fluctuations have many reasons. In this study, the development of solar thermal and PV applications in Turkey has been examined. Over the years, the ups and downs in these areas and the factors causing them have been evaluated. Updated development in SDHWS and PV markets and industries have been given in present study.

2 TURKEY's ROLE IN GLOBAL SDHWS MARKET

Although there are many different ways to utilize solar energy in Turkey, the most common one is to produce hot water. Production of SDHWS has increased steadily since the 1970s. In the 2000s, Turkey became world's third-largest manufacturer of solar collectors for heating water and the fourth-largest market in terms of usage. However, SDHWS industry has financial and market problems. The production and utilization of solar heating systems generally fluctuate over years due to the following

15. Changing fossil fuel prices
16. Changing foreign-exchange rates
17. Changing the price of SDHWS and raw materials of its (aluminum, copper, steel, glass etc.)
18. Changing taxes in fossil fuel prices

Solar collector is a device, which gather energy from sun and transfer into heat transfer fluid. SDHWS collectors have three different types according to its structure and using area. These are

19. Glazed flat-plate collectors
20. Glazed vacuum tube solar collectors
21. Unglazed solar collectors (without cover and insulation for pool heating)

Solar thermal technology is used extensively in all regions of the world to provide hot water, to heat and cool space, and to provide higher-temperature heat for industrial processes. Total capacity of glazed and unglazed solar thermal collectors continued to increase in 2015 [1]. Solar water heating collector additions is given in Figure 1. As seen from Figure 1, the largest markets in 2015 have been spread to all over the World. Total additions for 2015 are about 93%. Also, total newly installed capacity is nearly 37.2 GWth. However, this increment has been shown 14% decreasing according to 2014 increment. The key factor for this decreasing is to shrink markets in China and Europe. Also, Denmark, Turkey, Israel, Mexico and Poland have shown increasing according to 2014. In addition, the total capacity of SDHWS collectors for 2014 and 2015 is seen in Table 1. As seen from Table 1, the top 18 countries have nearly 92% of the total capacity.

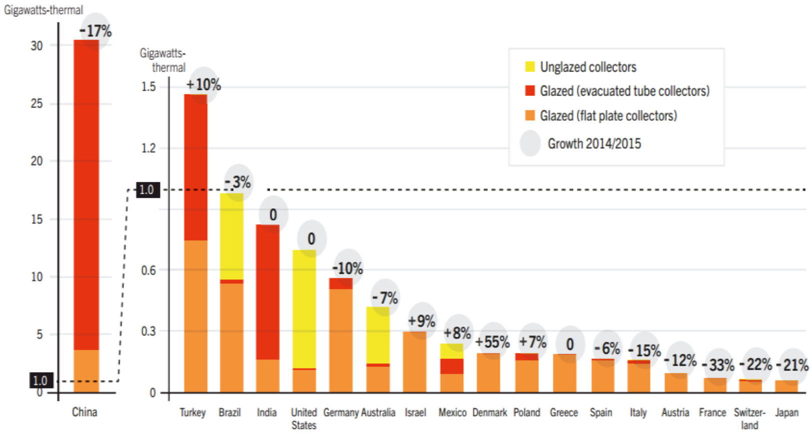


Fig. 1. Solar water heating collector additions in 2015 for the top 18 countries [1]

Solar collector utilization for thermal applications is most suitable in countries located between latitudes 25 and 45 degrees. These countries include Germany, Austria, Greece, Spain, Israel, Turkey, India, China, Japan, and the United States in the Northern Hemisphere and Australia and New Zealand are in Southern Hemisphere. Some countries in this zone have abundant fossil fuel sources thus do not show an interest in solar energy development or use.

Global capacity of solar water heating collectors for 2014 is seen in Figure 2. As seen from Figure 2, larger capacities solar energy system is in the counties have higher population. However, in order to evaluate more efficient, total capacity amount for per capita should be considered. When total capacity amount for per capita is considered, lower population countries such as Austria, Israel, Greece etc, have significant effect on global solar energy capacity.

Turkey is in fourth position in total capacity of solar water heating collectors. However, when total capacity of solar water heating collectors for per capita, Turkey has risen to second position in the World. Turkey provides little policy support for solar thermal technologies, annual installations were up 10% in 2015, to an estimated 1.47 GW_{th} (2.1 million m^2). These new installations were delivered by a strong supply chain that includes about 800 sales points and around 3,000 specialized installers [2]. The share of vacuum tube collectors increased again in 2015, to 49% (44% in 2014), up from almost zero 10 years earlier [3].

Table 1. Solar water heating collectors for 2014 and 2015 for the top 18 countries and world total [1]

	TOTAL END-2014 GWth			GROSS ADDITIONS 2015 MWth		
COUNTRY	Glazed	Unglazed	Total	Glazed	Unglazed	Total
China[1]	289.5	0	289.5	30,450	0	30,450
Turkey	12.7	0	12.7	1,467	0	1,467
Brazil	5.2	2.5	7.7	555	427	982
India[2]	5.2	0	5.2	826	0	826
United States	2.1	14.9	17	119	585	704
Germany	12.4	0.4	12.8	564	0	564
Australia	2.4	3.5	5.9	143	280	423
Israel	3.1	~0	3.2	300	1	301
Mexico	1.3	0.7	2	169	73	242
Denmark	0.7	~0	0.7	194	0	194
Poland	1.2	0	1.2	194	0	194
Greece	3.0	0	3	189	0	189
Spain	2.3	0.1	2.4	166	2	168
Italy	2.8	~0	2.8	161	0	161
Austria	3.3	0.4	3.6	95	0	95
France	1.7	0.1	1.8	71	0	71
Switzerland	0.9	0.1	1	61	4	64
Japan	2.6	0	2.6	59	0	59
Total 18 Top Countries	352.3	22.8	375.1	35,782	1,371	37,153
World Total	**383**	**26**	**409**	**38,100**	**1,500**	**39,600**

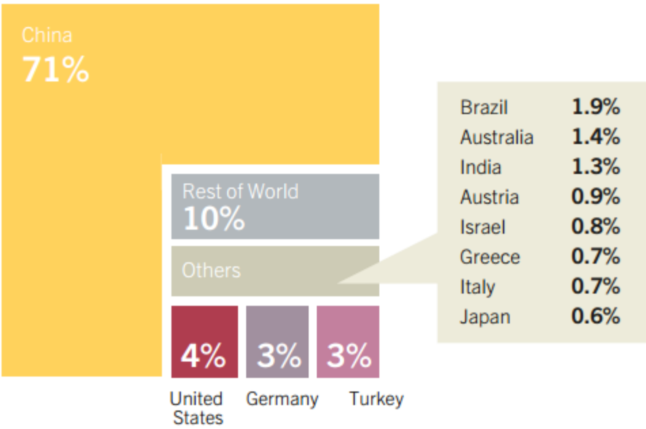


Fig. 2. Global capacity of solar water heating collectors for 2014 [1]

3 SDHWS COLLECTOR MARKET IN TURKEY

In Turkey, there are branches of the solar energy system industry that have reached a substantial size and do business worldwide. There are nearly 150 manufacturers, most of them in Central Anatolia and the Mediterranean and Aegean regions. The exact number of solar collectors and water tanks manufactured in Turkey is not known. The key and one way to estimate their amounts is to get information from the companies that supply the raw materials (such as glass, insulation material, etc.) to solar energy system companies [4].

Almost all of the solar collectors manufactured in Turkey are the flat-plate solar collectors. Recent years, manufacturing of the vacuum tube solar collector has shown rising. However, the large amount of vacuum tube collectors is imported. The number of solar collector manufactured and imported in Turkey changing with year is given in Figure 3. The utilization and sale of solar energy water heating systems change depending on cost of conventional energy systems and foreign-exchange rates. Figure 3 shows that sales of solar water heating systems have increased after 2001 economic crisis. Because energy prices and foreign exchange rates have increased dramatically with economic crisis. Until 2004, solar collector sales and productions have increased. After 2004, sales and production of the solar water-heating collectors have decreasing because of rising foreign-exchange rate and decreasing natural gas prices. Between 2008 and 2010, because of the effect of the worldwide financial crisis, sales and production of the solar water-heating collectors decreased sharply. After 2010, sales and producing of the domestic solar energy water heating systems increased until 2012. However, domestic solar water heating collectors (flat-plate collector) has decreased with the getting cheaper natural gas prices. Also, profit for flat-plate solar collector sales has decreased dramatically with increasing raw materials prices for solar collectors. Lastly, in the middle of 2016, the one of World's biggest flat plate solar collector producer from Turkey has stopped production activities. Domestic and flat-plate collector production is going to decreasing sharply in future years.

