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Implementation of TEST toolkit in Al Rajeh factory as an Energy Management Tool

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DEDICATION

Our **parents**, everything we are because of you. Thank you for all that you have done for us. We will never be able to repay you for the time and love you showed us growing up, but know that we love and appreciate it all, every single day. Thank you for the countless memories.

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In the name of Allah, the Most Gracious and the Most Merciful. First and foremost, we would like to thank **Allah** for his blessings to complete our study journey.

Our boundless gratitude to our wonderful supervisor **Dr. Mohammad Al-Sayed** for bringing the weight of his considerable experience and knowledge to this project. His high standards have made us better at what we do.

Many thanks for our **family** and **friends** for their constant encouragement and support throughout the project.

ABSTRACT

Energy – its source, price, security, and efficiency- are important issues for the world. Energy management includes planning and operation of energy production and energy consumption units as well as energy distribution and storage. Objectives are resource conservation, climate protection and cost savings, while the users have permanent access to the energy they need. Resorting to energy management which is the process of tracking and optimizing energy consumption, is important to conserve energy sources as much as possible.

The rapid growth of industrial, and the huge growth of population have led to tremendous energy demand in Palestine in recent years, so we have to find ways to reduce the dependence on others, that's by reducing the load on power plants as fewer kilowatt hours of electricity are needed, which achieve by energy management. From this background, this research has started.

The idea of this project is to implement an energy management program according to the UNIDO methods for Al Rajeh factory which located in the city of Nablus. The methodology consists of four steps, where the first one consists of eight stages, and in this project, the last four stages were implemented.

A walk through the factory was done, in four departments (plastic, detergents, wipes, administration). The bills of 2021 were collected, whereas the electricity consumption was 447,858 kWh. In addition, the most consumption was from the cooling system that consider as the utilities, which are 3 chillers, and 2 cooling towers. Measurements of (currents, voltage, power) for each equipment was done by using multimeter. These measurements were felt in mapping tool that helps to understand the factory better. Then a comparison between measurements and bills was did to check the energy balance.

After that, a saving opportunities cards were did. These cards contain the ways of achieve saving by improving the energy efficiency. There were 5 cards felt, as follow, ‘Changing diesel forklift to electrical forklift’, ‘Purchase the plastic bottles from outside instead of producing them inside’, ‘Changing the cooling system equipment by a central chiller, and installing inverter (VSD)’, ‘Changing the cooling system equipment by two chillers, and installing inverter (VSD)’, and ‘Installing inverter (VSD) for each cooling equipment’. The annual of each card as follow: 12,130.8 ILS/year, 86,202.32 ILS/year, 5,338.63 ILS/year, 4,859.36 ILS/year, and 10,514.82 ILS/year, respectively.

An action plan that is a checklist for the steps or tasks you need to complete in order to achieve the goals you have set, was did. It depends on high savings, less SPP, and less risk. So, the action plan for this project is to ‘Purchase the plastic bottles from outside instead of producing them inside’, then ‘Changing the diesel forklift to an electrical forklift’.

NOMENCLATURE

UNIDO	United Nations Industrial Development Organization	NPO	Non-product output
TEST	Energy management tool	KPI	key performance indicator
VSD	Variable speed drive	RECP	Resource efficient and cleaner production
SPP	Simple payback period	NG	Natural gas
EnM	Energy management	LPG	Liquefied petroleum gas
LF	Load factor	GHG	Greenhouse gas
OPI	Operational Performance Indicator	IRR	Internal rate of return
NPV	Net present value	PV	Photovoltaic

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CHAPTER 1: INTRODUCTION

Overview

Government organizations, business and industries have all been under economic and environmental pressures in the last years, that’s because of the rapidly increasing in the energy demand. Energy saving has become an important action, where the energy management is an important tool to help in this issue.

In Palestine, the energy situation is improving in the west bank and is severe in Gaza strip. This complexity in the energy situation is due to scarcity of natural resources, high density population, bad political conditions, the insufficient grid, and the relatively low-income level. Palestine depends on other countries in electricity imports, and its fossil fuel imports for 87% ,100% respectively. To reduce these percentages, implementation of energy savings programs and projects in distribution, commercial, residential and industrial sectors are essential.

Energy management “EnM” involves conservation, analysis, and imperative actions that lead to a decrease in the system losses for efficient use of available conventional and renewable energy resources of the region.

EnM aims to protect the environment by restricting the prevailing climate changes resulting from fossil fuel burning. It also aims to optimize energy generation, distribution, and utilization to minimize energy cost without affecting quality. Therefore, EnM is involved in the assessment and identification of energy-saving opportunities along with the controlling and monitoring of the energy consumption.

There are many organizations that focus on energy and environment, UNIDO is an example. It's established by way of the General Assembly in 1966, UNIDO have become an UN-specialized agency in 1985 whose mandate is to sell business development and cooperation. UNIDO gives tailor-made solutions for the sustainable commercial development of developing international locations. It cooperates with governments, enterprise institutions, and the private industrial zone to construct commercial competencies for meeting the challenges and spreading the blessings of globalization of the enterprise.

To support its services, UNIDO has engineers, economists, and era and surroundings professionals in Vienna, as well as expert personnel in its community of investment promoting carrier places of work and area workplaces, which might be headed through UNIDO Regional and Country Representatives.

There is an online toolkit called "TEST" has been developed by way of the United Nations Industrial Development Organization (UNIDO) within the framework of the SwitchMed Program, an initiative funded by the European Union. The target users of the toolkit are practitioners and service providers working for the manufacturing industry interested in learning an integrated methodology (TEST) and a set of tools to help businesses improve their competitive advantage by adopting resource efficiency strategies and solutions. The purpose of this regional initiative is about promoting the shift toward sustainable production and consumption in seven Arab’s countries which are Palestine, Algeria, Jordan, Lebanon, Morocco, Tunisia, and Egypt. In addition, the occupying Zionist entity.

Our case is in Al Rajeh Detergents Factory, which is located in the industrial area in the city of Nablus. It was established in 1986. The factory area is 3000 square meters. On top of the factory there are 1200 square meters of solar energy that generates more than 400 kilowatts of electricity per day. The factory consists of several section: sales section, manufacturing, marketing and laboratory. The factory aims to provide chemical detergents products such as, Modhish, Dishwashing liquids, Wipes, Cloraj, and another 42 products, with high quality and good price to supply them to the local market, through distribution lines that reach most sectors of the local market.

Existing problem

Factories in general consume huge amount of energy for operating its systems. Existence of losses in the factory’s machines considered as a problem that needs immediate action. The main machines in the factory are chiller, compressor, pump, plastic machines, and water treatment plant. There are obvious losses from the compressors.

Objectives

1. Achieve the saving in the factory bills and consumption.
2. Schedule and arrange the way of operating the equipment.
3. Improve their productivity and increase their product or service quality.
4. Monitoring and measuring electrical energy consumption and collecting information.
5. Finding ways to save energy and estimating how much energy each method can save by systematic analysis of the measured values, to find and identify the waste of daily sources also calculate the amount of energy savings when using alternative methods.

CHAPTER 2: LETRATURE REVIEW

Current research points to a large energy efficiency potential in the industry which is still left unexploited. One of the most promising means of reducing energy consumption and related energy costs is implementing an energy management. [1]

Energy conservation in utilities has played a vital role in improving energy efficiency in the industrial, commercial and residential sectors. The electrical energy consumption in Palestine has increased sharply in the past few years and achieved by the end of 2001 to 10% per year. It is expected that this percentage will increase to about 12%. [2]

Smart manufacturing and data analytics can help in manufacturing sector, where the current scenarios transmission and data analysis from across the plant create manufacturing intelligence; it can be used to have a good impact across all side of operations. Predictive analysis helps that in a lot of ways in smart manufacturing. [3]

Related to energy management system (EMS), building energy management system (BEMS), industrial, company and factory energy management system (I/C/F/EMS); and EMS for heating, ventilation, air conditioning (HVAC) and refrigerating equipment, artificial lighting systems, motors and others (EMS for equipment). EMS for equipment) is analyzed to evaluate varied energy saving effects. Statistical results show that saving effects of BEMS increased from 11.39% to 16.22% yearly. Inversely, Regarding to EMS for equipment, there is no obvious trend but only the averaged saving effect can be reported. EMS for artificial lighting systems has the highest saving effect up to 39.5% in average. For HVAC and other equipment, energy saving effects are around 14.07% and 16.66% respectively. These energy saving performances are correlated with developed EMS functions. The key EMS functions could be identified from their developing progress for effective energy savings. [4]

The use of renewable energy sources as an alternative to fossil fuels and nuclear energy is a significant opportunity for reducing CO2 emissions. However, carbon emissions from electricity generation are dependent on the type of renewable energy source and the quantity of the electricity that is produced. [5]

The energy situation in Palestine, the efficient use of energy and energy conservation in industry is not in a better condition than most developing countries. So, they start or a beginning step toward the efficient use of energy and energy conservation in industry through conducting energy analysis of industrial consumption in Palestine and through conducting energy audits in some industries in Palestine. [6]

CHAPTER 3: METHODOLOGY

In this project, focusing on the problems in this factory was did by using an Excel sheet called ‘Mapping Tools’. It is an energy auditing tool, that’s a program into which energy data (current, power, voltage, PF, duty cycle, LF) that collected from the factory, are entered. It helps to know the potential for our work and where to achieve saving.

STEP 1.5 SETTING UP FOCUS AREAS

Understanding which areas of a production system have the greatest potential for improving resource efficiency requires the distribution of the NPO data from the company system boundary to individual resource/energy users. The latter may be identified as cost centers and/or production lines or steps, depending on the complexity of the company. This process will lead to identifying the focus areas for each of the priority flows identified in step 1.4, and to further improve the company’s information system for the next business year.

For energy flows, the cost allocation process can be based on three different levels of accuracy depending on the existing information system:

- Energy consumption estimates based on the nominal plate value of machines;
- Data collected during spot measurement campaigns;
- Real-time energy consumption from metering systems in place.

Water consumption at specific processes can similarly be estimated or measured. As for the allocation of material losses, this can be more challenging considering that even companies with cost accounting and production planning systems may not have this information in place for most material flows. Therefore, material losses at specific processes are often estimated in the first place and can be updated later if measurement campaigns are conducted.

This step will highlight the areas in the company (specific departments, production units, cost centers) that generate the most significant share of the total NPO costs. Benchmarking with international best available techniques or expert opinions can confirm whether specific areas with a high ratio of NPO costs also have significant potential for improvement and should be selected as focus areas. Note that another reason for deciding on a focus area is that it is a source of significant environmental and health risks – e.g. use of toxic substances. The chosen focus areas will be further analyzed in step 1.6.

The TEST Team should define Operational Performance Indicators (OPIs) for the selected focus areas (e.g. energy use per unit of production at the drying stage). These OPIs are to be included in the information system on flows (a monitoring system for regular data measurement and survey of process resource efficiency.

Calculating and recording the baseline for OPIs at this stage enable future performance monitoring and validation of RECP improvements at the company site. Note that the KPIs set at the company boundary level for priority flows cannot be used for monitoring real savings associated with an RECP measure, as several measures may have contributed to the improvements in the use of a specific material or energy flow.

STEP 1.6 REVEALING SOURCES AND CAUSES OF INEFFICIENCY

As the last level of the TEST diagnosis, this step centers on selected priority flows and focus areas and helps to identify the most cost-efficient RECP interventions, as it may not be feasible or worthwhile to analyze every action in detail.

The priority flows within the identified focus areas are analyzed in detail to disclose inefficiencies – the physical points where a production input becomes a loss (non-product output) – and understand the causes. These usually relate to several factors that drive material and energy use, including process input quality, specific process operating parameters e.g. temperature, throughput, speed, etc., features of the process technology, human behavior, and product design. Several widely applied tools can be used for cause analysis. Depending on the complexity of the selected focus areas, detailed material, and energy-mass balances can be required to model specific sub-processes, mapping all inputs (energy, water, auxiliaries, operating and packaging materials) and outputs of the focus area to understand all the causes of the losses.

