e-ISSN: 2146 - 9067

International Journal of Automotive Engineering and Technologies

journal homepage:
https://dergipark.org.tr/en/pub/ijaet

Original Research Article

Investigation of energy efficiency studies in a sample facility research (Automobile Industry) (SFR)

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ARTICLE INFO

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Doi: 10.18245/ijaet.1259800

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Received: Mar 3, 2023
Accepted: May 3, 2023

Published: 30 Jun 2023

Published by Editorial Board Members of IJAET

ABSTRACT

Energy, which is one of the foundations of social and economic development, is decisive for the future of humanity. The situation becomes more important every day. Today, the total sales of the electrical energy market alone have exceeded the level of 1 trillion dollars. In this research, SFR's (Sample Facility Research) energy efficiency studies in the automotive sector were examined. Energy efficiency studies were started in SFR in 2021. Comparisons were made according to 2019. Within the scope of the research, the current literature on the subject was scanned and the data of SFR (were examined. According to the data obtained, it has been determined that the factory saves approximately 693 thousand kW of electrical energy annually. Based on this value, it has been understood that as a result of the energy efficiency applications, an energy saving of 36.47% was achieved in 2021 compared to 2019. It was determined that the biggest gain was in the curing section with 94,246 kW.

Keywords: Energy efficiency, Automotive Industry, Energy saving, Energy consumption.

1. Introduction

The welfare level of societies is directly affected by energy. The reason for this is that all the fields it is related to are the main fields of activity to the gross national product (GNP). Energy is among the more or less basic inputs of all these fields, including industry, agriculture, commerce, construction, communication, transportation, public, housing, private sector and financial institutions. From this perspective, when considered together with the gross domestic product, which determines the welfare and development levels of countries, it is understood that meeting the energy needs of a country is the basis of its social and economic development and its sustainability [1]. This situation transforms economy and energy into concepts that are directly related to each other.

The energy element is included in the production elements. Due to this situation, countries have to provide the energy they need in low cost, safe, high quality, continuous and environmentally friendly manner and to diversify their energy sources within the energy supply security [2]. In this context, it is not enough to produce and provide energy alone, it is also necessary to make plans to provide clean energy in an environmentally friendly manner.

Today, the total sales of the electrical energy market alone have exceeded the level of 1 trillion dollars. In the next 20 years, it is estimated that energy consumption will increase by approximately 59% and the increase will be 25% in industrialized countries, while it will increase twice as much in developing countries, especially in Asia, South and Central America [3].

In the globalizing world, operating according to the market economy requires the increase in production, the application of technology, efficiency, profitability, quality in production, efficiency and competition [4]. The fact that energy provides input to all areas where it enters and directly affects the competitiveness of the industry makes it different from other sectors. In this research, it is aimed to analyze the energy efficiency of a sample facility research (SFR).

2. Energy Efficiency Policies in Türkiye

Within the scope of the "Energy Efficiency Law" no: 5627, the following applications are aimed to be carried out in 2007 to increase energy efficiency. The activities planned to be carried out in relation to energy management are listed below [5]:

- Industrial enterprises assign energy managers from among their employees (the “Energy Efficiency Law No. 5627”). In organized industrial zones, an energy management unit is established to serve industrial enterprises with less than one thousand toe energy consumption in the region.
- The management or building owners of commercial buildings, public sector buildings and service buildings with an annual energy consumption of five hundred toe and above, or a total construction area of at least twenty thousand square meters, appoint energy managers or receive services from energy managers.
- An energy management unit is established under the responsibility of the energy manager in industrial enterprises with a total annual energy consumption of fifty thousand toe and above, which are not included in the public sector.
- The procedures and principles regarding the responsibilities and duties of energy management units and energy managers are determined by a regulation to be put into effect by the ministry.

According to the Energy Efficiency Law, some targets are as follows [6]:

- First of all, (some) studies should be carried out to reduce energy imports.
- Potential (alternative) energy should be used efficiently and environmental benefits should be provided.
- Measures should be taken to prevent environmental pollution in the use of energy resources.

