THE NATIONAL COUNCIL FOR SUSTAINABLE DEVELOPMENT
MINISTRY OF ENVIRONMENT

CASE STUDY ON IMPLEMENTATION OF THE OPTIMIZING COMPRESSED AIR USAGE IN GARMENT INDUSTRY IN CAMBODIA

FOR IMPLEMENTATION OF OUTPUT 1.1.4:

AWARENESS RAISING AND LESSON LEARNED DISSEMINATION WITH FOCUS ON RESOURCE EFFICIENCY IN CAMBODIA

UNDER THE FRAMEWORK OF THE UNIDO PROJECT
LOW CARBON DEVELOPMENT FOR PRODUCTIVITY AND CLIMATE CHANGE MITIGATION THOUGH THE TRANSFER OF ENVIRONMENTALLY SOUND TECHNOLOGY (TEST) METHODOLOGY

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CASE STUDY ON IMPLEMENTATION OF THE OPTIMIZING COMPRESSED AIR USAGE IN GARMENT INDUSTRY IN CAMBODIA

I. Introduction of Transfer of Environmentally Sound Technology (TEST)

In the last three decades, a number of conceptual ideas and tools have been created to assist industry with being more manageable and sustainable in its production and more efficient in its utilization of resources. These incorporate pollution prevention, waste minimization, cleaner production, eco-efficiency, and eco-innovation; with a particular depend on waste, energy, and materials. These conceptual ideas and tools have the shared objective of bringing two apparently clashing purposes together, financial profit and environmental improvement. The term Resource Efficient and Cleaner Production (RECP) is to the appropriated adaption of cleaner creation methods to speed up the use of preventive environmental techniques to processes, products and services, with the purpose of improving material and energy efficiency and diminishing dangers and risks to people and the environment. Resource efficiency approaches are looked for as building blocks of the Circular Economy (UNIDO, 2018).

The approach anticipated in these guidelines, which it is called the TEST approach, builds on all the concepts and tools mentioned above. TEST stands for Transfer of Environmentally Sound Technologies in which is an integrated approach that provides industries and small and medium enterprises (SMEs) with a combined set of tools to initiate a cycle of continuous improvements within their business operations to manage the transition towards a sustainable production. By combining combines internationally proven preventive environmental practices in Resource Efficient and Cleaner Production (RECP), the core elements of an Environmental Management System (EMS) and an Energy Management System (EnMS), which include exploring new eco-efficient technologies and an effective and supportive information system for material and energy flows based on Material Flow Cost Accounting (MFCA). TEST integrates all levels of the business management through creative thinking and effective collaboration. The project participant's companies applying TEST methodology follow the learning cycle "Plan-Do-Check-Act" to evaluate their processes and facilities to determinate improvement measures and feasible technologies as shown in the table 1

Table 1: TEST methods and their tools

TEST Methodology	TEST Integrated tools
Build on "one-stop improvement" approaches to resource efficiency in the system	Resource Efficient and Cleaner Production
Facilities creative thinking and effective collaboration through teamwork	Material Flow Cost Accounting/Environmental Management Accounting
Match the needs of an enterprise within its operating framework conditions and enhance organizational learning	Environmental/Energy Management System
Address all levels of a business (operational, managerial, and strategic). Follow the learning cycle in line with ISO standard PLAN-DO-CHECK-ACT	Corporate Social Responsibility

On the other hands, the effectiveness of TEST integrated approach contributes to the Sustainable Development Goals (SDGs) 6: Clean Water and Sanitation, 9: Industry, Innovation and Infrastructure, 12: Responsible Consumption and Production, and 13: Climate Action as shown in the figure 1 below.