Implementing this step of detailed analysis may require both expert appraisal and data analysis to understand what is actually happening within a specific part of the process. Data measurements are also useful for setting up the baseline and the Operational Performance Indicators (OPIs) at the level of specific processes, and these can be used for more accurate feasibility analysis of improvement options and/or for calculating real savings and performance improvements. It is recommended to install a permanent monitoring system for systematic monitoring of the resource efficiency performance of important sources of losses.

STEP 1.7 OPTIONS GENERATION AND FEASIBILITY ANALYSIS.

This step builds on the root causes of significant material and energy losses identified in the previous step. It starts by broadening the scope of potential solutions by generating a broad menu of possible options and then narrowing the menu down to an optimal set of feasible measures to be subjected to feasibility studies, as illustrated in the figure.

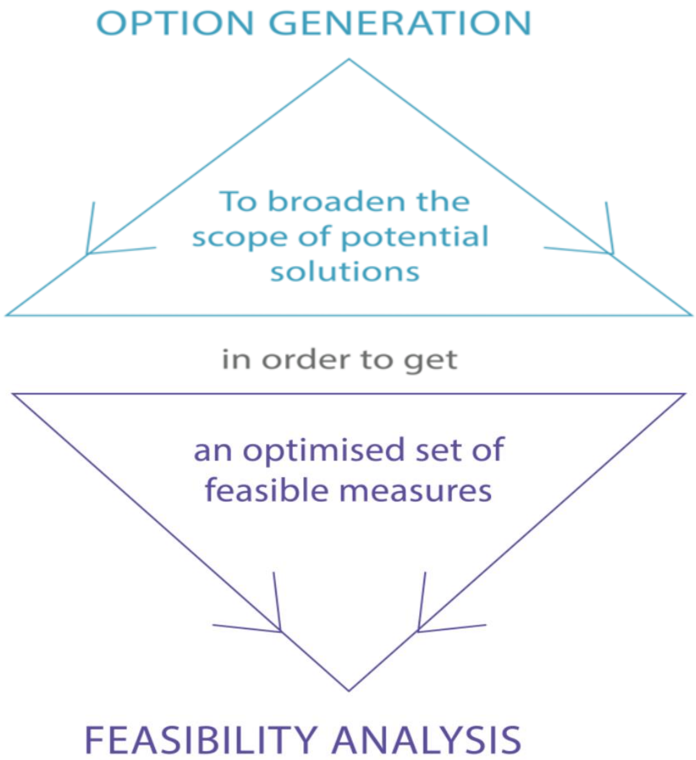

Figure 1. Developing improvement measures.

Options generation

Once the company diagnosis in step 1.6 has been completed, possible options for improvement can be generated effectively. A brainstorming approach should be used, where the participants should be encouraged to think "outside the box" as much as possible, and where the proposing of options, even radical ones, should be encouraged. Options can be explored according to the hierarchy shown in the figures below.

The TEST Team should first focus on identifying options that prevent NPOs from being generated in the first place or, failing that, minimize them (so-called reduction at source). Such options fall into the categories of good housekeeping, changing input specifications, improving process control, modifying equipment, changing technologies, modifying products, turning wastes into by-products, and onsite reuse and recycling of wastes.

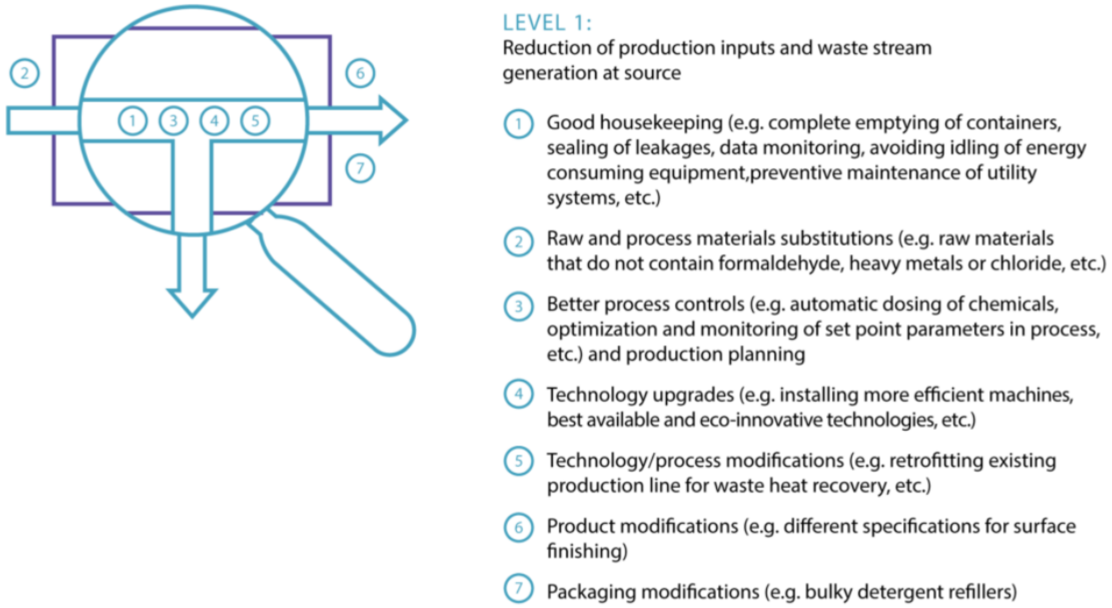

Figure 2. Options to reduction NPOs at source.

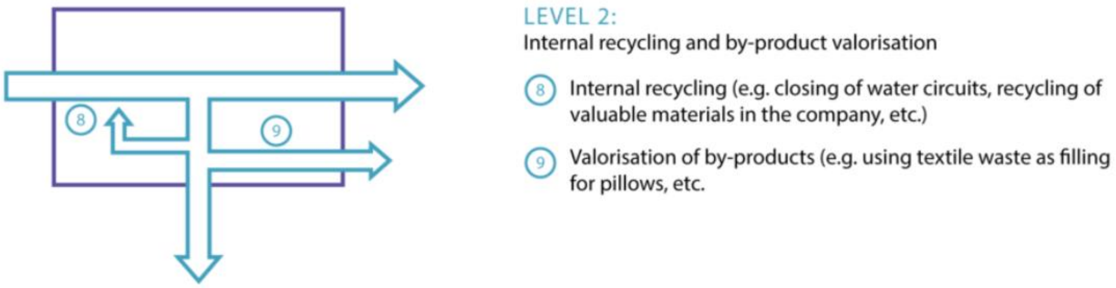

Figure 3. Techniques for internal recycling and valorization of by-products.

While external recycling leads to a reuse of a waste and thus a reduction in environmental impacts, it does not reduce NPO and it entails risks to the environment during transport off the site to a new site of use as well as in processing to make it reusable. This is why these techniques should be investigated at a later stage after the economically most feasible preventive solutions have been explored.

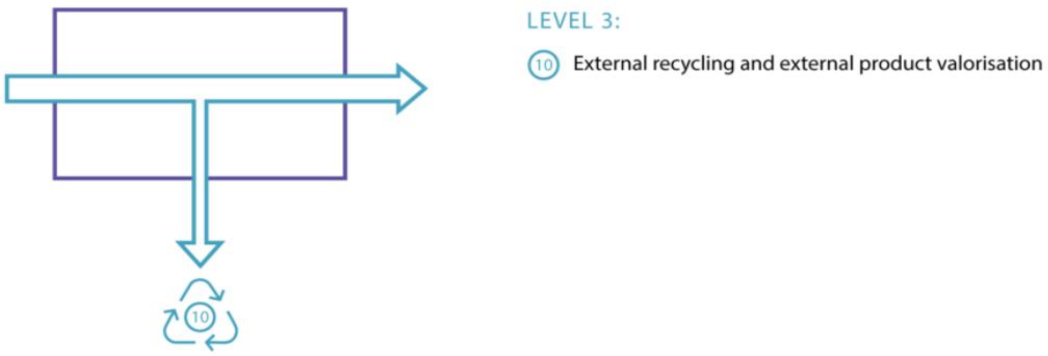

Figure 4. Techniques for external recycling and valorization of external products.

Pollution and waste treatment options (also called end-of-pipe solutions) should be investigated at the very end. While these kinds of solutions are often required to comply with emission limit values and waste management requirements, even after preventive solutions have been adopted, they require high capital expenditures, have continuing operational costs, and show no return on investment. By following this hierarchy, the TEST Team can substantially reduce, and in some cases eliminate, the investments and operational costs for end-of-pipe solutions.

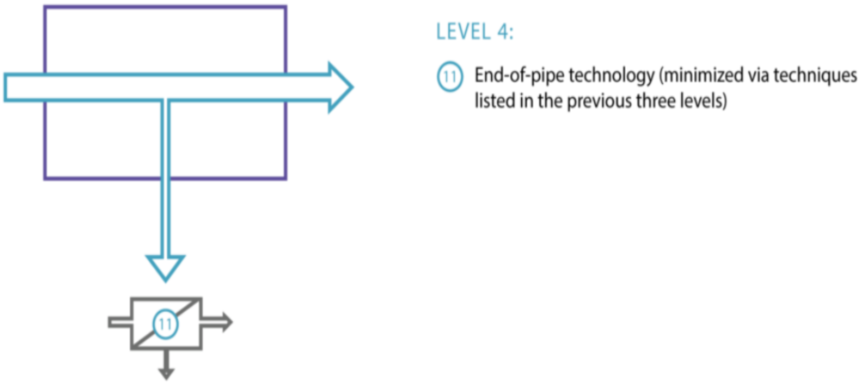

Figure 5. End of pipe technology.

Feasibility analysis

The TEST Team can now assess the feasibility of the options which they have identified. To do so, they will use technical, environmental and economic criteria in order to decide on the optimal set of options for the company to implement as part of its TEST action plan. The TEST Team should bring in the perspectives of different internal stakeholders as indicated in the figures below.

The TEST Team will first use technical and environmental criteria to exclude options that might have an adverse impact on product quality or might cause cross-media environmental side effects that could potentially offset the expected environmental benefits.

For those options surviving the technical and environmental assessment, the TEST Team will carry out a cost-benefit analysis. This analysis will quantify the economic savings from implementing each option, the capital expenditures required to implement the option, the change in operating costs brought about by implementing the option, and finally the return on investment. With respect to the economic assessment, options can be classified into three main categories:

1. Good housekeeping measures, requiring little or no cost to implement;
2. Low-medium cost measures, which can be implemented using the company's own technical and financial resources;
3. High cost measures that might require external financing. These measures normally entail an initial prefeasibility study and a subsequent more complex technical and financial appraisal that is often carried out by the company.\

Resource efficiency criteria can assist companies in optimizing basic technological parameters and identifying the most appropriate technology providers from a range of suppliers on the market.

The outcome of the feasibility analysis is the "savings catalogue", which the TEST Team will submit to top management for their review and approval. This provides the technical description and the key economic and environmental indicators for the set of feasible improvement measures which the TEST Team recommends to be implemented. This set of measures is usually a mix of good housekeeping measures, measures to improve operational control, modifications of the existing technology, as well as investment in new equipment.

Figure 6. Basic requirements for a new technology investment based on different stakeholders' perspective.

STEP 1.8 – ACTION PLAN

Companies often do not realize that the actual costs of the waste and pollution which they generate are not just comprised of disposal fees, treatment and equipment costs, but they also include the costs of purchasing materials that are turned into waste or excess energy. These costs are called "non-product output" costs (NPO costs) and are, on average, one order of magnitude higher than the costs for waste disposal and emissions treatment.

Priority flows are selected based on the following criteria:

- Total economic loss due to the inefficient use of specific material, water or energy flows (NPO costs).
- Potential for monetary and physical savings of material, water or energy (benchmarking is performed in order to estimate the magnitude of the realistically potential savings for specific flows).

The total inputs and outputs from the previous business year are collected in both volume and monetary value to complete the balance. Losses of inputs (materials, water and energy) and related costs are estimated. The material inputs are broken down into raw, auxiliary and packaging materials, which end up as products, waste or emissions, but the goal is to define the baseline of the total NPO costs and to record improvement options for the information system so there is better data available for the coming accounting periods.