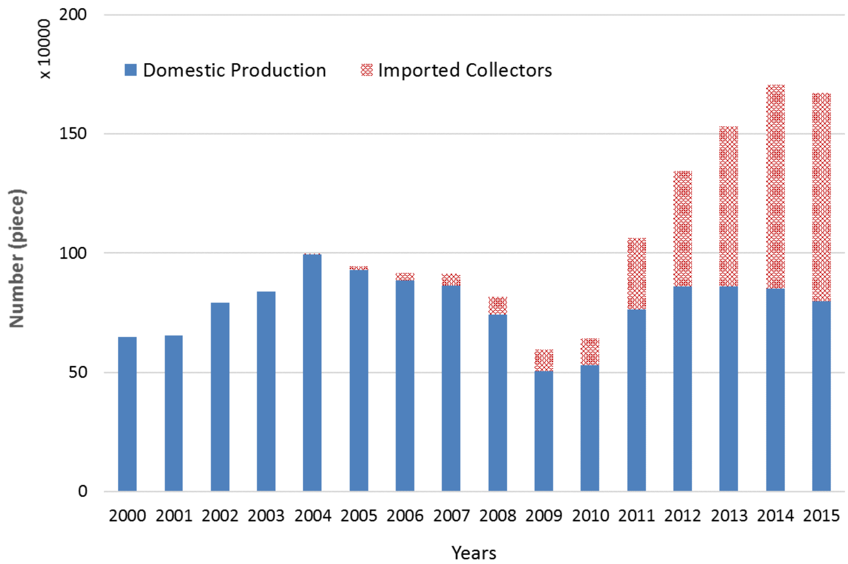


Fig. 3. The number of solar collectors, which are produced and imported in Turkey [5]

Until 2001, Turkey had a totally closed solar energy market. Then large increases in foreign-exchange rates and the fuel price crisis increased interest in solar energy. The increased sales of solar energy systems that took place in Turkey until 2004 piqued the interest of many Chinese and European companies, and they started to sell vacuum tube solar collectors to Turkey. As can be seen in Figure 3, foreign companies sold only 4,000 m2 of solar collectors in 2005, but they increased that number to 350,000 m2 in 2015. In Figure 3, we can also see the changing numbers of flat-plate solar collectors and vacuum tube solar collectors sold by year. As the figure shows, in spite of increased importation, the number of solar collectors sold in Turkey decreased rapidly in 2008–2010. While Turkey had been one of the biggest solar collector manufacturers, manufacturing decreased and importation increased during this period capturing 15–20 % of the domestic market. Due to the increase in demand for vacuum tube solar collectors, some domestic manufacturers began to manufacture them.

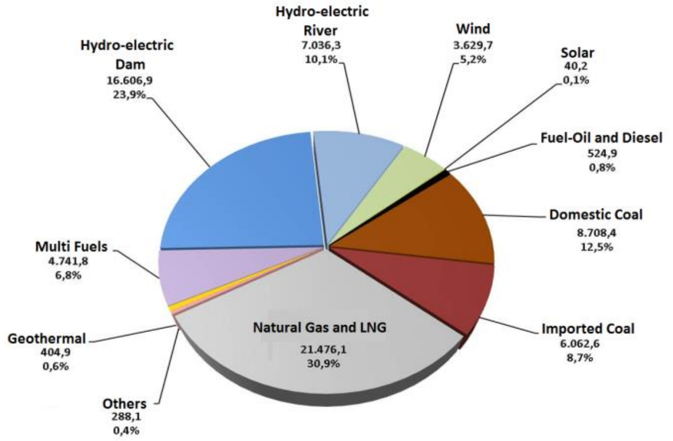
Now, there are approximately 20 million m^2 flat-plate solar collectors in Turkey. This number was reached in 2010 and has remained constant. New systems are either refurbished old systems or replacements for broken ones. These systems fulfil the important role of supplying daily energy needs for Turkey and today the economic contributions of these systems are nearly $800–900 million/year, depending on oil prices. As a result of on-going reductions in the production of solar systems since 2004, some companies in the sector have shifted to other sectors. Some small and medium firms have become importers of vacuum tube solar collectors manufactured in the Far East. The main reason these companies prefer importing the vacuum tube solar energy systems is that they can obtain these products at very low prices from China. Recently, however there have also been renewed domestic production efforts [4].

4 DEVELOPMENT OF GENERATING ELECTRICITY FROM SOLAR ENERGY

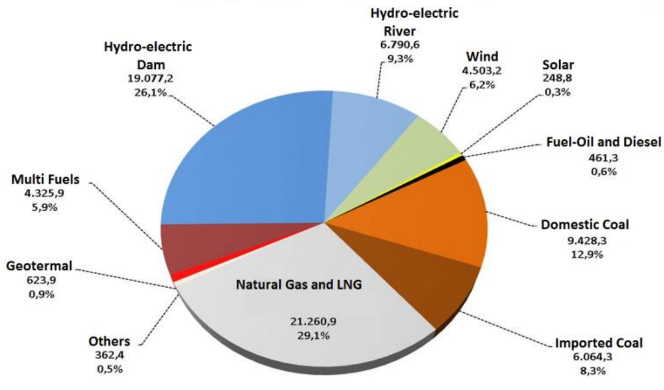
In Turkey, in contrast to the widespread use of solar energy for thermal applications, there has been very slow development of solar electricity generation by the thermal and photovoltaic methods. The reason is that there was no legislation concerning solar power until 2005. The Renewable Energy Law, which has been issued in 2005, though it covered all renewable energy resources in general, it particularly paved the way for only wind energy. On December 2011, renewable energy law was revised to promote the use of all renewable energy sources. Under the new law, different tariffs have been imposed on electrical energy obtained from different renewable sources. In addition, the law allows the price of solar electricity to be higher by up to 20 % in the case of machinery and equipment used for generating electricity from domestic sources. This has been one of the most original parts of the new Renewable Energy Law.

Installed electric energy power for Turkey with the end of October 2016 is shown in Figure 5. As seen from Figure 5, total installed power is 78433.8 MW. Solar electricity is 745.7 MW. It is 1% of the all installed electric energy power. However, attention for solar electricity has increased with Renewable Energy Law. This situation is seen with comparing to Figure 6 and 5. In Figure 6 a and 5, installed electric energy powers for Turkey are given for 2015 and 2014. As seen from Figure 5 and 6, installed solar electricity power has significantly increased. As seen from Figure 4, PV capacity has significantly increased since 2014. The reason of this increasing is that Ministry of Energy and Natural Sources guarantee to buy PV electricity for 10 years and 13.3 USD cent for per kWh.

In order to study the identifying regions of radiation higher than 1,650 KWh/m^2, within the framework made by General Directorate of Renewable Energy, and determine the potential of solar energy in Turkey, an area of 4600 km^2 was calculated. After all the necessary calculations were made in the case of using this area for solar energy production, it was determined that 638–718 billion kWh of electricity could be generated per year with 440–495 GW_p installed PV power. Considering that the installed electric power system is approximately 77 GW and annual production is approximately 200 billion kWh, Turkey has high potential for solar power.



Total installed power (2014): 69,519.8 MW



Total installed power (2015):73,146.7 MW

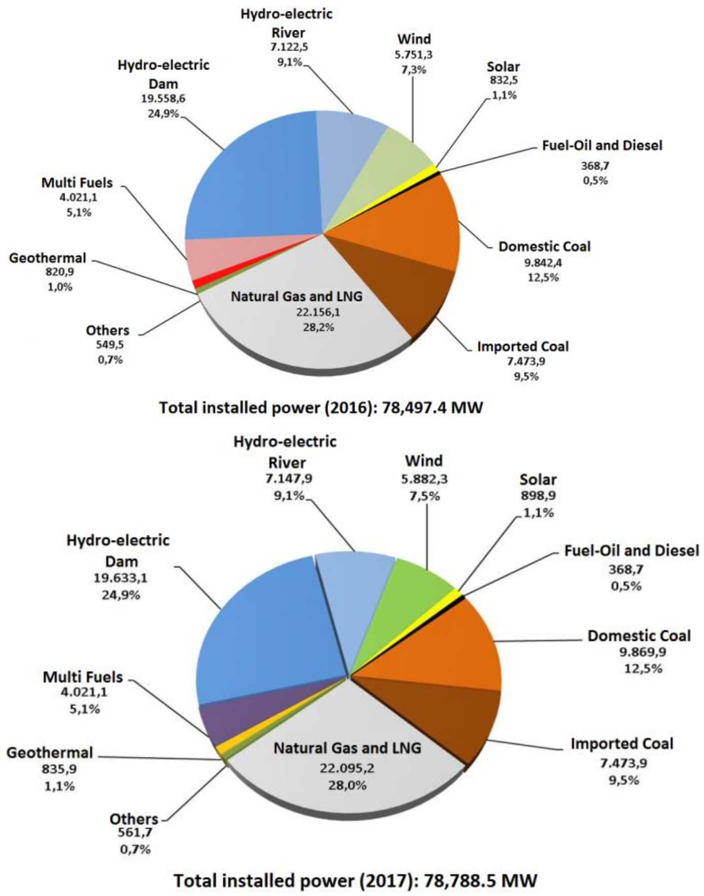


Fig. 4. Total installed electricity power for Turkey a) 2014, b) 2015, c) 2016 d) February 2017 [6]

5 CONCLUSIONS

Turkey has a very large capacity for the production of solar collectors. As a result, there is an enormous potential for the use of these systems. However, the sector hasn't increased this capacity in recent years. Companies have chosen to focus on other production areas or have restricted their activities to importing and marketing foreign systems.