Figure 1: TEST towards to achieve SDGs

II. Support mechanisms through policies and alignment with relevant ministries

Cambodian industry is highly energy inefficient, with energy consumption per unit of outputbeing higher than in many countries in the region and more than double that of the developed countries. Moreover, through the industrial production process and activities, there has been generate a lot of solid waste, hazard waste, wastewater pollution significantly into the environment and atmosphere. For instant, the food and beverage (F&B) sector will generate around 2,410,034 tons of waste in 2020, mostly in the form of industrial wastewater (IWW).[1] Garment waste represents 70% of industrial waste going to landfill and includes textile, footwear and leather offcuts and rejects. To cope with those issues, the current UNIDO's project called TEST project is designed with the purposes to analyze energy consumption data and trends, and identifies Significant Energy Users (SEU) to recommend potential energy saving practices, opportunities, and technological improvements.

Beside this, the Royal Government of Cambodia has formulated, developed, and implemented a series of national policies, strategies, action plans, and programs in order to ensure holistic social development and sustainable development, to promote green environment and renewable energy, to encourage efficient use of energy and to minimize detrimental environmental effects resulting from energy supply and use, and to encourage private investment on the green business, etc. The table 2 the briefly description of the Cambodia's policies, law, strategies, action plans, guidelines, other programs on/related to the promotion of renewable energy, power sector, green environment, waste management, and green industry, etc.

Table 2: List of policies, law, strategies, and action plans

No	Name	Period	Remark
1	Power Sector Strategy	1999-2016	
2	Cambodia's Law on Electricity	2000	
3	Renewable Electricity Action Plan (REAP)	2002-2012	
4	National Policy, Strategy and Action Plan for Energy Efficiency	2013	
5	National Policy on Green Growth	2013-2030	
6	Strategic Plan for Green Growth	2013-2030	
7	National Strategic Development Plan (NSDP)	2019-2023	

[1] The Economic, Social and Environmental Impacts of Greening the Industrial Sector in Cambodia, GGGI, 2018

8	Cambodia Climate Change Strategic Plan (CCCSP)	2014-2023	
9	Climate Change Action Plans (CCAPs)	2014-2018	
10	Intended Nationally Determined Contribution (INDC)	2015	
11	Environment and Natural Resource Code	-	Draft
12	National Energy Efficiency Policy	2018-2035	
13	Sub-decree on energy efficiency standards and labeling for electrical appliances and equipment	-	Draft
14	National Waste Management Strategy and Action Plan	2018-2030	
15	National Policy on Solid Waste Management in Cities	2018	Official in Khmer version
16	Sub-decree on Solid Waste Management in the Cities	2015	Official in Khmer version
17	Sub-decree on Plastic Bags Management	2017	Official in Khmer version
18	Guideline on E-Waste Management	2017	
19	Sub-decree on E-Waste Management	2016	
20	Water Resources Management Law	2007	
21	Sub-Decree on Water Pollution Control	1999	

Government has a critical role in accelerating the energy transition. Government has the responsibility to enact an enabling policy framework that provides long-term certainty for the private sector and ensures a positive environment for the energy transition. The roles of the main actors in the power sector and wastewater management are set out in the below table 3.

Table 3: The roles of the main actors in the power sector and wastewater management

No	Ministry/Institute's Name	Duties
1	Ministry of Economy and Finance (MEF)	Involves in allocating the budgets.
2	Ministry of Mines and Energy (MME)	Is responsible for developing policies and strategies, power development plans, overseeing the electricity trade with neighboring countries, major investment projects and management of the rural electrification sector.
3	Ministry of Industry, Science, Technology and Innovation (MISTI)	Is responsible for developing policies and strategies related to green industry and involves in providing drinking water in 11 provincial capitals and for approximately 60 medium sized and small towns.
4	Ministry of Public Works and Transport (MPWT)	Involves in wastewater management.
5	Electricité du Cambodge (EDC)	Involves in generating, transmitting and distributing electricity throughout Cambodia. Its main functions are supplying electricity, developing the transmission grid and facilitating import and export of electricity to and from neighboring countries.
6	Electricity Authority of Cambodia (EAC)	Is the power sector regulator, and is responsible for granting licenses, approving and enforcing performance standards, and determining tariffs, rates and charges for electricity. The EAC may grant various types of electricity license, including licenses for generation, transmission, distribution, retail, or a combined license.
7	Ministry of Environment (MoE)	Reviews and approves Environmental Impact Assessments (EIAs) and Environmental Management Plans (EMP) for all energy and water related projects, etc.