As part of this step, the TEST Team can initiate the information system for resource efficiency for the selected priority flows, by:

- Setting up key performance indicators (KPIs) for each priority flow.
- Calculating the baseline for the KPI.
- Formulating an objective for each priority flow and setting up a specific target.

In the final step of the planning phase, the TEST team presents the savings catalogue to the top management and subsequently, the company decides which of the proposed actions are to be implemented based on internal priorities and resources.

In some cases, the management requests that certain measures are subjected to further study of their technical-financial aspects before they take a final decision. The TEST Team is encouraged to record all feasible measures in the savings catalogue, including those that have been rejected by top management, as they could be relevant for implementation at a later stage.

At the end of the internal review and consultation process, the TEST Team will formalize the TEST action plan. As part of the TEST action plan, the TEST Team should establish a monitoring plan to measure the real savings from implementation. the TEST Team should define indicators and set up a cost-effective monitoring system for both consumption and driving factors. This is the final element of the overall information system for resource efficiency that has been developed step by step throughout the TEST methodology.

Finally, after step 1 the company must be containing an information system and this system is important for continuous improvement of the company's performance against objectives and targets defined in the RECP policy. The information system is involved of several elements, such as: a set of resource efficiency indicators linked to important flows at the level of the whole company. Routine procedures for measuring, recording and analyzing specific data in the production and accounting departments, installed measurement devices (both software and hardware), a well-defined monitoring plan with frequency and responsibilities for monitoring.

CHAPTER 4: FACTORY DESCRIPTION

In ‘Planning’ step, there are eight stages, for the second graduation project, the last four steps which are setting up focus areas, revealing sources and causes of inefficiency, options generation and feasibility analysis, and action plan will be applied.

In the first, understanding the process is an important for detecting the problems in the manufacturing process. Due to bad operational behavior and poor planning, there are many losses in factories, which means there are high opportunities to save energy, and resources by modifying the behavior of operating manufacturing processes, or by rearranging the layout of the factories.

In Palestine, the factories at the beginning are usually small and then expand in the future, as a result of the increase in demand, often this may lead to poor factory layout.

Bad factory layout may make the distribution system long, which increases the possibility of loss, and thus leads to increase in electrical consumption. In addition, this may lead to increase the transportation distance of materials within the factory through the forklift, and thus lead to increase the fuel consumption.

In Al Rajeh factory case, the factory consists of two parts, a wipes section and a detergents section. The layouts of the ground floor, first floor of the detergent section, and the wipes section are shown below in figure 7,8, and 9, respectively. The factory consists of several lines which are production line, packaging line, and distribution line. The layout of the factory is good, whereas the production line layout is like a loop where the input and the final product output are in the same place. In addition, the raw materials for each section are transported through internal elevators, and each raw material has a special pump. So, there is almost no increase in consumption resulting from bad factory layout.

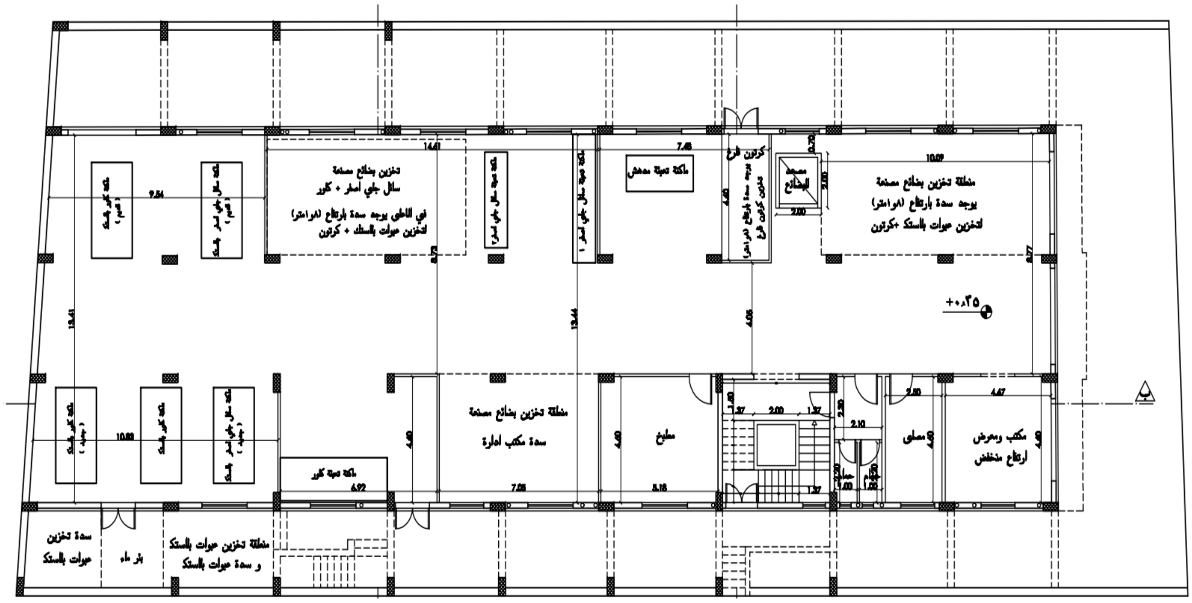

Figure 7. Detergent section ground floor layout.

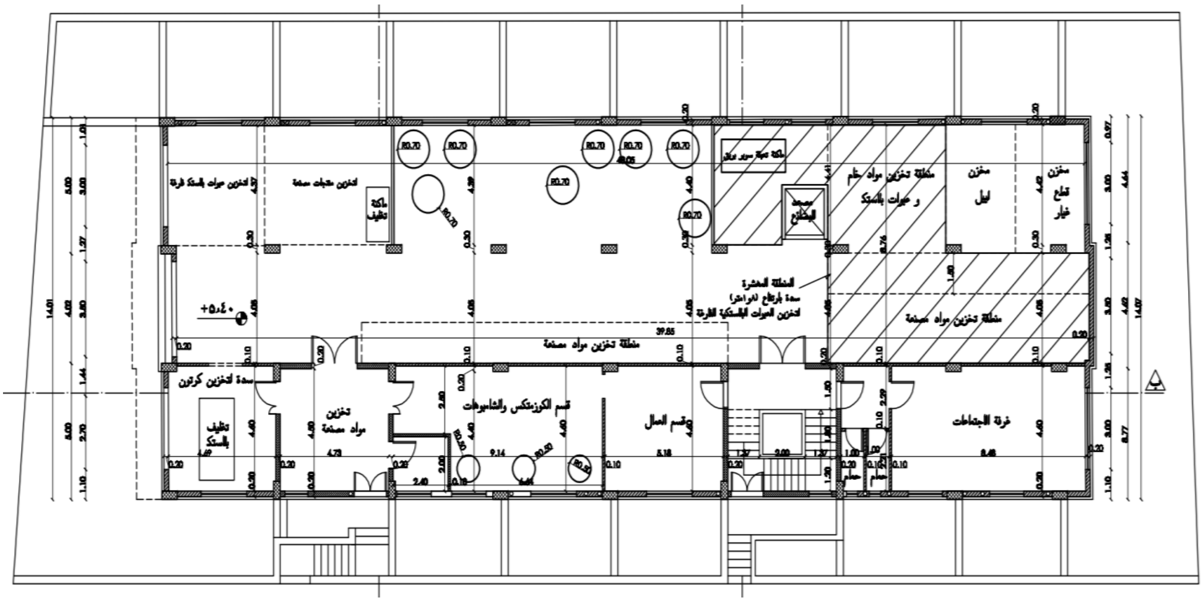

Figure 8. Detergent section first floor layout.

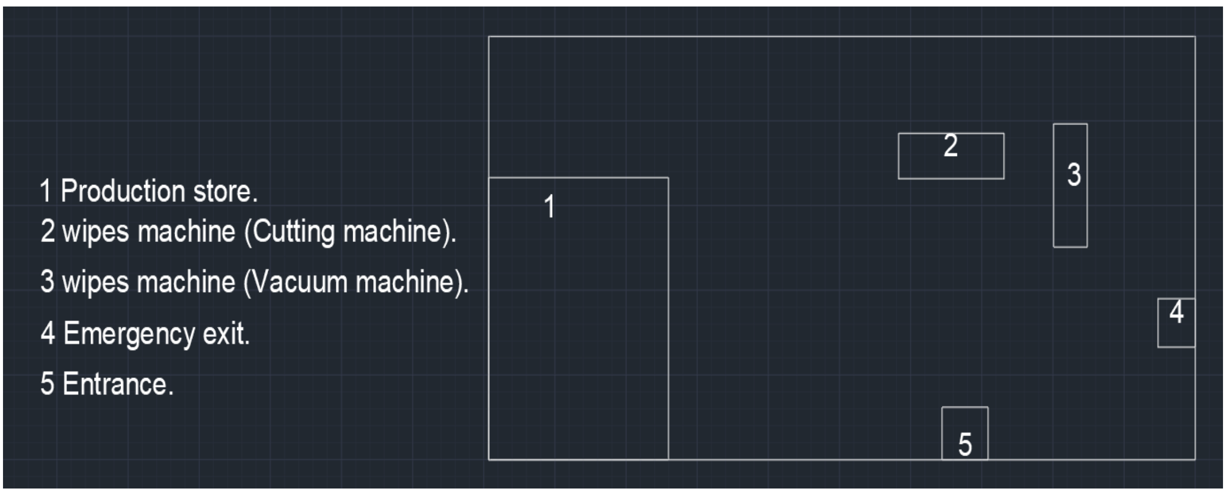

Figure 9. Wipes section layout.

Beginning with the setting up focus areas, as mentioned before it has a tool called mapping tool, which is an excel tool that divided for three sections. First, the registration sheets that used for register the consumption of electricity, oil, NG, LPG, KPI, and mapping of annual energy consumption. Second, results and diagrams that shows the results of the first section in many figures and tables. Third, greenhouse gas calculator, that used to calculate the carbon dioxide emissions from energy use and process.

To start filling the mapping tool, the facility has to be divided into sections. In our case, the factory is divided into four sections which are administration, plastic process, wipes process, and detergents process. Each process must be studied to know how to deal with it. Starting in administration department, it contains 3 offices, each has electrical appliances that is shown in table 1 below. This department is powered by on off-grid PV system.

Table 1. Types of electrical appliances in the administration department.

Office name	appliances	Rated power (W)	Number of units	Operating hours (h)
Manager room	Refrigerator	150	1	24
	PC	70	1	8
	TV	60	1	2
	Light	15	2	5
	AC	2000	1	10
Executive director	Refrigerator	87	1	24
	TV	60	1	2
	Telephone	7	1	1
	PC	70	1	8
	Printer	40	1	1
	Paper cutting machine	750	1	0.25
	Light	7	15	5
	AC	1500	1	10
	Water cooler	600	1	24
Meeting room	Light	7	34	2
	AC	1000	1	2

Lap	Printer	40	1	1
	Refrigerator	87	1	24
	PC	70	1	8
	Electrical furnace	1000	1	1
	Light	14	3	10
	AC	1000	1	10
Administration building	Light	7	24	5

In plastic production process, there are three stages which are raw material's storage, plastic production, and final product's storage. In table 2 below, types of technology that used in each stage. The process of plastic production as follow, the raw plastic is fed into the plastic machine, this machine has a heater for melt the raw plastic. After that, the melted plastic is getting inside the blowing machine, that depend on the compressed air in doing this task. Cooling system is a part of this process, by using chiller, and cooling tower to cool the machine. If there is any damage in the output plastic, it will pass through shredder then the crushed plastic can be used again as a raw plastic. The process flow chart is shown in figure 10 below.

Table 2. Technology used in plastic production process.