In accordance with the Energy Natural Resources Strategic Plans between 2015 and 2019, it is aimed that the energy efficiency in the central and provincial organizations of the relevant institutions will increase by at least 20% compared to 2013. On the other hand, contributing to energy saving and efficiency by completing maintenance, repair and modernization works in public power plants has been accepted as the main target [5].

Recently, the importance of energy efficiency in energy policies has been recognized. The basis of energy efficiency lies in high production with very little energy. In this way, it will be possible to save energy, reduce industrial costs, ensure security of supply in energy, reduce greenhouse gas emissions by preventing climate change, and consequently reduce the foreign dependency in energy [7].

Projects to increase energy efficiency are implemented by the Energy Savings Coordination Board, which is supervised by the Ministry of Energy and Natural Resources in Türkiye. The unit responsible for minimizing environmental pollution in Turkey and ensuring the efficient use of existing energy resources is the National Energy Savings Center (NESC) under the General Directorate of Renewable Energy (GDRE). Starting from 1990, NESC and EIE have been working on savings in the team and device industry within the scope of the “Energy Efficiency Test Tool Program”.

3. Importance of Energy Management in Automotive Industry

Energy management has a great importance in the automotive sector as in all other fields. It is known that this sector needs energy intensively due to the processes it contains. The increase in energy costs and the increase in the level of energy consumption day by day require management units and facilities to use energy more efficiently. In the automotive field, as in other fields, it is important to prevent energy losses and to reuse the said energy in the process. Thus, productivity increases [8].

The automotive manufacturing industry is facing new challenges, the number of which is increasing day by day. This is due to increases in overall vehicle production with the recent rise in energy costs and environmental responsibilities. Since automotive manufacturing is a complex and energy-intensive process, it consumes a significant amount of raw materials and water. In order to reduce carbon emissions and increase the sustainability of the process, the automotive production process needs to undergo an evolution [9].

3.1. Possible energy efficiency applications in automotive facilities

Automotive sector is among the main engines of the economy in all industrialized countries. It can be expressed as an industry branch covering the whole of the main industry where motor road vehicles are produced and the sub-industry that produces original or equivalent parts and systems in accordance with the technical documents determined by it. In addition, it is the main buyer of basic industry branches such as petro-chemistry and iron-steel and the driver of technological developments in these areas [10].

In the motor vehicle industry, the main research trends in energy efficiency have focused on two issues [11]:

- Fuel efficiency and reduction of carbon dioxide emissions in automobile use
- Alternative fuel sources in transportation

Therefore, existing studies on energy consumption and energy efficiency in the motor vehicle manufacturing industry are limited to descriptive analyzes of energy efficiency potentials, cleaner production and energy efficiency improvement strategies [12-15].

Primary energy sources in motor vehicle assembly plants are electricity, steam, natural gas and compressed air. Electrical energy constitutes approximately 45% of the total energy budget. The remaining 55% is natural gas energy [16].

An energy efficiency system has great potential to reduce energy consumption in manufacturing [17]. Energy consumption in automotive manufacturing can vary depending on various factors such as the size of the cars produced. Assumption of total energy of an automobile manufacturing plant determined by various variables such as operating system, energy efficiency management, HVAC system etc. The energy demand at the production facility is estimated to be between 1.39 and 3.42 MWh per car, with an average of 2.5 MWh [18]. It is estimated that this rate can be reduced by optimizing energy consumption [19].

Real-time control of production systems is becoming more critical in increasing system efficiency and responsiveness, as well as reducing downtime [20]. A study was carried out by Mouzon et al. [21] that proposes a multi-objective mathematical programming model that focuses on individual processes for improving energy efficiency. In the study, a large amount of energy is consumed when non-bottleneck machines are idle; It has been found that this is greatly reduced when the machines are not bottleneck. Starting and idling machines in production therefore requires a significant amount of energy. In Toyota, on the other hand, it has been found that 85% of the energy is consumed while the machines are "idling" and only 15% of the energy is used for processing functions [22].