8	National Council for Sustainable Development (NCSD)	Is a cross-sectoral and multi-disciplinary body with the mandate to prepare, coordinate and monitor the implementation of policies, strategies, legal instruments, plans and programs related to climate change in Cambodia. The NCSD aims to improve the coordination of climate change activities in Cambodia and to support a stronger, comprehensive and effective climate change response.
9	Ministry of Water Resources and Meteorology (MOWRAM)	Issues water licenses for hydropower projects.
10	Forestry Administration of the Ministry of Agriculture, Forestry and Fisheries (MAFF)	Is responsible for the management of wood-fuel and the production of crops as a source of renewable energy.
11	Ministry of Rural Development (MRD)	Involves in master plans and water supply and sanitation management in rural areas and towns.
12	Ministry of Interior and municipalities	Involve in master plans, operation and maintenance wastewater treatment system.

According to the above mentioned national regulations, laws, policies, etc. as well as following to all the relevant ministries and institutions' mandates and responsibilities related energy and power generation, waste management, and water supply and management, there are the fundamental ways and mechanisms in which allow for all stakeholders and private sector to access to water and energy consumption dramatically. In addition; so far, there were many supported activities and programs were provided and supported to those private sector and stakeholders for their businesses' program and activities as well. For example: Financial supports, capacity buildings, taxation reduction and exception for some imported equipment, issuing the licenses and certifications, and other services, etc. were provided.

III. Integrating the best practice approach into the factory environmental roadmap

In 2013; as collaboration with 11 enterprises, the UNIDO project on low carbon development for productivity and climate change mitigation though TEST methodology in Cambodia has been applied various technology cases or approaches in which mainly focus on energy consumption to help those enterprises to reduce their energy consumption, to improve their business activities and productions, and to make a better surrounding environment.

50 factories in the first phase from the garment including laundry, textile, footwear, and the food and beverage sectors were selected as demonstration companies and will benefit from the comprehensive project technical support and other services, such as the provision of trainings both collectively and in-house on the TEST tools, followed by RECP assessment and energy audits of the production facilities, which will be carried out jointly by the factory's TEST team and project experts to identify or find out the causes of inefficiencies as well as recommended improvement measures. Moreover, there are a lot of technologies were selected and applied to deal with those causes as well as integrated into each factory environmental policy during the project implementation, and these technologies can be considered as the best practice approach to help each factory not only to achieve the environmental policy target but also can help each project participant's factory to reduce resources consumption, financing expenditure, and greenhouses emissions, etc.

The below five measures can be the best practices that every factory owner could consider and apply:

- ✓ Optimize Compressed Air Usage by Repairing the Compressed Air Leakage and Optimizing Compressor Operating
- ✓ Increase the boiler efficiency by cleaning both water and fire side and optimize air fuel ratio
- ✓ Opportunities of installing Solar PV with Li-Battery System

- ✓ Advantages of replacing AC in the embroidery room with evaporative cooling
- ✓ Optimize resistive ovens for cooking, drying and baking with steam from LPG

Note: There are more appropriate technologies can be used and applied to improve each company's business. Please consult with UNIDO's project team for more information.

IV. The current status of the compressed air usage

An air compressor is a pneumatic device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). Compressed air is air kept under a pressure that is greater than atmospheric pressure, and it is an important medium for transfer of energy in industrial processes. It is used in practically all the process machines from blow rooms, carding, spinning, winding, weaving and other machineries for both controlling and operations. Air compressors are used to supply for process requirement to operate pneumatic tools and equipment, and to meet instrumentation needs. Only 20-30% of energy reaches, the point of end-use and balance 70-80% of energy of the power of the prime mover being converted to unusable heat energy and other system losses. In a modern mill, compressors account for 8-9% of total power consumption. Leakages can be a significant source of wasted energy in the compressed air system, sometimes wasting 20-50% of a compressor's output (Rajput, 2018).