In recent years, domestically produced solar water heating systems in Turkey have come under pressure from imported products made in the Far East. Chinese companies, which are supported by the Chinese state, have increased their sales by 50–100 % in Turkey. Although this is commonly known in the sector, because the industry is widely scattered and lacks lobbying power, no results have been obtained from attempts to reverse the trend. State institutions dealing with these issues should take the necessary measures to avoid issues such as production loss, market shrinkage, and importation of unqualified products.

In Turkey, there have been very important developments related to the installation of PV electricity systems. Over the next two to 3 years, approximately 1–2 % of Turkey's electricity will be generated from solar energy. If this demand and the state's commitment continue, this rate is likely to increase in the near term. PV capacity has significantly increased since 2014. The reason of this increasing is that Ministry of Energy and Natural Sources guarantee to buy PV electricity for 10 years and 13.3 USD cent. Now there are 18 companies in Turkey for PV laminating. There is no PV cell production in Turkey. However, the founding words for a big solar PV cell production company is continuing in 2016.

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Distributed Grid Integration of PV Generators and Islanding Protection in Turkey

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ABSTRACT . In this study, the technical infrastructure of the electrical connection of the Photovoltaic (PV)-based distributed generation (DG) systems to the conventional electrical grid from a low voltage level is investigated. The islanding protection and its possible effects to the grid are also presented in the paper. The paper also includes an application study that is realized to define the criteria for the Turkish Grid Code. An experimental study is performed in the laboratory, and a real-time Labview-based islanding detection method is investigated within the scope of the research. The developed system presents a hybrid protection system for integration of PV generators to the grid consisting of under/over-frequency protection, under/over voltage protection and a remote islanding protection system. This structure provides a sustainable operation of the PV system with the current Turkish electrical grid. The threshold values of the grid are defined in the study, and the grid connection criterions are indicated to specify the Turkish Grid Code. The proposed micro grid protection system and the developed islanding detection method provide a reliable grid integration of PV generators, and the obtained results verify this condition.

Keywords: Islanding detection, Grid code, Distributed generation, Protection in micro grids

1 INTRODUCTION

The reliability of the grid, providing high power quality and safety interaction with a DG system are the main concerns for a microgrid. Islanding is a significant protection issue for DG systems to provide the grid connection reliable and continuously.

The most of the distribution companies in the world define their grid connection standards, and these standards constitute the Grid Code. There are also some international norms for consideration of the grid connection, and IEEE 929-2000 shown in Table 1 is also the most important one of these standards [1]. Frequency and voltage threshold values are defined in IEEE 929-2000 and the required opening time for circuit breaker (CB) is important for islanding.

Table 1. IEEE 929-2000 specifications for microgrid protection

No	Frequency	Voltage	CB Opening Time
1	f_{nom}	$0,5V_{nom.}$	6 cycles
2	f_{nom}	$0,5V_{nom} < V < 0,88V_{nom}$	2 seconds / 120 cycles
3	f_{nom}	$0,88V_{nom} \leq V \leq 1,10V_{nom}$	Normal Operation
4	f_{nom}	$1,10V_{nom} < V < 1,37V_{nom}$	2 seconds / 120 cycles
5	f_{nom}	$1,37V_{nom} \leq V$	2 cycles
6	$(f_{nom}-0,7) \leq f \leq (f_{nom}+0,5)$ Hz	V_{nom}	Normal Operation
7	$f < (f_{nom}-0,7)$ Hz	V_{nom}	6 cycles
8	$f > (f_{nom}+0,5)$ Hz	V_{nom}	6 cycles

The grid is affected by abnormal operating conditions [2], thus the DG system has to be prevented the islanding. Islanding operation is defined in a DG that a situation while a DG system continues feeding the load through disconnection of the electrical grid from the load [3]. Islanding operation damages both DG system and the grid, so it must be detected before the event starting. The voltage and the frequency of the grid are not stable in islanding, and the electrical values of the grid are out of the reference values. Thus, a circuit breaker (CB) is required for disconnection of the grid. In islanding, DG gives the power to the system and CB is not switched to disconnect the grid. Voltage shutdown, equipment failure and short-circuit conditions cause islanding in a DG system [4,5].

The grid loses the synchronization in islanding condition and there have been a significant difference in power system stability. Voltage and frequency are out of desired grid reference values and as a result, the electrical devices of the system could be damaged in an islanding condition [6]. Also, the authorized people working in a DG system are life-critical. Figure 1 shows a blackout event realized on 4 November 2006 and affected nearly all of the EU countries.

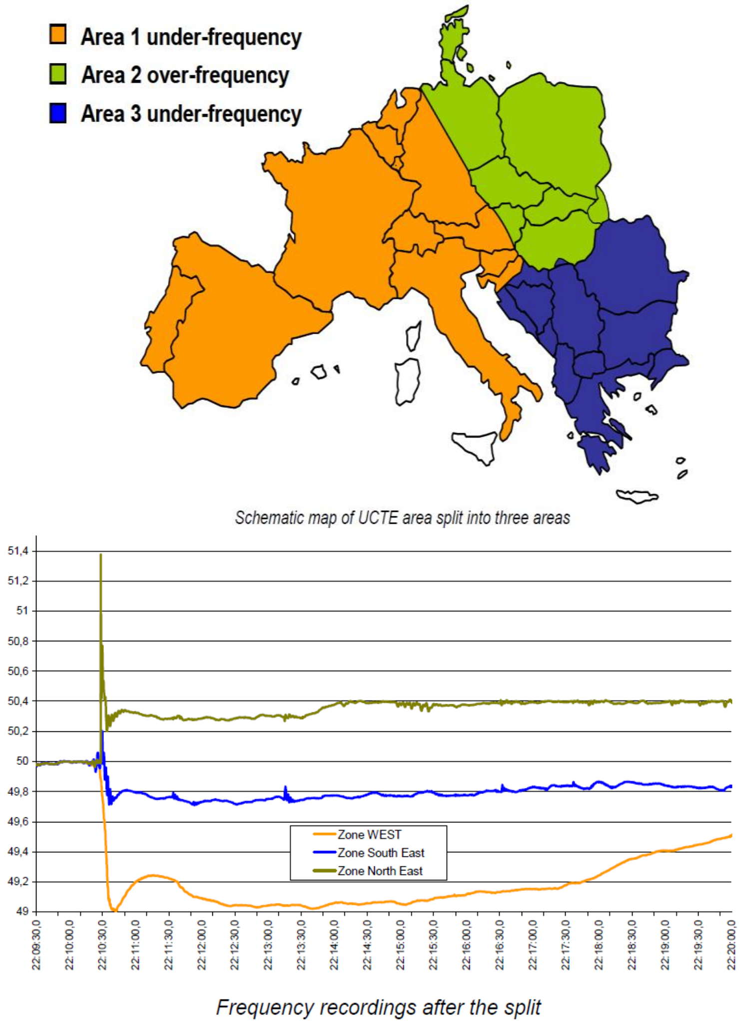

Fig. 1. A blackout event realized on 4 November 2006 in the EU [6]

Today, there have been many developments about islanding detection techniques and algorithms can be found in the literature [7,8]. These islanding methods classified into three principal methods are called as local, remote and intelligent detection methods. Remote methods measure the system parameters at a DG [9-11]. In the case, local methods use a remote method between DG and the grid [12-14]. Table 2 shows a comparison of current islanding detection methods.