4. Energy Efiiciency Studies in an Automotive Factory

In this section, data on the energy efficiency status of SFR are examined. Energy efficiency studies were started in SFR in 2021. Comparisons were made according to 2019. The reason for this is that accurate data could not be accessed in 2020 due to the fact that the factory did not work at full performance due to the pandemic.

Table 1 below contains monthly data on the electrical energy use of the factory. According to Table 1, it can be seen that the factory saved approximately 693 thousand kW of electrical energy annually. Based on this value, it was determined that as a result of the energy efficiency applications, an energy efficiency of 36.47% was achieved in 2021 compared to 2019. In addition, it is seen that an energy efficiency of 3.82% was achieved in 2022 compared to 2021. When analyzed by months, it is seen that approximately 95 thousand kW of electrical energy was saved in May. The least difference was in November with 13,600 kW.

When examined in general, it is understood that a significant energy efficiency was achieved in all months in 2021 and 2022. There is a significant decrease in the electrical energy used in all months. Table 2 includes the energy efficiency status by departments of the SFR. It is seen that a significant energy efficiency has been achieved in all departments. The biggest gain was in the curing section with 94,246 kW. In Table 3, 40-item energy efficiency measures are given by SFR within the scope of the 2030 CO_2 reduction scenario operational approach.

The company's E-JIT activity is based on the principle of using only as much energy as necessary to produce the required product. In this way, a significant reduction in CO_2 emissions and energy costs is aimed. With the E-JIT activity, it is aimed to completely eliminate the energy wasted during use. In this framework, SFR has identified 5 main areas where energy is wasted.

4.1. Energy waste during operations

Energy losses may occur during operations due to faults in management. Not turning off the lights when not in use has been identified among these losses. It has been calculated that fluorescent lights left on for one hour a day on desks generate an additional cost of US$34.6 per year.

Failure to comply with the recommended temperature settings of air conditioning systems has also been identified as one of the energy loss areas in this context. It has been observed that reducing the air conditioner temperature from 28°C to 27°C increases energy consumption by 10%. In addition, it has been calculated that insufficient cleaning in the heating/cooling systems creates an annual energy cost of 1520 USD for a 100kW air conditioning system, while keeping the filters clean provides 15% energy savings.

4.2. Equipment running during non-production

This situation is defined as the energy losses caused by the equipment working although there is no production. It has been calculated that an annual energy loss of 3000kW occurs for a 7.5 kW pump due to the operators' failure to stop the coolant feeding pump for various reasons when there is no production.

Table 1. Electricity Consumption Data

Months	2019 (kW)	2021 (kW)	2022 (kW)	Difference (2019-2022) (kW)
January	155.570	99.366	94.398	61.172
February	164.608	104.307	100.135	64.473
March	156.355	79.524	77.138	79.217
April	135.328	82.398	80.750	54.578
May	159.173	71.372	64.235	94.938
June	152.567	82.904	77.101	75.466
July	192.216	131.816	125.225	66.991
August	127.970	86.736	85.001	42.969
September	172.762	96.289	92.437	80.325
October	125.598	86.599	84.867	40.731
November	116.051	103.470	102.435	13.616
December	124.218	107.663	105.510	18.708
Total	**1.782.416**	**1.132.444**	**1.089.232**	**693.184**
Energy Efficiency	36.47%	3.82%		

Reference: Mercimek, 2023: 57.

Table 2. Energy efficiency by factory divisions

	2019	2021	2022	Difference
Pressing	222.802	141.556	136.154	81.247
Body	187.154	118.907	114.369	68.247
Painting	204.978	130.231	125.262	74.747
Mount (Assembling)	169.330	107.582	103.477	61.747
Curing	258.450	164.204	157.939	94.246
Steam	240.626	152.880	147.046	87.746
Air sys.	151.505	96.258	92.585	55.248
Lightining	133.681	84.933	81.692	48.748
Pumping	213.890	135.893	130.708	77.997
Total	**1.784.435**	**1.134.465**	**1.091.254**	**649.972**

Reference: Mercimek, 2023: 57.