1. Why is it important to check?

The check of compressed air systems is essential for two reasons:

a. To establish the system leak rate – for energy efficiency and reliability purposes; and
b. To check or verify the integrity of the pipe/fitting joints to ensure safety of personnel.

This leads to two distinct tests, the leakage test and the pressure (integrity) test. They have different objectives, but are often confused. The confusion may arise from the two tests are carried out one after the other, during the same commissioning visit to the site.

2. How to detect compressed air leakages?

Leakage detection methodology comprises two components, first is to quantify the total system leakages, and the second is to identify the area of leakages, and accordingly making an action plan to mitigate compressed air leakages.

Leakages can be found in any parts of a compressed air system, from the compressor to the points of use. Common problem areas include[2]:

- Couplings
- Hoses
- Tubes
- Fittings
- Pipe joints
- Disconnects
- Thread sealants
- Condensate traps
- Shut-off valves
- Pressure regulators
- Filters
- Lubricators
- Bag houses
- Cylinder rod packing

Figure 2: Compressed air monitoring system block diagram

[2] This information is retrieved from https://cbeuptime.com/how-to-detect-compressed-air-leaks/

There are three commonly used methods of the compressed air leak detection:

- Listening/feeling: A low-tech way to detect compressed air leaks is to listen for them, then feel for leaking air. This only works for very large leaks with direct physical access, and it can be difficult to hear leaks over the noise of the equipment. For these reasons, this method only works in very limited cases;
- Soapy water application: in this method, soapy water is applied with a paint brush to areas where a leak is suspected. If there is a leak, soap bubbles will form. While reliable, this leak detection method can be time consuming. It requires direct physical access, meaning leaks in hard-to-access areas of the piping system will go undetected. It also does not indicate which leaks are losing the most air, so there is no way to prioritize leak repairs; and
- Ultrasonic: The industry standard and best practice are to use ultrasonic leak detection equipment. These portable devices typically consist of directional microphones, amplifiers and audio filters, and have either earphones or visual indicators to help the user detect leaks. The equipment works by detecting the high frequency "hissing" sound created by compressed air leaking into the atmosphere, which is inaudible to the human ear. The sound is both directional and localized to the source, pinpointing the location of the tiniest leaks even in noisy environments. Unlike the other two methods, ultrasonic leak detection doesn't require direct physical access to the leaks. Some devices can estimate the volume of air leakage, so repairs can be prioritized.

3. Air compressor case of the project participant's factory

There were 3 screw air compressors in the project participant's factory (figure 3) with different capacities. Table 4 shows the information of all air compressors. The biggest one has the free air discharge capacity of 10 m3 per minute, and the smaller two compressors have the same free air discharge capacity of 3.6 m3 per minute. Only the biggest one of these three compressors runs at the time of auditing while the other two are kept for standby. The compressors are connected with each other and have three storage tanks with total capacity of 3 m3, which then sends compressed air to the whole factory using different pipes for each building.

Figure 3: Air compressors

Table 4: Compressors information

Compressor information	Data	Unit
Compressor I		
Model No.	Kaishan Lg-10/8g	
Rated capacity:	10	m3/min
Total run time:	2940	h
Loading time:	3345	h
Unloading time:	28	h
Air storage volume	3.0	m3
Power:	55	kW
Max-pressure:	8	bar
Unloading pressure	8.1[3]	bar
Loading pressure	7.1	bar
Running pressure	7.2	bar
Compressor II		
Model No.	EAS3CB/8	
Rated capacity:	3.6	m3/min
Compressor III		
Model No.	EAS3CB/8	
Rated capacity:	3.6	m3/min

The compressor is tested for its capacity efficiency which means that actual air delivery is measured against the rated capacity. The compressors' testing result is presented in Table 5. Leakage test was also conducted and results are presented in Table 6.

Table 5: Compressors information

Compressor	P1(bar)	P2 (bar)	P2-P1	Time (Second)	Test Result (m3/min)	Rated Capacity (m3/min)
1.	3	4	1	6	30	10

Table 6: Result of leakage test of compressed air

P2 (Bar)	P1 (bar)	P2-P1 (bar)	Time(s)	Leakage (m3/min)	Annual Leakage
8.1	7.1	1	60	3.00	529,200

[3] Refer for Figure 3-5 for actual setting of the company.