Table 2. A comparison of current islanding detection methods

Features	LOCAL METHODS		REMOTE METHODS	
	Passive	**Active**	**PLL**	**SCADA**
Operation Principle	Measuring the PCC parameters	Adding a disturbing signal to the grid	Grid impedance change in PCC	Using receiver and transmitter sensors between DG and grid
NDZ	Large	Small	No	No
Response Time	Short	Shorter than Passive Methods	Fast	Faster
Effect on DG	No	Yes	No	No
System Cost	Minimum cost	Average cost	Very high cost	Extremely high cost
Effect on Power Quality	No	Decreases the power quality of the system	No	No

In this study, the proposed method has not an NDZ problem because it checks all of the system parameters in real-time and proposes a new remote method by using communication of the circuit breakers. The goal of the study also chooses a remote detection method to prevent the NDZ and, local load problems existing in passive and active detection methods.

2 A NEW ISLANDING DETECTION METHOD FOR TURKISH GRID CODE

In this section, the prototype micro grid system constituted in the laboratory, and the proposed micro grid management system (MGMS) was described in detail. In the study, a Labview-based monitoring and management system was introduced.

The islanding detection appears of vital importance with the grid integration of PV-based DG power generation plants. The grid integration of PV power generation plants from LV level is realized with a new micro grid management system shown in Figure 2. This structure was implemented in Turkey within the scope of developing "Turkish Grid Code". Under/over-frequency protection, under/over voltage protection and a remote islanding detection system was performed to investigate a proper micro grid management system. This structure achieved a consistent operation of the PV system with the present electrical grid of Turkey.

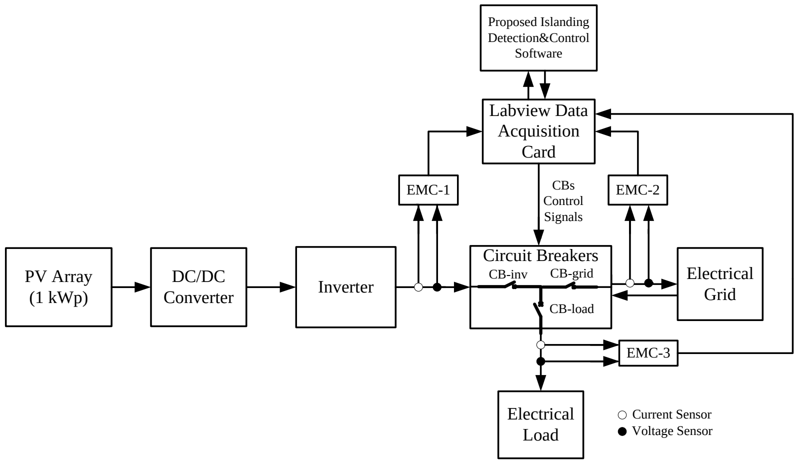

Fig. 2. The general structure of the developed protection system [12]

The developed real-time micro grid management system (MGMS) with Labview was designed and implemented to provide all requirements of the related international standards by considering the fundamental requirements of “Grid Code” in Turkey. The goal of the study is to develop a new grid-interactive system that has a smart micro grid management system in real-time. A new islanding detection method related to the remote islanding detection methods that are the best solution to detect islanding was also investigated. Consequently, the proposed system was implemented to define the requirements for the grid integration of the PV power generation plants with consideration to build a Grid Code.

3 EXPERIMENTAL RESULTS

3.1 Normal Operation of the Developed Microgrid

The active, reactive and apparent powers of the micro grid system are calculated and displayed with developed MGMS software. This situation can be clearly seen from the Figure 3. The MG system generates 304 W active powers and load consumes nearly 94 W active powers. Generated excess power is sent to the grid.

3.2 Operating the microgrid in an islanding condition

The proposed MGMS is also capable of the islanding detection, and MGMS software detects the variations in threshold values of the grid voltage and the grid frequency.

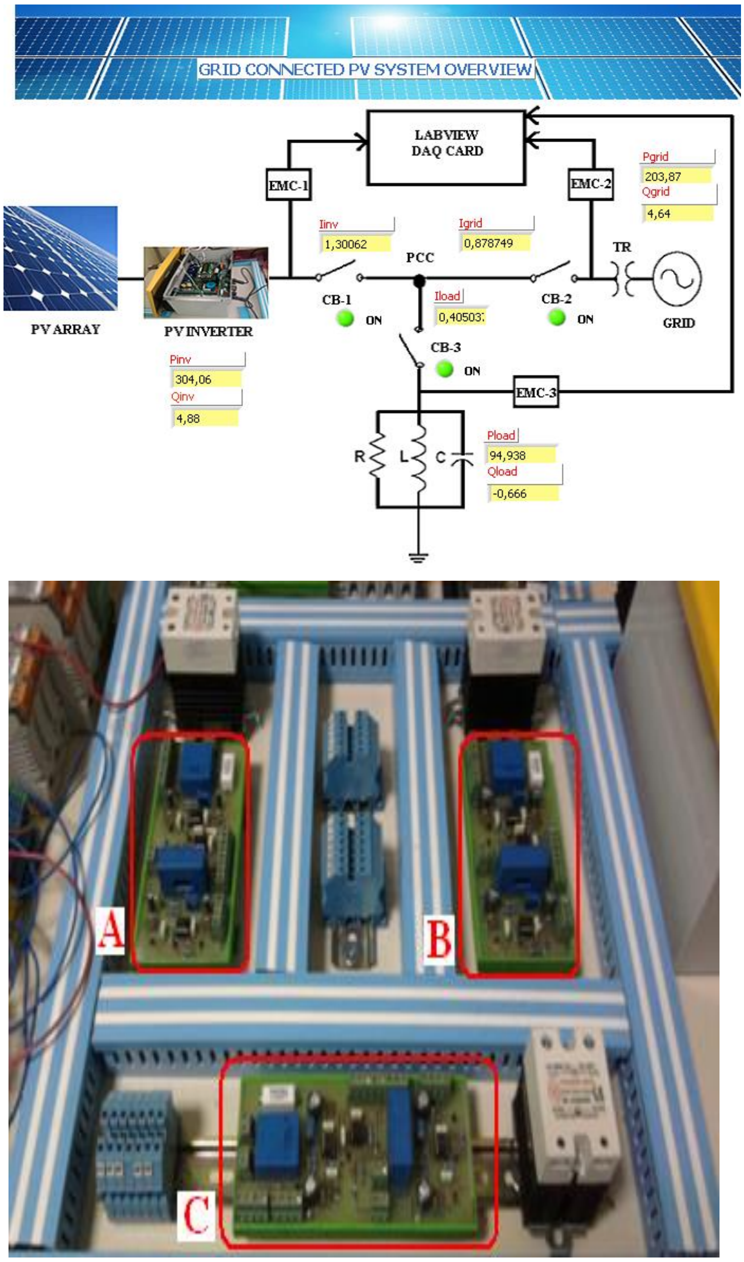

Fig. 3. The PV system with proposed MGMS software interface and the experimental setup

3.2.1 Over-frequency Operation of the Microgrid

. The developed islanding detection process continuously evaluates the feedbacks from the DG system and controls hybrid micro grid system. When islanding occurred, circuit breakers are switched immediately, and the DG system has no connection to the grid. Figure 4 shows the advanced software interface in real-time for the over-frequency condition. When the grid frequency increases to 50.3 Hz, control system waits for five cycles to check the islanding situation, and then a trip signal triggers the circuit breakers.