Raw material's storage	**Plastic production**	**Final product's storage**
Lighting	Air compressor	Lighting
Forklift	Chiller	
	Cooling tower	
	Air dryer	
	Blowing machine	
	Shredder machine	
	Lighting	
	Forklift	

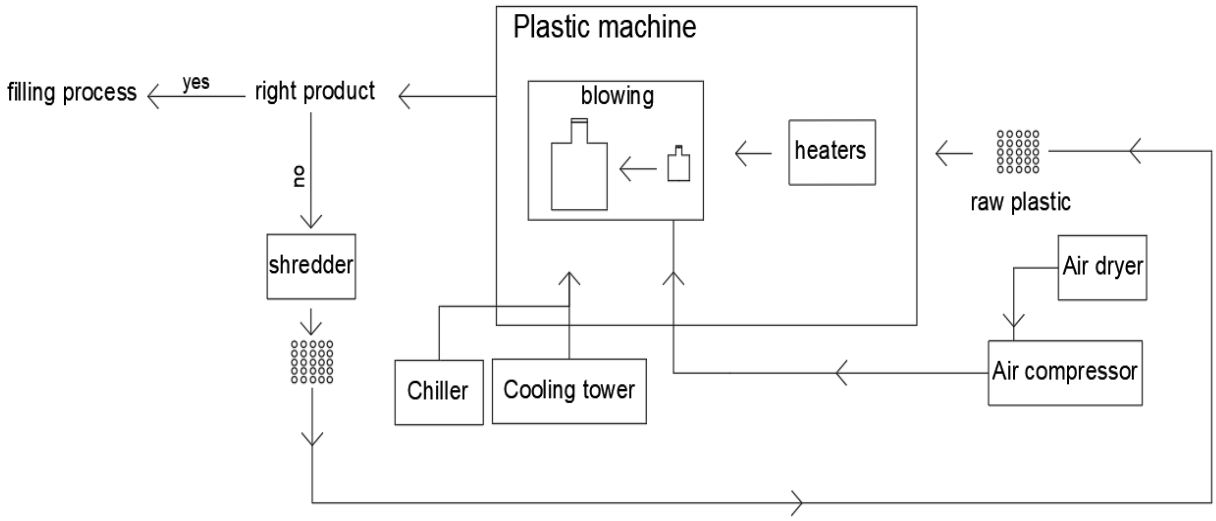

Figure 10. Plastic production process's flow chart.

In wipes production process, there are three stages which are raw material's storage, wipes production, and final product's storage. In table 3 below, types of technology used in each stage. There is a machine in which a device is drawn air in to the interior through pieces called air selectors, and then distributed to pistons located inside the machine, this piston is connected with the cutting materials. So, the compressed air is used for cutting the wipes to small pieces. This process is accompanied by the removal of hot air from the machine, in addition to exist of an isolated room around the hot air outlet, which is used to heat raw materials that freeze in the winter, that is instead of creating a heating room that runs on electricity. The process flow chart is shown in figure 11 below.

Table 3. Technology used in wipes production process.

Raw material's storage	**Wipes production**	**Final product's storage**
Lighting	Air compressor	Lighting
Forklift	Vacuum machine	
Firefighting system	Cutting machine	
	Lighting	
	Ventilation	
	Forklift	

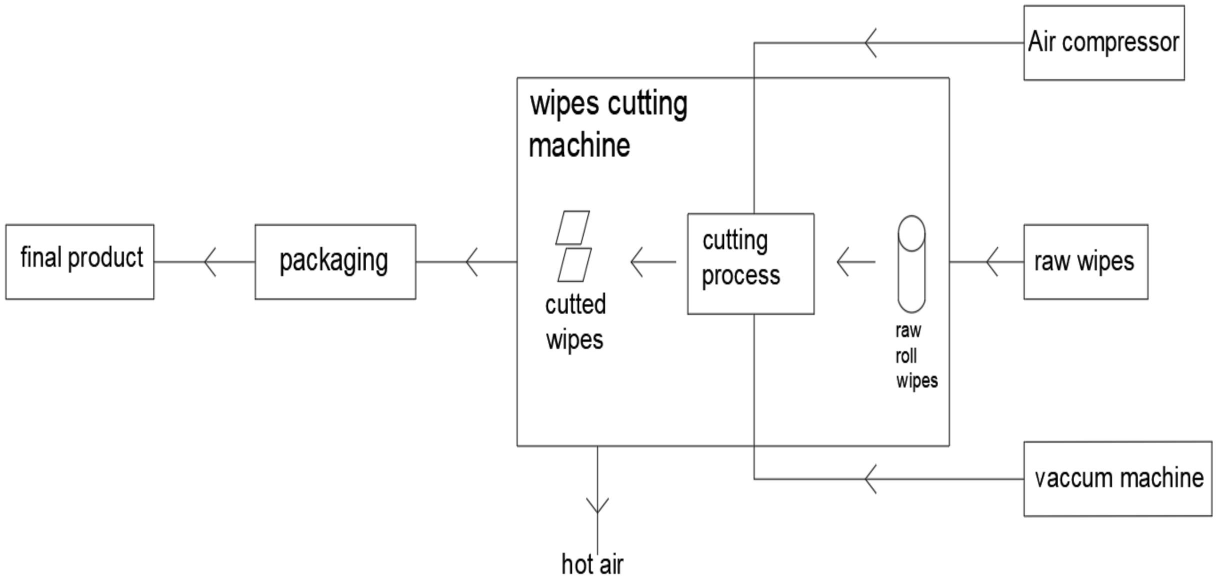

Figure 11. Wipes production process's flow chart.

In detergents production process, there are five stages which are water treatment process, raw material's storage, detergents production, primary product's storage, and secondary product's storage. In table 4 below, types of technology used in each stage. The process of detergents production as follow, the water gets inside water treatment plant, then it will be going to the mixer simultaneously with the raw material that is also pumped with their special pumps. After that, the filling process will be done by using compressed air. Then the packaging process is the final stage. The process flow chart is shown in figure 12 below.

Table 4. Technology used in detergents production process.

Water treatment	**Raw material's storage**	**Detergents production**	**Primary product's storage**	**Secondary product's storage**
Pumps	• Flammable material: Forklift AC	Pumps	Lighting	Lighting
Softener plant		Mixers		Forklift
lighting		Lighting		Shrink machine
		Ventilation		
	• non-flammable material: Forklift Lighting			
	• Powder material: Forklift AC			

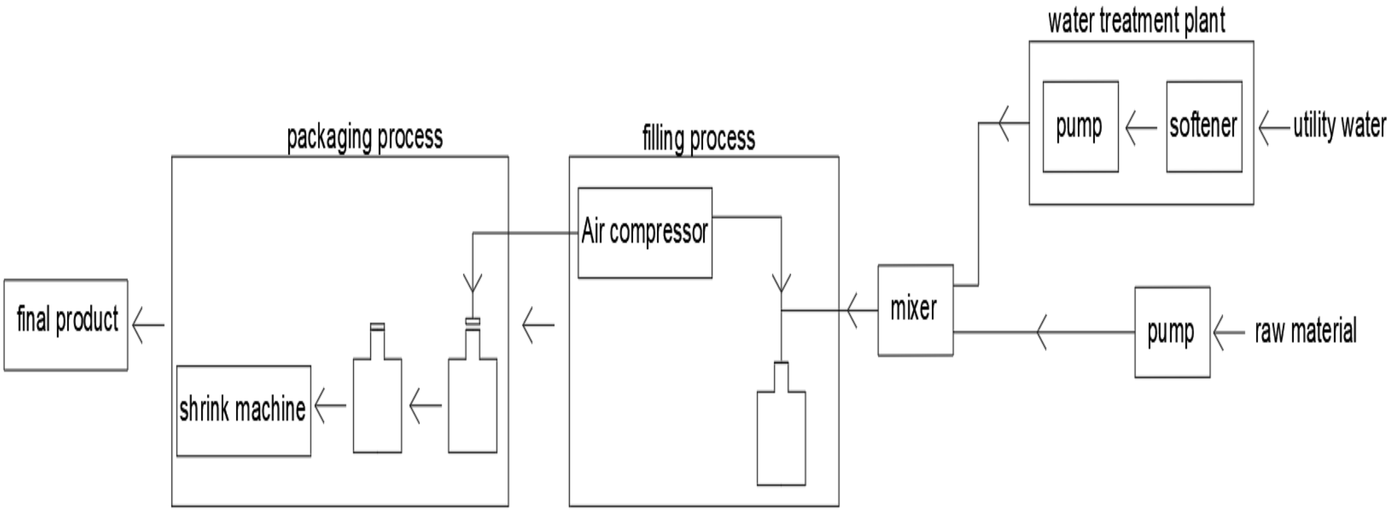

Figure 12. Detergents production process's flow chart.

Most of the factories in Palestine don't have a complete information system. The information systems contain stock management system, cost accounting system, and production planning. If a stock management system is in place, this would be a useful source of recordings of the volumes of materials purchased and used for production. Stock management is often not installed consistently and does not provide actual aggregate amounts in volumes by raw material categories or does not trace operating materials. In cases where cost accounting and production planning are established mostly larger companies, these are valuable sources of information and should be used to check consistency of material flows recorded for the fiscal year. The only information system available in all companies is the financial accounting system, that is contain the annual or monthly bill for the facility in general.

In our case, there is no information system in the facility. So, the annual or monthly amount of input and output materials that is not known precisely, and this constitutes a difficulty in studying the flow of each product. There was an obstacle in understanding the exact condition of the plant, that's because the production quantities are not know precisely. The production quantities were estimated based on electrical consumption. Knowing the consumption and production accurately helps to reach the problems that occurred in some months and try to solve them. In addition, it helps to know what is the base consumption, and try to reach the highest production with the lowest possible consumption. The relation between the consumption in kWh/month, and the production in ton for the wipes section, detergents section is shown in figure 13, and 14, respectively.

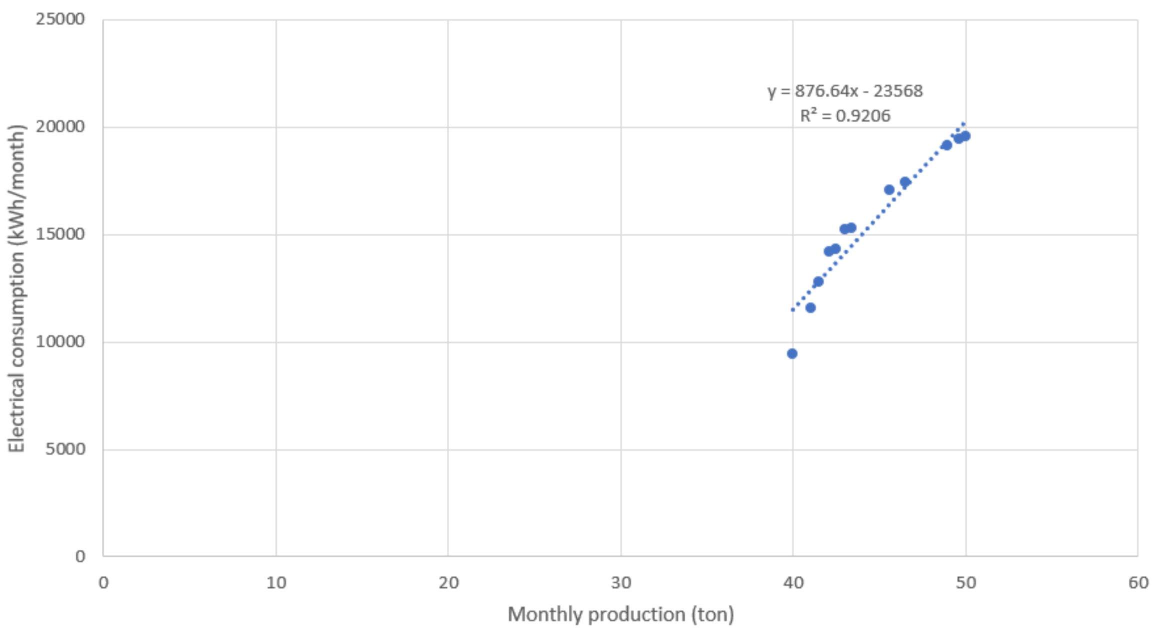

Figure 13. The relation between the consumption, and the production for the wipes section.