Table 3. Measures of Energy Saving

Cat.	Equipment	No	Precautionary Name
E-JIT (Energy- Just in Time)	Boiler	1	Close at-hand valves in unnecessary area
		2	Adjustment of air ratio
		3	Periodic inspection and diagnosis of steam strap
		4	Thorough steam leak repair
		5	Retainin warmth of piping and valve
		6	Removal of unnecessary piping
	Air-conditioning	7	Periodic cleaning of filter and heat exchange fin
		8	Thorough power off when not needed
		9	Automatic stop by air conditioner timer (external signal)
		10	Compliance with temperature setting
	Lighting	11	Use of natural illumination (skylights)
		12	Removal of unnecessary lighting
		13	Tum off the ceiling light which is double lighting
		14	Turn off when not needed
	Compressor	15	Close at-hand valves in unnecessary area
		16	Thorough air leak repair
		17	Periodic filter cleaning
	Fan, pump	18	Periodic strainer cleaning
		19	Linking pump & fan and production facility
	Other	20	Thorough power off during non-operation time
		21	Implementation of energy saving outage
Improvement of equipment efficiency	Boiler	22	Removal of large-sized (plant) boilers
		23	Heat recovery by feed water preheater (economizer)
		24	Installation of boiler number control device
	Air-conditioning	25	Removal of R22 refrigerant air conditioner
		26	Making the building glass highly insulated and heat shielding glasses
	Lighting	27	Change to LED light
	Compressor	28	Installation of inverter air compressor
		29	Installation of air tank
		30	Installation of compressor number control device
		31	Looping of main piping
		32	Change from air cylinder to electric cylinder
		33	Change air blow to blower (Motorized)
		34	Improvement of air blow gun efficiency
	Fan, pump	35	Automatic operation with fan/pump temperature
		36	Adjustment of water volume by changing the pump to the inverter equipped
		37	Adjustment of blast volume by changing the fan to the inverter equipped
		38	Use of high efficiency electric motor (IE3 or higher)
	Other	39	Heat insulation and retaining warmth of heat source equipment
		40	Transformer: Renewal to top runner system high efficiency type

Reference: Mercimek, 2023: 57.

For this reason, it is emphasized that all equipment should be kept closed when production is not in progress.

4.3. Waste due to excess supply

When more energy is supplied to the system than needed, losses due to excess energy occur. In order to prevent this situation, the water, air and steam pressure values in the production process must be adjusted correctly. It has been calculated that operating a 100kW air compressor with an extra pressure of 0.1 MPa causes an annual loss of 2170 USD. It has been found that it is possible to reduce the electricity consumption by about 7% by reducing the pressure by 0.1MPa. In this context, it is suggested that the pressure level required for the equipment should be investigated and the pressure should be adjusted downwards.

4.4. Waste due to leakage

Energy losses may occur due to leakages caused by equipment failure or faulty equipment. These leaks are defined as air leakage or heat loss.

It has been determined that the air supply system has an electricity consumption of 0.007-0.014 USD per 1 m3 of air and causes an electricity loss of 0.0011 to 0.0016 kWh in small air leaks and up to 0.11 kWh in large air leaks.

In terms of heat loss, it has been calculated that the gas, which costs 36.96 USD per year without heat retention, is wasted in a 100 mm pipe (1 m). By carefully insulating the areas with high heat dissipation, it is aimed to reduce the heat loss and thus the amount of gas usage. In Figure 3.1, the change in the thermal images of the pipes before and after insulation are given.