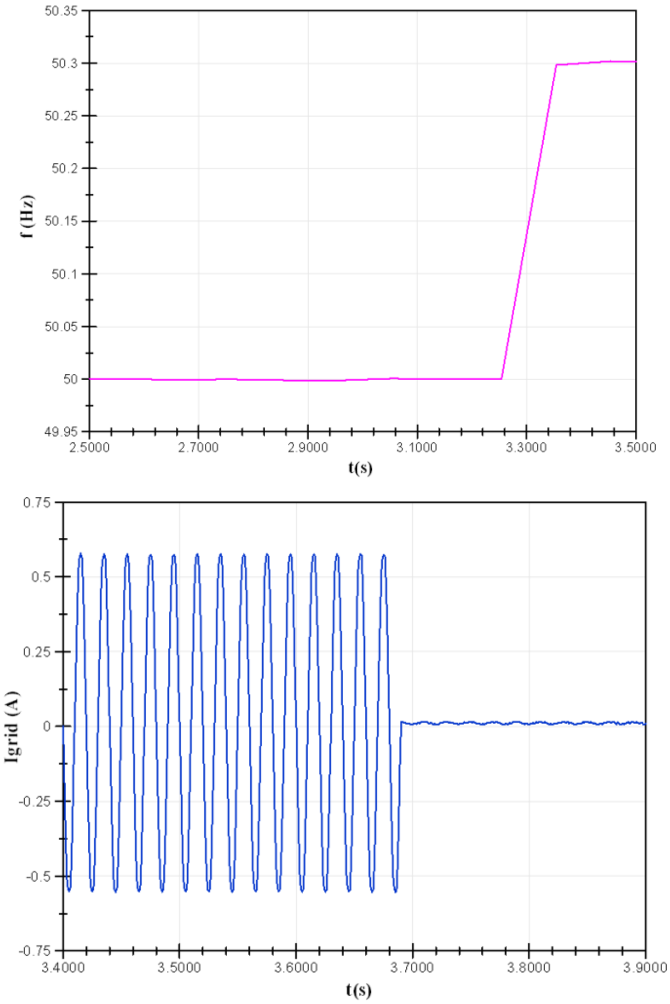

Fig. 4. (a) The software interface, **(b)** grid frequency for over-frequency condition

3.2.2 Under-Voltage Operation of the Microgrid

. The under voltage and the over voltage threshold values also are described in improving the islanding detection method. Figure 5 indicates the advanced software interface for under voltage condition. When the grid voltage is under defined threshold value (195 V), control system waits for checking the islanding situation and then a trigger signal is generated for circuit breakers and islanding is detected. Grid voltage decreases with the threshold value 195 V; circuit breaker is switched off, and the DG system has no connection to the grid.

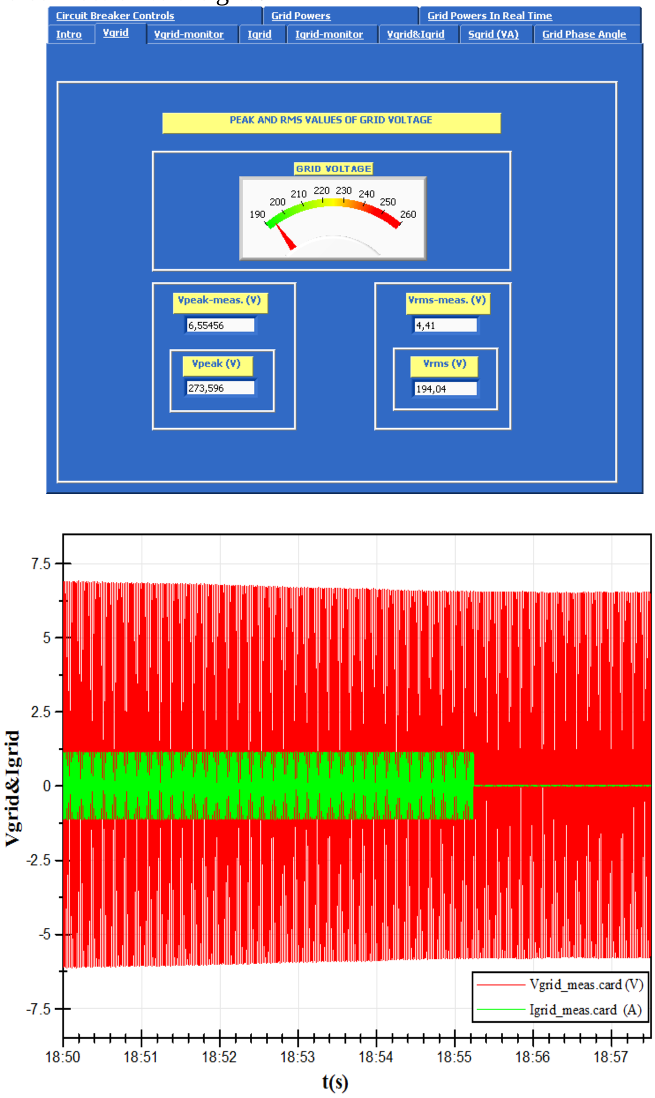

Fig. 5. The grid voltage and EMC control signals of grid voltage&current

4 CONCLUSION

In this study, the legal and the technical infrastructure of the electrical connection of the PV-based DG systems to the conventional distributed system from a low voltage level in Turkey was researched. The existing problems and the possible effects of the grid were also investigated. Besides, the paper also includes an application study realized to define the criteria for the Turkish Grid Code and the obtained results from this study were presented. A prototype grid-connected PV system was constituted in the laboratory, and a real-time Labview-based monitoring and control system realized within the scope of the research. Under/over-frequency protection, under/over voltage protection and a remote islanding detection system was performed to investigate a proper micro grid management system. This structure achieved a consistent operation of the PV system with the present electrical grid of Turkey.

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Lunar Solar Power Systems and Computational Efficiency Analysis of a Microwave Receiver Center in Turkey

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ABSTRACT. The general purpose of this study is to do a detailed research and design a computer program on lunar solar power systems which makes possible to generate solar energy during 24/7 continuously via excessively different and upper technology than the consuetudinary methods with restricted conditions and limited sources on Earth.

In this study, the needed technology of lunar solar power systems is examined, construction steps are discussed and a computational model is designed with Matlab Gui 2011. It is aimed with this model that getting 20 TWe energy on Earth and doing antenna calculations under different conditions and with different possible technologies to decide the best options for a LSP system. The site analysis are done for three city in Turkey as Ankara, Konya and Gaziantep to construct receiver center for microwave power transmission. Konya might be the best option with 900,85 MW net power value on a 3,95 km^2 rectenna because of the latitude effect and annual rainfall rate for 5,8 Ghz^{-1} and 230 W/m^2.

With respect to the theoretical and computational results; it is concluded that the Lunar Solar Power System can be a safe and clean alternative to current options to meet Earth's total energy need for long decades in case of economic and technical problems are solved.

Keywords: Lunar Solar Power, Energy, Microwave, Laser, Modelling

1 INTRODUCTION

Energy is at the core of economics and social life in today's world. There is a growing demand for energy and meeting it safely and environmentally is a key challenge, especially after the growing concerns about global warming and seasonal change due to greenhouse gases. Nevertheless, current renewable energy sources with using current techniques are evaluated as that they will not provide the future energy demand [1] because of the rapid increase of population. According to the statistical and academic researches, by the year 2050, people will require at least 20,000 GWe of power [2] that is more that 10 times the 1,800 GWe now provided by the world's electric power stations [3]. The situation is comparatively critical for Turkey, with a rapidly increasing population and with a growing economy, it has become one of the fastest growing energy markets in the world in the last decades [4].

It does not matter with a local or global point of view, conventional energy systems become useless for us in the near future. At this point, we have to think about new ideas to get limitless power for the next generations. The answer can be the Moon. The equator of the Moon approximately receives 13,000 TWs of solar power [5] and building a commercial power system to transfer the solar energy on Moon to the Earth at a moderate price can be a solution. In 2013, The Shimizu Corporation, a Japanese construction firm has introduced the biggest solar power concept ever. It starts with constructing a huge lunar base and a belt of solar cells around the Moon's 11,000-kilometer equator, then continues with transforming the electricity into microwaves or lasers to beam to Earth, and finishes on ground with transforming the beams back to electricity as a commercial power. According to the mathematical calculations of the company, it can supply World's total energy need for long decades [6].