4. Optional measure for better air compressor system

Another option to optimize the compressed air system with conserving a lot of energy is the variable-speed drive (VSD) air compressor (figure 4). It is a new technology that takes advantage of the air compressor system. This type of compressor uses a special drive to control the speed (RPM[4]) of the unit, which in turn saves energy compared to a fixed speed equivalent. This is done to improve the efficiency of the compressor as varying the displacement or compression ratio of a compressor generally introduces significant inefficiency, or is impractical to implement. The VSD air compressor can operate anywhere in the range between its minimum and maximum speed, and it adjusts automatically the speed, so, production of compressed air matches demand in real time. When demand increases, the motor speeds up. When demand decreases, the motor slows down. This capability saves energy because the compressor doesn't have to run flat out whenever it's on. VSD air compressor comes to the three most important attributes of VSD air compressors: Efficiency, reliability and connectivity.[5]

Figure 4: Modern design of Atlas Copco Oil-free Variable Speed screw Air Compressor

Benefits:

- On average from 35% up to 50% energy savings during fluctuations in production demand with an extensive turndown range,
- Reduce power cost and operation cost,
- Lower noise operation,
- No wasted idling times or blow-off losses during operation
- Eliminate peak current penalty during start-up,
- Minimize system leakage due to a lower system pressure,
- Maintenance-free drive system (100% maintenance-free; totally enclosed and protected against dirt and dust),
- Integrate Elektronikon® Graphic controller controls the motor speed and high efficiency frequency inverter,
- Better environmentally-friendly characteristics, and
- Zero ozone depletion, etc.

V. Energy saving opportunity and benefit of CO2 mitigation reduction through the response measures and investments

After finding and monitoring the problems of compressed air leakage, the fixing all of those problems are really helpful and give many benefits return to the project participant's companies.

As the project implementation policy, all the project participant's companies were given a free service for energy audit from the project. Therefore, below examples are the real cases finding from energy audit of each factory.

[4] RPM stands for Revolutions per minute. It is the number of turns in one minute and is a unit of rotational speed or the frequency of rotation around a fixed axis.

[5] This information is retrieved from: https://www.atlascopco.com/en-sg

a. For the case of garment factory A:

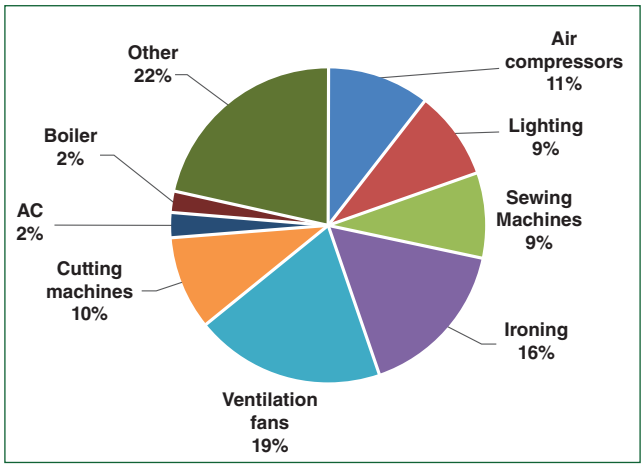

Figure 5: Electrical Energy Breakdown by Equipment

b. For the case of garment factory B:

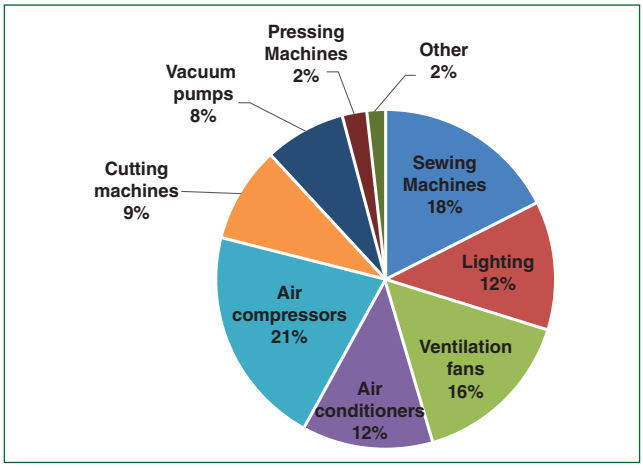

Figure 6: Electricity Consumption in 2018 Breakdown

Table 7: The real case of energy audit for garment factory A (OECC, 2019)