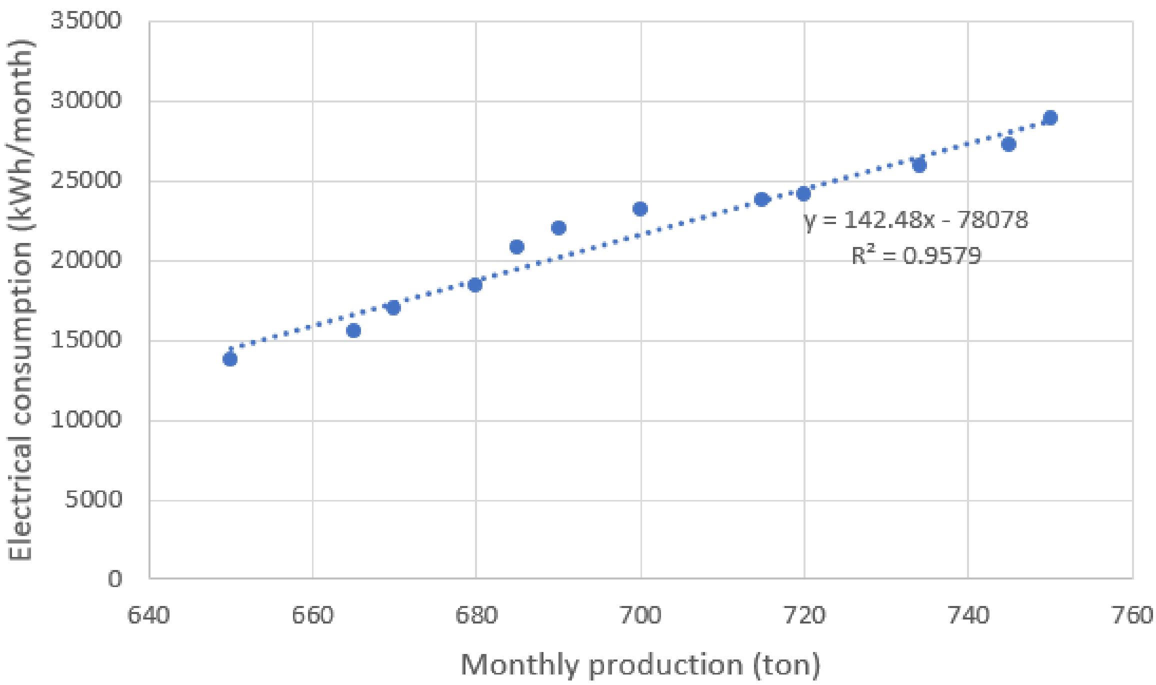

Figure 14. The relation between the consumption, and the production for the detergents section.

After dividing the facility sections, there were four sections which are administration, plastic process, wipes process, and detergents process. The summary of factory sections is show below in table 5, and the mapping tool was filled as shown in table 6 below. The measurements of electrical power were taken by clamp meter. In addition, thermal camera was used to check the insulation, and the hot spot areas of the machines.

Table 5. summary of factory sections.

Building	Function/ Department	Process	Energy Form	Technology	Mode of Operation
smooth	Zone S	-not a process-	Electricity	Lighting	Mixed
plastic	Zone P	Raw storage s	Steam	Heating	Continuously
detergents	Zone D	S production	Gas	Motors	On-off
Administrator	Admin	Storage for marketing s	Oil	Electronics	Valve/damper
	Utilities	Raw storage p	District Heating	Cooling	VSD
		P production		Compr. Air	
		Storage for marketing p			
		Raw storage f			
		Raw storage non-flammable + powder			
		D production			
		Storage for marketing 1+2 d			
		AC + light+ electrical equipment			

Table 6. Mapping of annual energy consumption.

Description (free text)	Building	Function/ Department	Process	Energy Form	Technology	Mode of Operation	Max Power Consump. [kW]	Load Factor [%]	Number of Units	Operational Hours [h]	Duty Cycle [%]	Energy Consumption [kWh/year]
Lighting	smooth	Zone S	Raw storage s	Electricity	Lighting	On-off	0.020	100	20	2,304	100	922
Fork lift	smooth	Zone S	Raw storage s	Electricity	Motors	On-off	9.200	100	1	2,304	100	21,197
Air Comp. 1	smooth	Utilities	S production	Electricity	Compr. Air	VSD	4.700	100	1	2,880	100	13,536
Vacuum	smooth	Zone S	S production	Electricity	Motors	On-off	1.080	100	1	2,304	100	2,488
cutting machine	smooth	Zone S	S production	Electricity	Motors	On-off	4.800	100	1	2,880	100	13,824
lighting	smooth	Zone S	S production	Electricity	Lighting	On-off	0.250	100	4	2,304	100	2,304
Lighting	smooth	Zone S	Storage for marketing s	Electricity	Lighting	On-off	0.007	100	68	2,304	100	1,097
Lighting	plastic	Zone P	Raw storage p	Electricity	Lighting	On-off	0.250	100	13	2,304	100	7,488
Air Comp. 2	plastic	Utilities	P production	Electricity	Compr. Air	VSD	30.400	100	1	2,736	100	83,174
Chiller1 & 3	plastic	Utilities	P production	Electricity	Cooling	Continuously	9.600	100	2	2,880	100	55,296
Air Drier	plastic	Zone P	P production	Electricity	Heating	On-off	1.250	100	1	2,736	100	3,420
Cooling tower 1&2	plastic	Utilities	P production	Electricity	Cooling	On-off	2.760	100	1	2,880	100	7,949
Blowing machine(cloraj)	plastic	Zone P	P production	Electricity	Heating	On-off	7.300	100	2	3,456	100	50,458
Lighting	plastic	Zone P	P production	Electricity	Lighting	On-off	0.020	100	22	2,304	100	1,014
shredder(big)	plastic	Zone P	P production	Electricity	Motors	On-off	1.000	100	2	478	100	956
Chiller 2	plastic	Zone P	P production	Electricity	Cooling	Continuously	4.100	100	1	2,880	100	11,808
Lighting	plastic	Zone P	Storage for marketing p	Electricity	Lighting	On-off	0.100	100	1	2,304	100	230
Lighting	detergents	Zone D	D production	Electricity	Lighting	On-off	0.030	100	7	2,304	100	484
Lighting	detergents	Zone D	Raw storage non-flammable +powder	Electricity	Lighting	On-off	0.007	100	62	2,304	100	1,000
Mixer 2	detergents	Zone D	D production	Electricity	Motors	On-off	0.570	100	1	864	100	492
Mixer 1	detergents	Zone D	D production	Electricity	Motors	On-off	0.470	100	10	864	100	4,061
pump	detergents	Zone D	D production	Electricity	Motors	On-off	0.390	100	2	432	100	337
Lighting	detergents	Zone D	Storage for Marketing 1+2 d	Electricity	Lighting	On-off	0.250	100	4	2,304	100	2,304
Shrink machine	detergents	Zone D	Storage for marketing p	Electricity	Motors	On-off	1.120	100	1	288	100	323
Softener	detergents	Zone D	D production	Electricity	Motors	On-off	1.350	100	2	1,728	100	4,666
Ventilation	smooth	Zone S	S production	Electricity	Motors	On-off	3.500	100	2	2,880	100	20,160
elevator 1	smooth	Zone S	S production	Electricity	Motors	On-off	1.800	100	1	144	100	259
Blowing machine (modhesh)	plastic	Zone P	P production	Electricity	Heating	On-off	4.100	100	1	3,456	100	14,170
blowing machine (washing dish)	plastic	Zone P	P production	Electricity	Heating	On-off	11.890	100	2	3,456	100	82,184
shredder(small)	plastic	Zone P	P production	Electricity	Motors	On-off	0.500	100	1	478	100	239
Obada AC + router	smooth	Zone S	Raw storage s	Electricity	Cooling	On-off	1.012	100	1	288	100	291
elevator 2	detergents	Zone D	D production	Electricity	Motors	On-off	0.900	100	1	288	100	259
cameras	Admin.	Admin	Ac+light+eq	Electricity	Electronics	On-off	0.009	100	60	8,760	100	4,730
												413,120

From table 6, the total actual electrical measurements were 413,120 kWh/year, while the electricity bills for 2021 that shown below in table 7, the total electrical consumption was 447,858 kWh/year, and annual energy generated from the PV system was 170,325 kWh. The electricity consumption, and PV generated power are shown in figure 15 below.

Table 7. Electricity bills of 2021.

Electricity Summary								Day Units		PV Generation
2021	**Total Consump-tion**	**Total Tariffed Cost**	**Total Other Charges**	**Total Cost**	**Average Unit Cost**	**GHG Emissions**	**Target Consump-tion**	**No. of Units**	**Cost / Unit**	**No. of Units**
	[kWh]	**[ILS]**	**[ILS]**	**[ILS]**	**[ILS/kWh]**	**[tCO_2]**	**[kWh]**	**[kWh]**	**[ILS/kWh]**	**[kWh]**
Jan	22,486	17,427	0	17,427	0.775	18.5	0	31,120	0.560	-8,634
Feb	14,372	12,981	0	12,981	0.903	11.8	0	23,181	0.560	-8,809
Mar	24,238	19,675	0	19,675	0.812	19.9	0	35,134	0.560	-10,896
Apr	14,647	18,250	0	18,250	1.246	12.1	0	32,590	0.560	-17,943
May	9,076	16,678	0	16,678	1.838	7.5	0	29,782	0.560	-20,706
Jun	17,966	21,507	0	21,507	1.197	14.8	0	38,405	0.560	-20,439
Jul	23,020	24,062	0	24,062	1.045	18.9	0	42,968	0.560	-19,948
Aug	23,188	23,041	0	23,041	0.994	19.1	0	41,144	0.560	-17,956
Sep	34,129	27,134	0	27,134	0.795	28.1	0	48,453	0.560	-14,324
Oct	33,816	26,093	0	26,093	0.772	27.8	0	46,594	0.560	-12,778
Nov	27,469	20,829	0	20,829	0.758	22.6	0	37,194	0.560	-9,725
Dec	33,125	23,124	0	23,124	0.698	27.3	0	41,293	0.560	-8,168
Total	**277,533**	**250,800**	**0**	**250,800**	**0.904**	**228.4**	**0**	**447,858**	**-**	**-170,325**

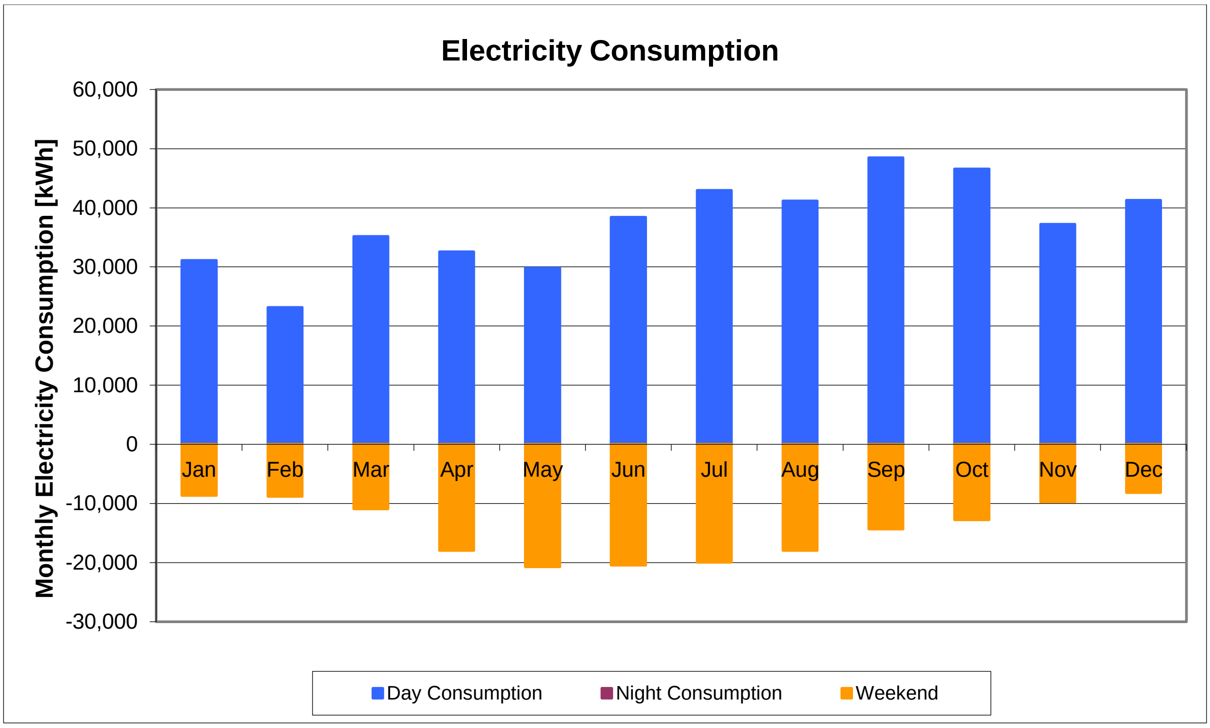

Figure 15. Monthly electricity consumption, and PV generated energy.