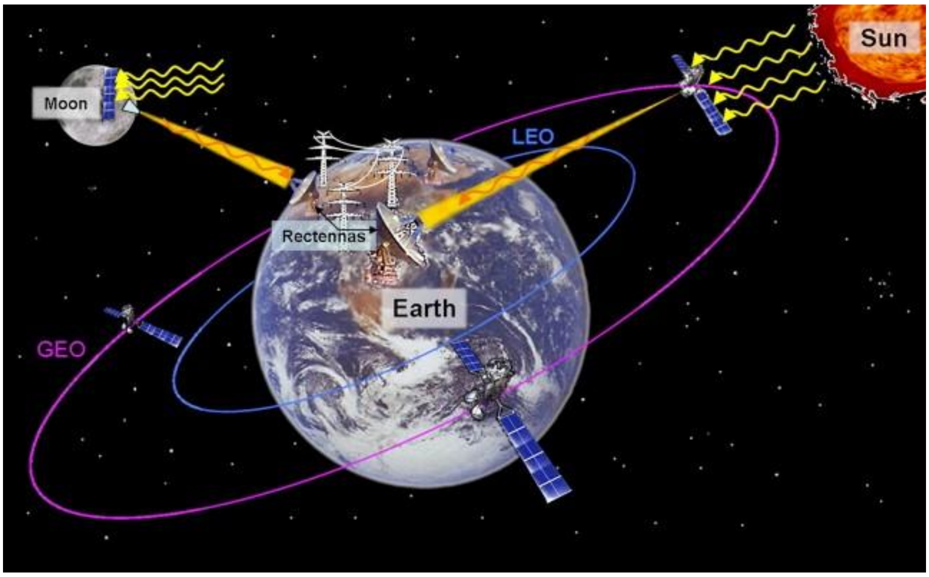


Fig. 1. Positions of SPS and LSP Systems

2 METHODOLOGY OF ANTENNA CALCULATION

Because of the chemical composition of the atmosphere of Earth, microwaves of wavelength pass through clouds, rain, fog, and dust with little absorption. Each rectenna on Earth would convert 85% or more of the microwave power also, they can have an average output of approximately 200 MWe/km^2 as IEEE limitations say, so many thousands of rectennas, totaling approximately 100,000 km2 in area, are required on Earth to get 20 TWe to customers on Earth. In the light of the data from NASA and from the other studies various rectenna schemes have been proposed up to now and the maximum conversion efficiencies anticipated so far are 91.4% at 2.45 GHz and 82% at 5.8 GHz. The RF-DC conversion efficiency, of the rectenna (η_{RF-DC}) is over 80 % of experimental results. Decrease of the efficiency is caused by several reasons such as array connection loss, change of optimum operation point of the rectenna array caused by change of connected load, trouble of the rectenna, cables, etc. The final power of solar cells on Moon, P_{f-SC} can be found from the formula (1). Here, P_{final} is the final power on Earth, 20 TWe. The η_{RF-DC} is the RF to DC conversion efficiency, η_{R-A} is the receiver antenna efficiency, η_{T-A} is the transmitter antenna efficiency, η_{DC-RF} is the DC to RF conversion efficiency of the system and η_{atm} is the atmospheric efficiency

$$P_{final} = P_{f-SC} (\eta_{RF-DC} \times \eta_{R-A} \times \eta_{atm} \times \eta_{T-A} \times \eta_{DC-RF}) \quad (1)$$

The collection efficiency is proportional to a design parameter τ, which is expressed as Goubau's relation

$$\tau = \sqrt{(Ar\ At)} / \lambda D \quad (2)$$

Where, Ar is the area of the receiver antenna, At is the area of the transmitting antenna, λ is wavelength of the radiation and D is the distance between the transmitting and receiving antennas. The relation between the transmission efficiency η_b for Gaussian beams and aperture sizes of the transmitting and receiving antennas can be defined as;

$$\eta_b \sim 1- \exp(-\tau^2) \quad (3)$$

The conversion efficiency of the whole system is the DC power at the receiver end over the AC input power captured by the rectenna also can be written as;

$$\eta_{R-A} = P_{out} / P_{in} = (V_{dc}^2 / R_{load}) (1 / P_d A_{eff}) \quad (4)$$

On the other hand, rectennas located on Earth between 60º N and 60º S can receive power directly from the moon approximately 8 hours a day [8]. In this case, site selection for the receiver antenna facility is an other important issue in consequence of several criterias in addition to location such as distribution of the energy, land space, security or military reasons. In other respects, the further from the equator a rectenna is sited, the lower the average power intensity of the microwaves that it receives [9,10]. It is because of the distance increase and angle to the satellite causes the pattern of microwaves on the ground to cover a larger area than for a rectenna exactly on the equator. The general equation of the factor with different latitude can be described as;

$$W_{lat} = \cos (lat * 10,94 * \pi / 180) \quad (5)$$

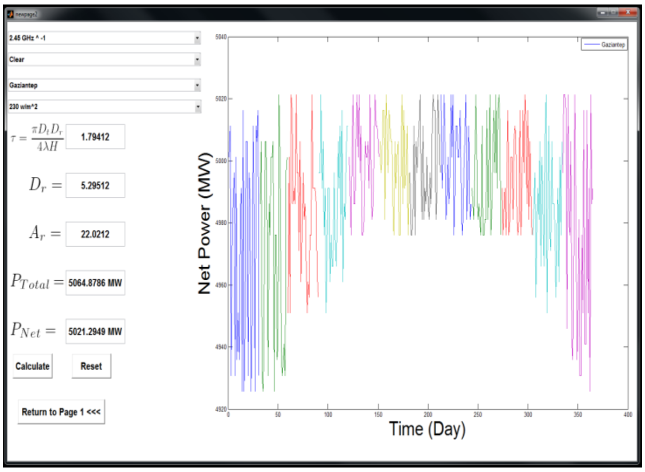
Turkey lies between latitudes 35° and 43° N, and longitudes 25° and 45° E. Considering the latitude effect, rainfall rate and topographical properties of the cities in Turkey, this receiver center may establish in Konya, Ankara or Gaziantep would have a rectenna diameter 2,245 km for 5,8 GHZ which will cover approximately 3,95 km2 on ground with a transmitter antenna diameter 20 km on Moon. Gaziantep lies between 36 ° 28 'and 38 ° 01' east longitude and 36 ° 38 'and 37 ° 32' north latitude.

The number of rainy days in Gaziantep was measured as 86 days [12]. Ankara lies between the 39.92° latitude and 32.86° longitude coordinates [13]. The number of rainy days in Ankara was measured as 104 days [12] and finally the Latitude and Longitude of Konya is 37.8667 and 32.4833 respectively [14]. The number of rainy days in Ankara was measured as 83,5 days [12].

There are lots of parameters that affect the design of a LSP system but for simplicity, it is accepted that the most important factors are transmission type, frequency and wavelength selection, solar panel type, concentration rate, weather condition on Earth and beam intensity of the transmitted energy. There is no legally accepted value for beam intensity in Turkey for MPT and so, user can decide it computationally. The user can decide the city for the construction of a receiver center in the options of Konya, Ankara and Gaziantep. The latitude value and rainfall rate changes due to the city selection. The program takes the statistical data from the official web page of the Meteorology General Management of Turkey [11], at this web page one can reach all the weather statistics for a selected city in Turkey. When the user decides the city on the interface of the Matlab screen, the program connects this web page on internet. It takes only the average rainy day column and monthly total rainfall rate column. It rounds the day value to upper integer number and checks the average rainfall rate and decides the interval of the weather. After that, it gives random N_{atm} values between these intervals up to rainy day number, then it subtracts rainy day number from total day number of the month and gives random N_{atm} values between clear and light rain intervals

3 RESULTS

1) Differences between $\lambda = 2{,}45\ GHZ^{-1}$ and $\lambda = 5{,}8\ GHZ^{-1}$, clear weather, Gaziantep, Beam intensity = 230 W / m^2.



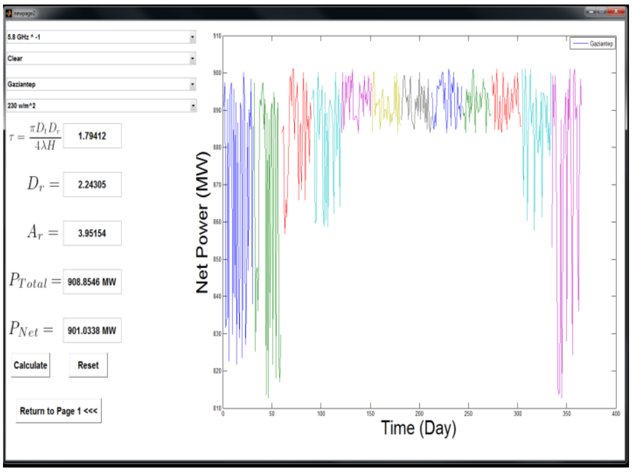


Fig. 2-3. λ = 2,45 GHZ^{-1} and λ = 5,8 GHZ^{-1} Clear, Gaziantep, 230 W/m^2

3) Selected; λ = 5,8 GHZ-1, clear weather, Konya, Beam intensity = 230 W / m2.

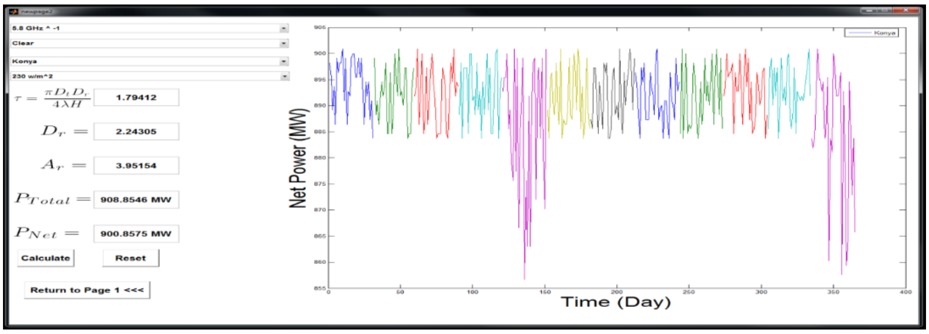


Fig. 4. λ = 5,8 GHZ$^{-1,}$ Clear, Konya, 230 W/m^2

4) Selected; λ = 5,8 GHZ-1, clear weather, Ankara, Beam intensity = 230 W / m2.