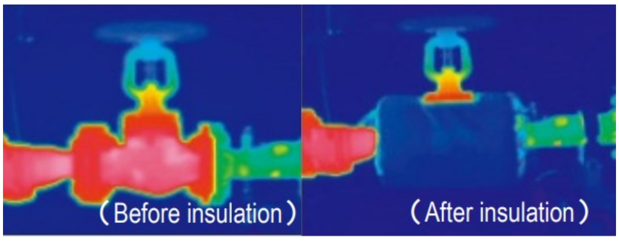

Figure 1. Effect of insulation

4.5. Waste while waiting (idling)

It is defined as the energy losses due to the fact that the machines are not working physically but still consuming energy. It has been calculated that there is an annual electricity loss of 1120 USD per 1000 personal computers when the personal computers in the offices are not unplugged.

On the other hand, in the facilities, if the control panel main power switches are not turned off and left on all night, it has been observed that the annual cost of electricity is approximately 46,000 USD.

Heating times stand out as another heat loss area. In the summer months, the heating period is shorter and a large loss occurs as the heating process is completed before the production starts. It has been calculated that the cost of heat lost in 1 hour of warming up in 1 unit is $73.9. For this reason, it has been determined that this loss can be prevented by starting the heating process later in the summer months.

5. Conclusion

Energy has been among the most important issues that countries benefit from in terms of gaining competitive advantage in the century. With the recent Russia-Ukraine war, the importance of energy has been understood much more. With the effect of war, especially in Europe, the energy crisis started. In this context, energy efficiency studies have accelerated to reduce energy use.

Today, many industrial organizations are working on energy efficiency. In addition, they started to establish solar and wind power plants in order to produce their own energy. In this study, the studies of SFR on energy efficiency were examined.

According to the data obtained, it has been determined that the factory saves approximately 693 thousand kW of electrical energy annually. Based on this value, it has been understood that as a result of the energy efficiency applications, an energy saving of 36.47% was achieved in 2021 compared to 2019. It was determined that the biggest gain was in the curing section with 94,246 kW.

In addition, according to the 2030 CO_2 reduction scenario, it has been determined that a significant reduction in CO2 emissions and energy costs is targeted by SFR. With the E-JIT activity, it is aimed to completely eliminate the energy wasted during use. The following savings have been revealed:

- As an example of energy losses experienced during operations, it has been calculated that fluorescent lights left on for one hour a day create an annual cost of 34.6 USD.
- It has been determined that 15% energy savings are achieved by keeping the air conditioner filters constantly clean.
- It has been calculated that an annual energy loss of 3000 kW occurs for a 7.5 kW pump due to the fact that the operators do not stop the operation of the coolant feeding pump for various reasons. For this reason, it is emphasized that all equipment should be kept closed when production is not in progress.
- It has been calculated that operating a 100kW air compressor with an extra pressure of 0.1 MPa causes an annual loss of 2170 USD. It has been found that it is possible to reduce the electricity

consumption by about 7% by reducing the pressure by 0.1MPa.

- It has been determined that the air supply has an electricity consumption of 0.007-0.014 USD per 1 m3 of air and causes an electricity loss of 0.0011 to 0.0016 kWh in small air leaks and up to 0.11 kWh in large air leaks.
- It has been calculated that there is an annual electricity loss of 1120 USD per 1000 personal computers when the personal computers in offices are not unplugged.
- • In the facilities, it has been observed that if the main power switches of the control panel are not turned off and left on all night, electricity loss with an annual cost of 46,000 USD occurs.
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Thanks to all these data, it is seen that a noticeable energy saving has been achieved within the SFR. The use of energy-saving lighting equipment in factory interior lighting is important for energy saving.

Buildings can be provided to produce their own energy with roof solar energy systems. In this way, it will be possible to reset the energy costs. It is foreseen that the external insulation application will also reduce the heating costs.

As a suggestion for future researchers, comparisons between companies can be made by examining the energy efficiency studies of companies in other sectors. In addition, energy efficiency studies and models for sectors can be made.

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