Energy Balance between actual measurements and real electricity consumption was did, and there is a difference equal to 8.4%. This diffidence is an indicator that most of the machines was measured, and taking an instantaneous measure for some of the machines were wrong idea.

CHAPTER 5: RESULTS

The results of filling the electrical consumption mapping tool are to know where is the highest electrical consumption process, and to the most energy source that used in the facility, to try to reduce them. The electricity as a source of energy is covered about 87% of the total energy source used in the factory, while the diesel oil was about 13%, as shown in figure 16 below. The distribution of electricity usage in the factory departments is shown figure 17 below. From the figure, the highest consumption was from the plastic production department.

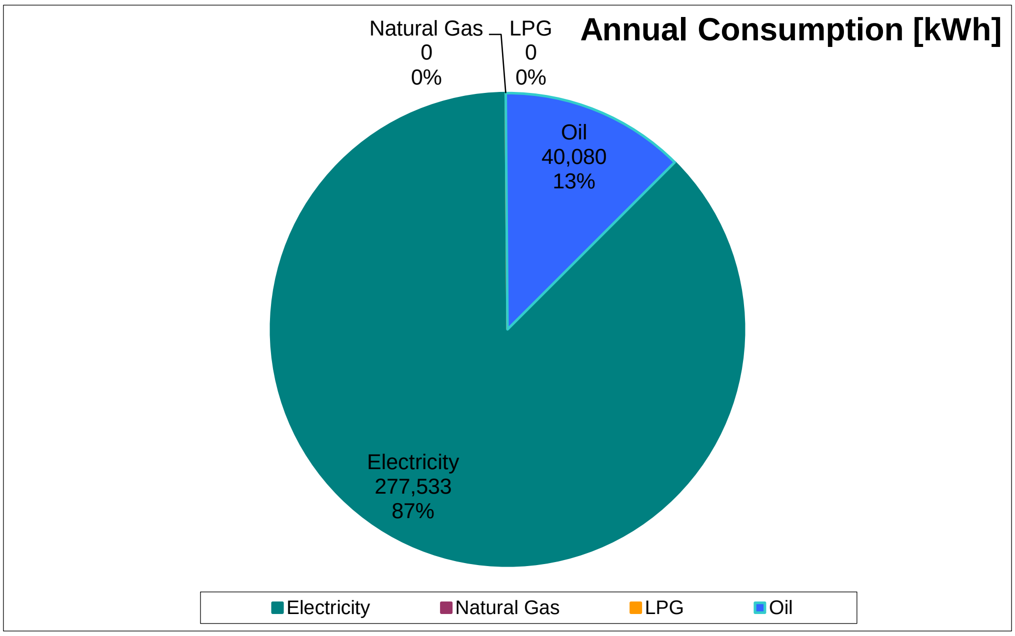

Figure 16. Percentage of source of energy used in the factory.

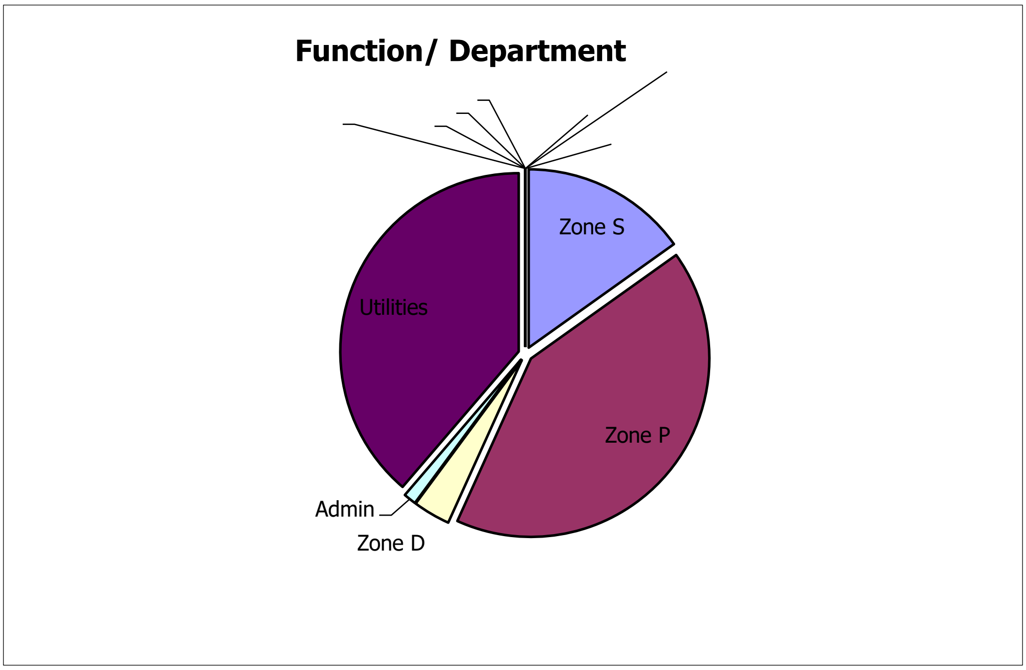

Figure 17. Distribution of electricity usage in the factory departments.

The Opportunities for saving in Al Rajeh factory are: ‘Changing the diesel forklift to an electrical forklift’, ‘Purchase the plastic bottles from outside instead of producing them inside’, ‘Changing the cooling system equipment by the central chiller, and installing an inverter (VSD)’, ‘Changing the cooling system equipment by two chillers, and installing inverter (VSD)’, ‘Installing inverter (VSD) for each cooling equipment’. To be mentioned, the saving catalogue cards that contain the calculation steps are in the appendices.

1. Changing the diesel forklift to an electrical forklift

In this factory, there are one diesel forklift and one electrical forklift. The idea is to change diesel to electrical, to have two electrical forklifts in the end. This approach will achieve savings about 12,130.8 ILS/year. In the same time, the CO_2 emissions will reduce by 15.55 tCO2/year.

2a. Purchase plastic bottles from the outside instead of producing them inside.

The production of plastic needs support from many utilities machines, which are cooling systems, and compressors. In this factory, there are 3 chillers and 2 cooling towers that are used to cool 5 plastic production machines. These machines consumed energy a lot. So, the idea is to stop producing plastic bottles of (chlor, Modhesh, dishwashing liquid) and to purchase it from local plastic factories.

Therefore, the 5 plastic production machines (2 for chlor bottles,2 for dishwashing liquid bottles, and one for modhesh bottles), two cooling towers, 3 chillers, and 3 shredders will be stopped. In addition, the compressor load will decrease to 50%, since it’s used to operate the plastic machine especially for blowing the bottles, moreover, it’s used for the packaging process. This approach will achieve saving about 86,202.32 ILS/year, In the same time, the CO_2 emissions will reduce by 217.8 tCO2/year.

In addition, by removing all machines, a 200 m^2 will be available. It can be used for increasing the production capacity, or it may offere for rent, it will gain 5,000 ILS/month (60,000 ILS/year). In addition, the 6 employees may work in the new production area, if it is chosen. Furthermore, the plastic machines, cooling tower, and chillers may offer for sale with a price of 250,720 ILS.

2b. Changing the cooling system equipment by central chiller, and installing inverter (VSD).

The production of plastic needs support from many utilities machines, which are cooling systems, and compressor. In this factory, there are 3 chillers and 2 cooling towers that supply a cooling load equal to 24.83 Ton (cooling). These utilities used to cool 5 plastic production machines. So, the idea is to change this equipment by a CSD water chiller that cover about 30 Ton (cooling), to prevent the existing of chilling shortage, and installing an inverter on chiller. This change help to reduce the electrical consumption, and to reduce the maintenance cost. This approach will achieve saving about 5,338.63 ILS/year, In the same time, the CO_2 emissions will reduce by 1.96 tCO2/year. Furthermore, the chillers may offer for sale with a price of 26,320 ILS.

2c. Changing the cooling system equipment by two chillers, and installing inverter (VSD).

The production of plastic needs support from many utilities machines, which are cooling systems, and compressor. In this factory, there are 3 chillers and 2 cooling towers that supply a cooling load equal to 24.83 Ton (cooling). These utilities used to cool 5 plastic production machines. So, the idea is to change this equipment by Two CSD water chiller that cover about 30 Ton (cooling), and installing inverter on each chiller. To be mentioned, a 20-ton chiller will be purchased and the remaining 10 tons will be covered by one of the chillers that exists in the factory. This change help to reduce the electrical consumption, and to reduce the maintenance cost. This approach will achieve saving about 4,859.36 ILS/year, In the same time, the CO_2 emissions will reduce by 4.2 tCO2/year. Furthermore, the chillers may offer for sale with a price of 15,720 ILS.

2d. Installing inverter (VSD) for each cooling equipment.

The production of plastic needs support from many utilities machines, which are cooling systems, and compressor. In this factory, there are 3 chillers and 2 cooling towers. These utilities used to cool 5 plastic production machines. So, the idea is to add inverter (VSD) on each equipment, which means 5 inverters will be added. This change help to reduce the electrical consumption by 25%, reduce harmonics distortion that effect the electrical grid, boost a chiller's power factor, and to reduce the maintenance cost. This approach will achieve saving about 10,514.82 ILS/year. In the same time, the CO_2 emissions will reduce by 15.45 tCO2/year.

The final results of implementation TEST methodology on the factory is shown in table 8 below. In addition, the action plan for saving opportunities implementation is shown in table 9 below.

Table 8. Results of implementation TESE methodology.

ACTION	Investment (ILS)	Savings (kWh/year)	Savings (ILS/year)	SPP (year)	IRR (%)	NPV (ILS)
Purchase plastic bottles from the outside instead of producing them inside.	-	264,647	86,202.32	-	-	-
Changing the diesel forklift to an electrical forklift	21,000	-	12,130.8	1.7	55.09	38,057.58
Total			**98,333.12**			

Table 9. Action plan.

No	Objective	Title of measure	Responsible	Budget (ILS)	Classification (low, moderate, high cost)	Approved by top management			Retained for study	Discarded
						implemented	Under implementation	Planned (start - end date)		
1	Energy saving	Purchase the plastic bottles from outside instead of producing them inside	Top management	-	-					
2		Changing diesel forklift to electrical forklift	Top management	21,000 ILS	Moderate cost					
If the first opportunity doesn't approve, the opportunities below can be done.										
3	Energy saving	Installing inverter (VSD) for each cooling equipment.	Top management	35,000 ILS	Moderate cost					
4		Changing the cooling system equipment by two chillers, and installing inverter (VSD)	Top management	41,000 ILS	High cost					
5		Changing the cooling system equipment by central chiller, and installing inverter (VSD)	Top management	47,000 ILS	High cost					

CHAPTER 6: CONCLUSION

Energy management can be broadly defined as the proactive, organized and systematic management of energy use in a building or organization to satisfy both environmental and economic requirements. After ensuring the administration's commitment, the TEST methodology was applied to Al-Rajeh factory for detergents and tissues.