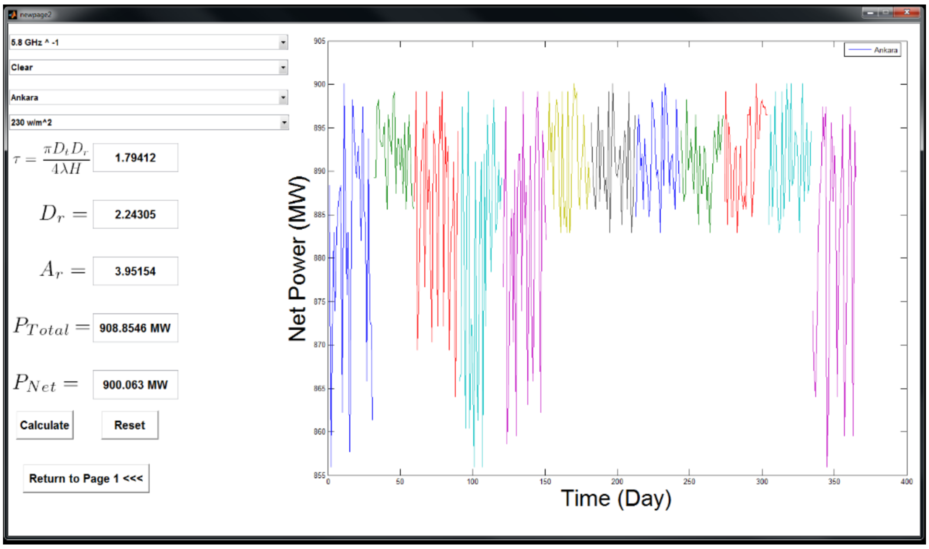


Fig. 5. λ = 5,8 GHZ^{-1}, Clear, Ankara, 230 W/m^2

4 DISCUSSION AND SUGGESTIONS

As shown in Figure 2 and Figure 3, wavelength selection is directly changes the area of the receiver antenna. There is a huge difference between the receiver antenna areas for λ = 2,45 Ghz^{-1} and λ = 5,8 Ghz^{-1}. Unfortunately, one of the most expensive part of a LSP system is the building receiver centers and receiver antenna on Earth [3]. Even though with λ = 2,45 Ghz$^{-1,}$ one can have higher power output with a huge receiver antenna system from economical side of view λ = 5,8 Ghz^{-1} may be a better solution for LSP system. A rectenna can begin outputting commercial power after it reaches ~ 0,5 km diameter. One square kilometre area of rectenna area can output 180 MWe [5]. In our computational calculation with the assumptions λ = 5,8 Ghz^{-1}, clear weather, D_T = 20 km, and beam intensity = 100 W / m^2, we need a rectenna that has a 2,245 km diameter and in this case we can get 395,154 MWe in Gaziantep. When the beam intensity increases to 230 W/m^2, 908,85 MW total power can be get from the system. On the other hand, all the risks about exposure limits must be evaluated before deciding the beam intensity. Human health or environmental profits must not be ignored to get higher power. As seen in Figure 3, 4 and 5, latitude and weather conditions of the cities does not affect the efficiency of the whole system more than 1 MW. At the worst case, P_{net} value on the graphs decreases 10% in a heavy rainy weather during 8 hours in a day. For a 20 TWe big scale LSP project, it is a very small number that can be ignored in the big frame. Nevertheless, Konya might be the best option for a receiver center construction in Turkey. The peaks on the computational graphs for Konya, says us that the rainy day number of this city is less than the other options. So, more steady power output can be get in Konya. On the other hand, as mentioned before, site potential analysis for rectenna construction is not enough, more detailed and comprehensive studies must be done. These studies may find better alternatives than Konya for Turkey.

5 CONCLUSION

In the light of mathematical and computational calculations, LSP System has a huge potential of power to utilize as a commercial power on Earth. It eliminates the worries about day – night cycle and climate change unlike on Earth, it promises a 7 / 24 continuous power. By means of this computational design, we compare technological possibilities on one screen that are discussed in previous theoretical studies. The variables and the parameters of the program can change easily, other city options can be added in the future due to the next developments or studies. It might give a rough estimate while designing a LSP system. On the other hand, the realization of the lunar solar power plan depends on the preparation of appropriate test platforms, developments of subsystem technologies and adequate budget. Turkey should effort more than the developed countries to gain a place in this big plan. More studies should be done to find a logic way to meet its growing energy demand. A political strategy for the LSP is also very important, serious consideration should be given in many aspects related to the LSP construction and its full use. If the plan comes true, the Developing Nations can afford LSP electricity according to the Criswell's assumptions. LSP electricity may accelerate the economic growth of all nations because it gives changes to all nations to get energy independently from atmospheric effects, climate and location so, this situation may change all the power balances on the World.

When putting all these concerns besides, statistical studies shows that soon or late we will need a long-lived and clean energy supply to meet growing energy demand of the World. In case of a more economic solution can not find, expensive but reliable LSP or SPS system should be applied in near future.

6 NOMENCLATURE

SPS Space Power System
LSP Lunar Solar Power
NASA National Aeronautics and Space Administration
DOE Department of Education (ABD)
GEO Geosynchronous Orbit of the Earth
LEO Low Earth Orbit
IEEE The Institude of Electrical and Electronics Engineering
RF Radio Frequency
DC Direct Current
AC Alternative Current
TWe Megawatt Electric

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The Effects of Soiling On Solar Photovoltaic Systems In The Cyprus

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ABSTRACT. The Cypriot community is getting familiar with the PV systems and installations are expected to grow with a rapid pace. On the other hand, the effect of soiling is limited to few studies in Cyprus. This paper presents the effects of soiling on an installed PV system in the capital of Cyprus. The system consists of six poly-crystalline PV modules each one of them has connected to a micro-inverter. The system power outputs and irradiation level are monitored on individual level by using online portal. Initial monitoring phase is conducted for 1 year, and then the system divided in three groups. Each group consists of two PV modules based on their power outputs. Percentage power output difference between three groups will be evaluated. The cleaning schedule is assigned for each group which is divided as weekly, twice in a month and once in a month to find the effect of soiling. This will help to find a cleaning frequency for the PV systems in Cyprus. Furthermore, the least square method will be used to drive a mathematical model to evaluate the uncertainties.

Keywords: Bird droppings, Dust deposition, Nicosia, PV modules, Soiling

1 INTRODUCTION

Energy demand increasing every day and the need for clean sustainable energy plays a huge role on this. One of these sustainable green energy solutions is solar photovoltaic(PV) energy systems. The PV systems are using solar radiation to produce power. The most common used PVs are crystalline technologies and generally, the performance guarantee given as 90% for first 10 years and 80% for 25 years. However, those guarantees given under standard test conditions by avoiding the soiling effect such as dust, pollutants, bird droppings, etc.

PV system performance is evaluated by means of total energy produced and used for determining the return of investment period. Therefore, the effect of environment plays huge role as the dust deposition on the module is disturbing the solar irradiation hitting on the panel which causes less electricity production. Also, the dust accumulation may lead to hot spots on the panels due to inhomogeneous shading and effect the yield for long term. [1,2,3] This paper is showing the initial study on the effect of soiling on PV systems.

The study conducted in Cyprus, in one of the busiest roads at the capital. The first part includes the collection of data for one year to get more accurate results and the second part is to divide the system in 3 section to evaluate the effect of soiling by using least square method to develop a correction model. The future studies will include the mathematical modelling of the effect of soiling to evaluate the uncertainties and suggest a cleaning frequency.

2 METHODOLOGY

The aim of this study is to provide an understanding about soiling related power losses in Cyprus environment. The method is finding AC side soiling related power losses with real time power generating small-scale system.