In this project we archived more than opportunities for improvement, the results for our cards were in ''Plastic departments'' they're five cards (description for improvement), which are ''Changing diesel forklift to electrical forklift'','' Purchase the plastic bottles from outside instead of producing it inside'','' Changing the cooling system equipment by the central chiller, and installing inverter (VSD)'', ''Changing the cooling system equipment by two chillers, and installing inverter (VSD)'','' Installing inverter (VSD) for each cooling equipment''.

We have an action plan, an action plan is a checklist for the steps or tasks you need to complete in order to achieve the goals you have set, it depends on high savings, less SPP, and less risk. So, the action plan for our project are,'' Purchase the plastic bottles from outside instead of producing them inside'', also '' 'Changing the diesel forklift to an electrical forklift'', the saving is 86,202.32 ILS/year, 12,130.8ILS/year, respectively.

CHAPTER 7: APPENDICES

ID	1
Title of the measure	**Changing diesel forklift to electrical forklift.**
Description	*In this factory, there are one diesel forklift and one electrical forklift, we want to change diesel to electrical, to have two electrical forklifts in the end.*
Operational savings	*12,130.8 ILS can be saved per year.* *These savings were calculated by implementing the following calculations steps:* *1.The factory consumption 2000 ILS diesel per month, the cost for diesel during these days 5.98 ILS per month, so it is about 334 L of diesel per month.* *2.The power for electrical forklift = 9.2 kW, this type of forklift needs about 8 hours for charging each day.* *→ The consumption for electrical forklift = 9.2 kw * 8 hours *24 day * 0.56 ILS/kwh =989.1 ILS per month.* *3. So, we achieved saving = 2000 - 989.1=1010.9 ILS per month, which mean 12,130.8 ILS per year.*
Environmental savings	*4,008 liters of diesel can be saved per year, by change the forklift from diesel to electricity, that can prevent of producing 15.55 ton of* CO_2. *The estimated ton of* CO_2 *for each kWh of diesel is 0.000823* tCO_2/kWh. *Knowing that each L of diesel contains 10 kWh/L.* *4008 L/year *10 kWh/L*0.000823* tCO_2/kWh*=32.99* $tCO_2/year$. *21,196.8 kWh/year * 0.000823* tCO_2/kWh *=17.44* $tCO_2/year$. *Annual* CO_2 *saving = 32.99* $tCO_2/year$ *– 17.44* $tCO_2/year$ *= 15.55* tCO_2.
Suppliers	*Local market.*
Capital Investment	*The electrical forklift cost in our market is 21,000 ILS.*
Pay Back period/ IRR/ NPV	$SPP=\frac{investment}{Saving}=\frac{21000}{12130.8}$*=1.7 years, it means less than 2 years.* *NPV =-inv.+ A(P/A,i,n) =-21,000+ 12,130.8(P/A,0.1,7) = =-21,000+(12,130.8 * 4.8684) =38,057.58 ILS.* *IRR →* $NPV = -Inv.+A(P/A,i,n)=0 \rightarrow -Inv.+A*\frac{(1+i)^n-1}{i\cdot(1+i)^n}=0$ $-21{,}000+(12{,}130.8 \times \frac{(1+i^*)^7-1}{i^*\cdot(1+i^*)^7})=0 \rightarrow i^*=IRR=55.09\,\%$
Impact on product quality	There is no negative effect on the quality of the product.
Other barriers and constrain	There is no other constrain in our case.

ID	2.a
Title of the measure	**Purchase the plastic bottles from outside instead of producing it inside.**
Description	*The production of plastic needs support from many utilities machines, which are cooling systems, and compressor. In this factory, there are 3 chillers and 2 cooling towers that used to cooled 5 plastic production machines. These machines consumed energy a lot. So, the idea is to stop producing the plastic for the (chlor, Modhesh, dishwashing liquid) and to purchase it from plastic factories.* *Therefore, the 5 plastic production machines (2 for chlor bottles,2 for dishwashing liquid bottles, and one for modhesh bottles), two cooling towers, 3 chillers, and 3 shredders will be stopped. In addition, the compressor load will decrease to 50%, since it's used to operate the plastic machine specially for blowing the bottles, moreover it's used for packaging process.* *So, the idea is to purchase the plastic bottles of chlor, dishwashing liquid, and modhesh from outside.*
Operational savings	*86,202.32 ILS can be saved per year.* *These savings were calculated by implementing the following calculations steps:* *1. There are two plastic machines for produce chlor bottles that consumed 50,458 kWh/year* *→ 50,458 kWh/year *0.56 ILS/kWh =28,256.48 ILS/year.* *2. There are two plastic machines for produce dishwashing liquid bottles that consumed 82,184 kWh/year.* *→ 82,184 kWh/year *0.56 ILS/kWh =46,023.04 ILS/year.* *3. There are one plastic machines for modhesh bottles that consumed 14,170kWh/year.* *→ 14,170 kWh/year *0.56 ILS/kWh =7,935.2 ILS/year.* *4. There are two similar chiller that consumed 55,296 kWh/year.* *→ 55,296 kWh/year *0.56 ILS/kWh =30,965.76 ILS/year.* *5. There is one chiller that consumed 11,808 kWh/year.* *→ 11,808 kWh/year *0.56 ILS/kWh =6,612.48 ILS/year.* *6. There are two cooling towers that consumed 7,949 kWh/year.* *→ 7,949 kWh/year *0.56 ILS/kWh = 4,451.44 ILS/year.* *7. There are 3 shredders (2 shredders consumed about 956 kWh/year, each one is about 478 kWh/year), and the smallest one is consumed 239 kWh/year.* *→ 1,195 kWh/year *0.56 ILS/kWh =669.2 ILS/year.* *8. There is one compressor that consumed 83,174 kWh/year, but it will operate about 50%from its load. So, 0.5 * 83,174 kWh/year = 41,587 kWh/year.* *→ 41,587 kWh/year * 0.56 ILS/kWh =23,288.7 ILS/year* *∴ Annual electrical consumption =* ***264,647 kWh/year*** *∴ Annual electrical cost =* ***148,202.32 ILS/year*** *They consumed 240 ton of raw plastic per year to produce 180,000 bottles per month (2,160,000 bottles/year) for (chlor, modhesh, and dishwashing).*

Operational savings (continue)	*1 Kg raw plastic = 6 ILS → 1 ton = 6000 ILS.* ➔ *20 ton of raw plastic consumed per month.* ➔ *20 ton/month * 6000 ILS /ton=120,000 ILS/month* ➔ *120,000 ILS/month *12 month/year =**1,440,000 ILS/year**.* *In addition, there is an annual maintenance for the plastic machine, chillers, and cooling towers, that cost **10,000 ILS/year**.* *There are 6 employees that working in this section. The salary of each one is approximately 3,000 ILS/month, which mean **216,000 ILS/yr**.* *The annual cost for produced plastic inside the factory = annual cost of raw plastic + annual cost of its electrical consumption + annual maintenance cost+ salary of the employees = 1,440,000 ILS/year + 148,202.32 ILS/year + 10,000 ILS/year + 216,000 ILS/year= **1,814,202.32 ILS/year*** *To produce one bottle inside the factory, it will cost 0.839 ILS/bottle* $2{,}160{,}000\ \frac{bottles}{year} \rightarrow 1{,}814{,}202.32\ \frac{ILS}{year}$ $1\ bottles \rightarrow 0.839\ ILS$ *If they purchase plastic bottles from the local market, each one will cost **0.8 ILS.*** *So, 2,160,000 bottles/year * 0.8 ILS/bottle = **1,728,000 ILS/year.*** ➢ *Finally, the saving is 1,814,202.32 ILS/year - 1,728,000 ILS/year = **86,202.32** ILS/year* *By removing all machines, a **200** $\mathbf{m^2}$ will be available for increasing the production capacity. In addition, the 6 employees may work in the new production area. Furthermore, that area if it offered for rent, it will gain **5,000 ILS/month (60,000 ILS/year).*** *Furthermore, the plastic machines, cooling tower, and chillers may offer for sale with a price of **252,370 ILS**.* • *chiller 1 (10 ton): investment(B)=17,000 ILS,* *salvage value (S.V) =1000 ILS.* *n=25 year* $D_t = \frac{B-S}{n} = \frac{17000-1000}{25} = 640\,\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 17,000ILS – (640ILS/yr*10yr) =10,600 ILS* • *chiller 2 (4.83 ton): investment(B)=8,000 ILS,* *salvage value (S.V) =800 ILS.* *n=25 year* $D_t = \frac{B-S}{n} = \frac{8000-800}{25} = 288\,\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 8,000ILS – (288 ILS/yr*10yr) =5,120 ILS* • *chiller 3 (10 ton): investment(B)=17,000 ILS,* *salvage value (S.V) =1000 ILS.* *n=25 year* $D_t = \frac{B-S}{n} = \frac{17000-1000}{25} = 640\,\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 17,000ILS – (640ILS/yr*10yr) =10,600 ILS*

Operational savings (continue)	• *cooling tower 1: investment(B)=6,000 ILS, salvage value (S.V) =300 ILS. n=15 year* $D_t = \frac{B-S}{n} = \frac{6000-300}{15} = 380\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 6,000ILS – (380ILS/yr*10yr) =2,200 ILS* • *cooling tower 2: investment(B)=6,000 ILS, salvage value (S.V) =300 ILS. n=15 year* $D_t = \frac{B-S}{n} = \frac{6000-300}{15} = 380\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 6,000ILS – (380ILS/yr*10yr) =2,200 ILS* • *5 plastic machines: investment(B)=70,000 ILS (each), salvage value (S.V) =5,000 ILS. n=25 year* $D_t = \frac{B-S}{n} = \frac{70000-5000}{25} = 2{,}600\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 70,000ILS – (2,600ILS/yr*10yr) =44,000 ILS* *For 5 machines → **220,000 ILS*** • *2 shredder machines: investment(B)=1400 ILS (each), salvage value (S.V) =200 ILS. n=15 year* $D_t = \frac{B-S}{n} = \frac{1400-200}{15} = 80\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 1,400ILS – (80ILS/yr*10yr) =600ILS* *For 2 machines → **1200 ILS*** • *1 shredder machines: investment(B)=1050 ILS (each), salvage value (S.V) =150 ILS. n=15 year* $D_t = \frac{B-S}{n} = \frac{1050-150}{15} = 60\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 1,050ILS – (60ILS/yr*10yr) =450ILS*
Environmental savings	*264,647 kWh can be saved per year, by turn off the 14 machines, that can prevent of production 217.8 ton of CO_2.* *The estimated ton of CO_2 for each kWh of electricity is 0.000823 tCO_2/kWh.* *264,647 kWh /year*0.000823 tCO_2 /kWh= 217.8 tCO_2/year.*
Suppliers	*Local market (plastic factories).*
Capital Investment	-
Pay Back period/ IRR/ NPV	-
Impact on product quality	*There is no negative effect on the quality of the product.*
Other barriers and constrain	*There is no other constrain in our case.*

<table>
<tr><td>ID</td><td>2.b</td></tr>
<tr><td>Title of the measure</td><td>Changing the cooling system equipment by central chiller, and installing inverter (VSD).</td></tr>
<tr><td>Description</td><td>The production of plastic needs support from many utilities machines, which are cooling systems, and compressor. In this factory, there are 3 chillers and 2 cooling towers that supply a cooling load equal to 24.83 Ton (cooling). These utilities used to cool 5 plastic production machines. So, the idea is to change this equipment by a CSD water chiller that cover about 30 Ton (cooling), and installing inverter on chiller. This change help to reduce the electrical consumption, and to reduce the maintenance cost. The current COP of the equipment is equal to 3.6$\frac{kW_{cooling}}{kW_{electrical}}$.

To be mentioned, this change can face the problem breakdown of the system. To avoid the happening of it, a continuously maintenance must be done. In addition, a specialist in installation these types of system must be invited to ensure that the system is operating well.</td></tr>
<tr><td>Operational savings</td><td>5,338.63 ILS can be saved per year.

The new COP is equal to:
$$COP = \frac{kW_{cooling}}{kW_{electrical}} = \frac{101.7\ kW_{cooling}}{22.42\ kW_{electrical}} = 4.5\ \frac{kW_{cooling}}{kW_{electrical}}$$
These savings were calculated by implementing the following calculations steps:

1.There are two similar chiller that consumed 55,296 kWh/year.
→ 55,296 kWh/year *0.56 ILS/kWh =30,965.76 ILS/year.

2. There is one chiller that consumed 11,808 kWh/year.
→ 11,808 kWh/year *0.56 ILS/kWh =6,612.48 ILS/year.

3. There are two cooling towers that consumed 7,949 kWh/year.
→ 7,949 kWh/year *0.56 ILS/kWh = 4,451.44 ILS/year.

➔ The new chiller (29.9 kW_{elec} each) that will consume 86,112 kWh/year.
• 29.9 kW * 0.75= 22.42 kW, for 10 hours.

→ 64,569.6 kWh/year *0.56 ILS/kWh =36,239.61 ILS/year.

❖ To be mentioned, the 2 cooling towers will stay, with the new modification.

So, the annual saving is 37,578.24 – 36,239.61 =1,338.63 ILS/Year.

In addition, the annual maintenance cost was 10,000 ILS for the 5 machines, for the new modification it will be 6,000 ILS/year.

The annual savings is = 4,000 ILS/year + 1,338.63 ILS/year = 5,338.63 ILS</td></tr>
</table>

Operational savings (continue)	*Furthermore, the chillers may offer for sale with a price of* ***26,320 ILS****.* • *chiller 1 (10 ton): investment(B)=17,000 ILS, salvage value (S.V) =1000 ILS. n=25 year* $D_t = \frac{B-S}{n} = \frac{17000-1000}{25} = 640\,\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 17,000ILS – (640ILS/yr*10yr) =10,600 ILS* • *chiller 2 (4.83 ton): investment(B)=8,000 ILS, salvage value (S.V) =800 ILS. n=25 year* $D_t = \frac{B-S}{n} = \frac{8000-800}{25} = 288\,\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 8,000ILS – (288 ILS/yr*10yr) =5,120 ILS* • *chiller 3 (10 ton): investment(B)=17,000 ILS, salvage value (S.V) =1000 ILS. n=25 year* $D_t = \frac{B-S}{n} = \frac{17000-1000}{25} = 640\,\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 17,000ILS – (640ILS/yr*10yr) =10,600 ILS*
Environmental savings	*2,390.4 kWh can be saved per year, by changing the cooling system to one chiller. that can prevent of production 1.96 ton of CO_2.* *The estimated ton of CO_2 for each kWh of electricity is 0.000823 tCO_2/kWh.* *2,390.4 kWh /year*0.000823 tCO_2 /kWh= 1.96 tCO_2/year.*
Suppliers	*International or local market.*
Capital Investment	*The central chiller in our market cost 40,000 ILS.* *The inverter (VSD) in our market cost 7000 ILS.* *Total investment is equal 47,000 ILS.*
Pay Back period/ IRR/ NPV	*SPP=* $\frac{investment}{Saving} = \frac{47{,}000\ ILS}{5{,}338.63\ ILS/yr}$ *=8.8 years.* *NPV =-inv.+ A(P/A,i,n) =-47,000+ 5,338.63(P/A,0.1,25) = =-47,000+(5,338.63 * 9.077) = 1,458.7 ILS.* *IRR →* $NPV = -Inv. + A(P/A,i,n)$ *=0→* $-Inv. + A * \frac{(1+i)^n-1}{i\cdot(1+i)^n} = 0$ *-47,000+(5,338.63 x* $\frac{(1+i^*)^{25}-1}{i^*\cdot(1+i^*)^{25}}) = 0$ *→* $i^* = IRR$ *=10.4 %*
Impact on product quality	There is no negative effect on the quality of the product.
Other barriers and constrain	There is no other constrain in our case.

ID	2.c
Title of the measure	**Changing the cooling system equipment by two chillers, and installing inverter (VSD).**
Description	*The production of plastic needs support from many utilities machines, which are cooling systems, and compressor. In this factory, there are 3 chillers and 2 cooling towers that supply a cooling load equal to 24.83 Ton (cooling). These utilities used to cool 5 plastic production machines. So, the idea is to change this equipment by Two CSD water chiller that cover about 30 Ton (cooling), and installing inverter on each chiller. To be mentioned, a 20-ton chiller will be purchased and the remaining 10 tons will be covered by one of the chillers that exists in the factory. This change help to reduce the electrical consumption, and to reduce the maintenance cost. The current COP of the equipment is equal to 3.6* $\frac{kW_{cooling}}{kW_{electrical}}$ *.* *To be mentioned, this change can face the problem breakdown of the system. To avoid the happening of it, a continuously maintenance must be done. In addition, a specialist in installation these types of system must be invited to ensure that the system is operating well.*
Operational savings	*4,859.36 ILS can be saved per year.* *The new COP is equal to:* $COP = \frac{kW_{cooling}}{kW_{electrical}} = \frac{101.7\ kW_{cooling}}{21.5\ kW_{electrical}} = 4.7\ \frac{kW_{cooling}}{kW_{electrical}}$ *These savings were calculated by implementing the following calculations steps:* *1.There are two similar chiller that consumed 55,296 kWh/year.* *→ 55,296 kWh/year *0.56 ILS/kWh =30,965.76 ILS/year.* *2. There is one chiller that consumed 11,808 kWh/year.* *→ 11,808 kWh/year *0.56 ILS/kWh =6,612.48 ILS/year.* *3. There are two cooling towers that consumed 7,949 kWh/year.* *→ 7,949 kWh/year *0.56 ILS/kWh = 4,451.44 ILS/year.* *The new chiller (20 Ton) will consume 19.1 kW electric. After adding inverter (VSD) it will consume 14.325 kW, for 10 hours.* *→ 41,256 kWh/year *0.56 ILS/kWh = 23,103.36 ILS/year.* *And the 10-ton chiller will consume 9.6 kW.* *After adding inverter (VSD) it will consume 7.2 kW, for 10 hours.* *→ 20,736 kWh/year * 0.56 ILS/kWh = 11,612.16 ILS/year.* ❖ *To be mentioned, the cooling towers will stay operating.* *So, the annual saving is 42,029.68 – 39,170.32 = 2,859.36 ILS/Year.*

	In addition, the annual maintenance cost was 10,000 ILS for the 5 machines, for the new modification it will be 8,000 ILS/year. *The annual savings is = 2,000 ILS/year + 2,859.36 ILS/year = **4,859.36 ILS/year.*** *Furthermore, the chillers may offer for sale with a price of **15,720 ILS**.* • *chiller 1 (10 ton): investment(B)=17,000 ILS, salvage value (S.V) =1000 ILS. n=25 year* $D_t = \frac{B-S}{n} = \frac{17000-1000}{25} = 640\,\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 17,000ILS – (640ILS/yr*10yr) =10,600 ILS* • *chiller 2 (4.83 ton): investment(B)=8,000 ILS, salvage value (S.V) =800 ILS. n=25 year* $D_t = \frac{B-S}{n} = \frac{8000-800}{25} = 288\,\frac{ILS}{year}$ *After 10 years of operating, it's cost now is equal to 8,000ILS – (288 ILS/yr*10yr) =5,120 ILS*
Environmental savings	*5,106 kWh can be saved per year, by changing the cooling system to two chillers. That can prevent of production 4.2 ton of CO_2.* *The estimated ton of CO_2 for each kWh of electricity is 0.000823 tCO_2/kWh.* *5,106 kWh /year*0.000823 tCO_2/kWh= 4.2 tCO_2/year.*
Suppliers	*International or local market.*
Capital Investment	*The 20-ton chiller in our market cost 27,000 ILS.* *The inverter (VSD) in our market cost 7000 ILS each. (2 required)* *Total investment is equal 41,000 ILS.*
Pay Back period/ IRR/ NPV	*SPP=* $\frac{investment}{Saving} = \frac{41{,}000\ ILS}{4{,}859.36\ ILS/year}$ *= 8.4 years.* *NPV =-inv.+ A(P/A,i,n) =-41,000+ 4,859.36(P/A,0.1,25) = =-41,000+(4,859.36 * 9.077) = 3,108.4 ILS.* *IRR →* $NPV = -Inv. + A(P/A,i,n)$*=0→* $-Inv. + A * \frac{(1+i)^n - 1}{i \cdot (1+i)^n} = 0$ *-41,000+(4,859.36 x* $\frac{(1+i^*)^{25}-1}{i^* \cdot (1+i^*)^{25}}) = 0$ *→* $i^* = IRR$ *=10.9 %*
Impact on product quality	There is no negative effect on the quality of the product.
Other barriers and constrain	There is no other constrain in our case.

ID	2.d
Title of the measure	**Installing inverter (VSD) for each cooling equipment.**
Description	*The production of plastic needs support from many utilities machines, which are cooling systems, and compressor. In this factory, there are 3 chillers and 2 cooling towers. These utilities used to cool 5 plastic production machines. So, the idea is to add inverter (VSD) on each equipment, which means 5 inverters will be added. This change help to reduce the electrical consumption by 25%, reduce harmonics distortion that effect the electrical grid, boost a chiller's power factor, and to reduce the maintenance cost.*
Operational savings	*10,514.82 ILS can be saved per year.* *These savings were calculated by implementing the following calculations steps:* *1. There are two similar chiller that consumed 55,296 kWh/year.* *→ 55,296 kWh/year *0.56 ILS/kWh =30,965.76 ILS/year.* *2. There is one chiller that consumed 11,808 kWh/year.* *→ 11,808 kWh/year *0.56 ILS/kWh =6,612.48 ILS/year.* *3. There are two cooling towers that consumed 7,949 kWh/year.* *→ 7,949 kWh/year *0.56 ILS/kWh = 4,451.44 ILS/year.* *After adding inverter (VSD):* *1. There are two similar chiller (9.6 kW_{elec} each) that will consume 27,648 kWh/year.* • *9.6 kW * 0.75=7.2 kW each (14.4 kW for the two chillers), for 10 hours.* *→ 41,472 kWh/year *0.56 ILS/kWh =23,224.32 ILS/year.* *2. There is one chiller (4.1 kW_{elec}) that will consume 11,808 kWh/year.* • *4.1 kW * 0.75= 3.07 kW, for 10 hours.* *→ 8,841.6 kWh/year *0.56 ILS/kWh =4,951.29 ILS/year.* *3. There are two cooling towers (1.38 kW_{elec} each) that consumed 5,961.6 kWh/year.* • *1.38 kW * 0.75=1.035 kW each (2.07 kW for the two cooling towers)* *→ 5,961.6 kWh/year *0.56 ILS/kWh =3,338.49 ILS/year.* *So, the annual saving is 42,028.92 – 31,514.1 = 10,514.82 ILS/Year.*
Environmental savings	*18,777.8 kWh can be saved per year, by adding inverter for each cooling system equipment. That can prevent of production 15.45 ton of CO_2.* *The estimated ton of CO_2 for each kWh of electricity is 0.000823 tCO_2/kWh.* *18,777.8 kWh /year*0.000823 tCO_2/kWh=15.45 tCO_2/year.*
Suppliers	*Local market.*
Capital Investment	*The inverter (VSD) in our market cost 7000 ILS each. (5 required)* *Total investment is equal 35,000 ILS.*

Pay Back period / IRR/ NPV	$SPP= \frac{investment}{Saving} = \frac{35,000\ ILS}{10,514.82\ ILS/year}$ = 3.3 years. NPV =-inv.+ A(P/A,i,n) =-35,000+ 10,514.82 (P/A,0.1,12)= =-35,000 + (10,541.82* 6.8137) = 36,828.79 ILS. IRR → $NPV = -Inv. + A(P/A,i,n)$=0→ $-Inv. + A * \frac{(1+i)^n - 1}{i \cdot (1+i)^n} = 0$ -35,000+(10,514.81 x $\frac{(1+i^*)^{12} - 1}{i^* \cdot (1+i^*)^{12}}) = 0$ → $i^* = IRR = 28.6\%$
Impact on product quality	There is no negative effect on the quality of the product.
Other barriers and constrain	There is no other constrain in our case.

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