The stages of the method for determining soiling related power losses are as follows:

1. Installation of PV modules with same orientation and tilt angle under shade-free environment. Higher the number of installed PV modules will increase the accuracy of the results in case of any contamination on cleaned modules.
2. Installation of micro-inverters on each module for power generation.
3. Installation of module monitoring system.
4. For eliminating mismatch losses caused by the interconnection of solar cells within the module, monitoring of the system is carried out for one year.
5. After the initial monitoring stage, system is divided into three groups. Each group cleaned each week, every 2 weeks in a month and monthly, respectively.
6. Finally, based on their power output differences, systems are evaluated to find out the impact of soiling on PV modules.
7. Mathematical modelling will be used to evaluate the uncertainties based on the performance of the modules
8. The cleaning frequency will be determined

2.1 Installation Location

The PV system installed in the private office building is typical domestic installation constructed according to the latest guidelines determined by the IEE. PV system is installed for displaying and comparing purposes of micro-inverters with central inverter. Office building is located in Nicosia, the capital city of Cyprus (Latitude: 35.207364, Longitude: 33.338147). Installation building is located on one of the busiest avenues and very close to one of the biggest hospitals on the island and between two high schools with 300 m difference. The Figure 1 shows the picture of the installation.

Fig. 1. The picture of the installation.

2.2 System Specifications

Six polycrystalline 250Wp PV modules are installed with a capacity of 1500Wp. The PV system is commissioned on 16th of January with an array area of 9.9 m^2. Six pieces' micro-inverters with a rated power of 230 W are used with a Multi-gate system. The system includes DC isolators, DC cables, AC spurs, AC cables and current protection devices. The PV system inclination angle is 30° and an orientation (compass bearing ° measured from north) of 160° from north. The tilt angle decided based on the studies done before by considering the dust deposition and the energy production.

According to Hasan Qasem, [4] Increasing the tilt angle, decreases the dust accumulation due to gravity effect and the higher cleaning chance by rain. Decreasing the tilt angle causes vice versa situation. On the other hand, 1.4mg/cm2 dust remained on 30° tilt angle where 0.1mg/cm2 for 90° and 3mg/cm2 for 0°. The 30° tilt angle allows more dust settlement at the bottom but also creates a very clean area due to water slide. [5]

The system includes monitoring which is separated into two groups: Sensors which includes the temperature and irradiation sensor & AC power production of micro-inverters.

2.3 The Procedure to Determine The Soiling Effect

The PV system tracked for one year and then, divided in three parts. First and the fourth panel is in one group. The second group includes second and fifth panel and the last group is the third and sixth panels.

During the collection of data's, the shading detected on the PV modules after 14:30 PM due to the orientation of the neighbor buildings. Therefore, the power output values used in this experiment will be until the introduction of shade. The figure 2 shows the shading on the panels.

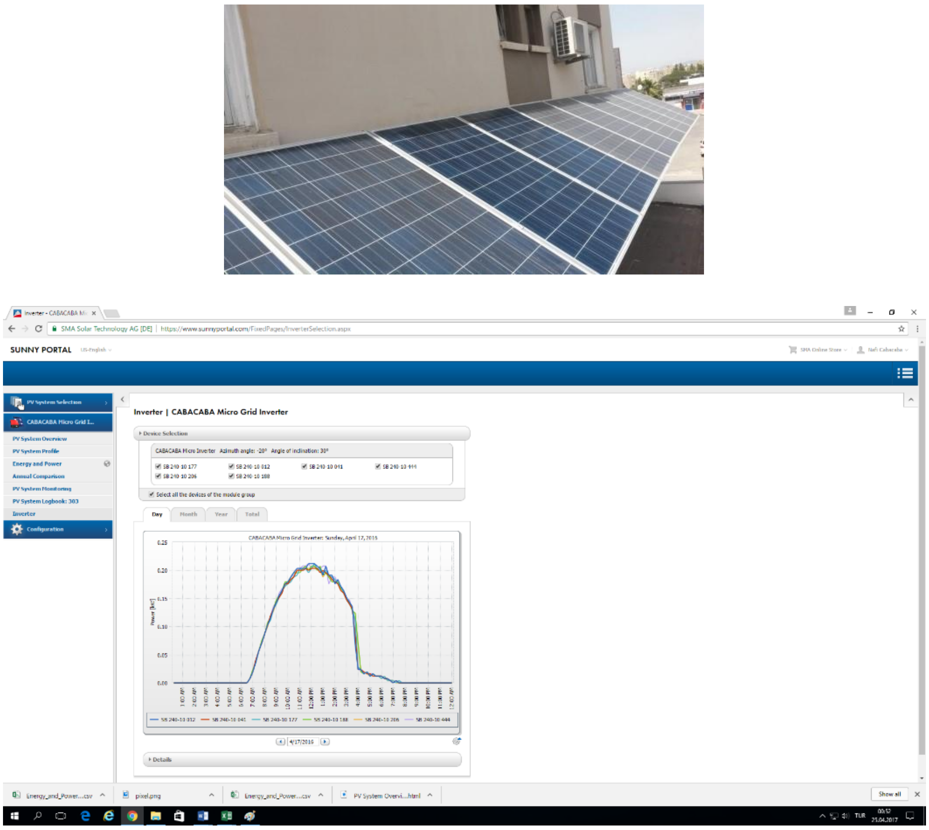

Fig. 2. Shading of PV modules around 14:30 PM due to the shade of the building.

Once the system is divided into three groups, first group is cleaning every day, the second is cleaning in every two weeks and the last one, once in a month.

3 RESULTS

The PV system not cleaned for a year and data collected during last year compared with expected production. The performance ratio (PR) calculated to obtain the losses. The results are given below in Table 8. The performance ratio is 90%. [6] Table 1 shows the Yield and Expected values for 2016. The percentage loss is startıng with 5% after the rain season in March and continue with 9% difference in next month. Then, the difference increases during May due to dust storms till 17% and drops to 12% in June due to dry wind and increase by 2% each month for next two months which is caused by thermal loses.

Average Solar Irradiation Intensity: 1800kWh/m2
Generator Area of PV System: 9.76128 m2
Efficiency Factor of PV panel: 15.34%
Electrical Energy Exported to the Grid: 2428 kWh/yr

$$Nominal\ Plant\ output = \frac{1800}{9.76128} x\ 15.34 = 2695 kWh/m2 \quad (1)$$

$$PR = \frac{Electrical\ Energy\ Exported\ to\ Grid}{Nominal\ Plant\ Output} = \frac{2428}{2695} = 0.9 = 90\% \quad (2)$$

Table 1. Yield and Expected values for 2016

Month	Yield	Expectation	Percentage
Jan 16	150.336	166.320	10%
Feb 16	161.397	186.840	14%
Mar.16	230.142	243.000	5%
Apr 16	235.303	257.310	9%
May.16	224.871	271.890	17%
Jun 16	231.728	262.170	12%
Jul 16	231.581	270.000	14%
Aug 16	224.262	266.490	16%
Sep 16	236.411	241.110	2%
Oct 16	217.178	213.840	-2%
Nov 16	169.100	167.400	-1%
Dec 16	115.575	153.630	25%
Total	**2.428**	**2.700**	**10%**

4 DISCUSSION

The performance ratio calculated as 90%. There is 10% loss which includes the frequent bird droppings, dust accumulation, conduction and thermal loses and shading on pv panels. The orientation of the PV system is shifted towards southwest due to the orientation of the building. In addition to that air circulation is limited to some extend since the system is installed on the straight wall of the building. The drawbacks listed above, causes system to generate less power yield in comparison to what can be harvested under the optimum conditions.

Soteris et al. has studied the effects of soiling in Limassol with two polycrystalline PV modules. One is exposed for natural contamination while other module is cleaned on the daily basis. Study suggested a power output reduction of 2.5% between PV modules during the first week of spring and after the third week power output reductions are stabilized at 4%. On the other hand, for the summer period the same experiment is run, for the first week a power reduction of 4% is recorded. [7]

5 CONCLUSION

The effects of soiling have been investigated on an installed PV system in the capital of Cyprus. The six poly-crystalline PV modules, each of them are connected to dedicated micro-inverters and their power outputs are monitored on individual level. After collecting data for one year, the performance ratio is calculated and seen that, there is 10% loss without cleaning. Deposition of Environmental pollutants along with the dust on PV module surfaces does scatter the direct solar irradiation from reaching the PV cells and causes power reductions. The bird droppings are also severe issue as the deposited dust on PV module surfaces and based on observations during a year, the deposition of the dust on PV modules was non-uniform. After comparing outcome of this experiment with the other studies conducted in Cyprus, confirms that the soiling of PV modules is highly location specific. The least square method will be used for a mathematical modelling to evaluate the uncertainties based on the performance of the modules at the second stage. The effective cleaning frequency will be determined at the end of the work as well.

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