Issue	It is observed that there are significant compressed air leakages in the whole compressed air system of the factory, especially in the sewing lines. As per the leakage test conducted during the audit, around 30% percent of the compressed air delivery for the whole factory is leaked at the rate of 3 m3/min, which is equivalent to 529,200 m3/year of compressed air. Leakages are often a waste of energy consumption from compressors and it can contribute to pressure drop problems as well. It is recommended to note that air is free, but compressed air is not free. Its cost is approximately 0.014 USD/m3. The whole leakage makes the company to lose nearly 7,360 USD/year or 42,059 kWh/year of electricity.
Locations of leakage	Below are common points of compressed air leakages found in the factory. Please note that the leakages points provided are just a result of quick inspection. To effectively repair all leakages, the company needs to conduct its own search-and-repair action on each leaking point especially on the following points: Hose connectors, Hose fittings, Compressed air girder, and Pipe cracking, etc.  Figure 7: Leakage areas in the Garment Factory A compressed air system in Phnom Penh
Solution	Repair all leakage areas in the compressed air system. Reduce leakage rates with an improved maintenance program. Additionally, replace/repair all broken pipes, valves and joints. Meanwhile, reinforce staff training to prohibit wasteful use of compressed air, for example, for cloth cleaning, etc. It is also recommended to establish a preventive maintenance program for all compressors to ensure best performance. Leakage test should be conducted once every month followed by repairing works.

Resource consumption	Average energy consumption by compressor is 47.68 kW x 10 hr/day x 294 days/ year = 140,179 kWh/year
Resource saving	7,360 USD/year or 42,059 kWh/year of electricity
Financial investment	3,000 USD (rough estimation on labor and part cost)
Financial saving	42,059 kWh/year x 0.175 USD/kWh = 7,360 USD/year
Payback period	= 3,000 USD/7,360 USD/year = 0.41 year (around 5 months)
CO2 emissions reduction	= 42,059 kWh/year x 0.000665 tCO2[6] /kWh = 28 tCO2/year

Table 8: The real case of energy audit for garment factory B

Annual average energy consumption	1,209,695	kWh/year
Leaked compressed air	4,550,094	m3/year
Financial Saving	69,983	USD/year
Electricity Saving	413,060	kWh/year
Investment cost	12,000	USD
Payback period	0.17	year
CO2 Saving	274.73	tCO2/year
% Electricity Saving compared to 2018	9%	

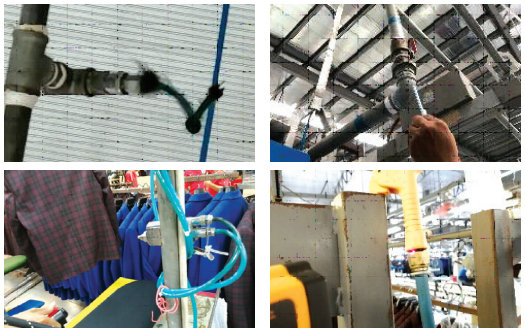

Figure 8: Leakage areas in the Garment Factory B compressed air system in Phnom Penh

VI. Recommendations founded during the energy audit assessment

Leakages are often a waste of energy consumption from compressors and it can contribute to pressure drop problems as well. It is recommended to note that air is free, but compressed air is not free. Its cost is approximately 0.014 USD/m3. Therefore, those leakages need to be monitored and repaired in order to save electricity consumption and financing, and to contribute to clean environment and reduce GHG emissions, and to improve working condition as a whole. With that, these can lead every company's products high competitive than the others.

By joining with the project implementation, all of the project participant's companies will be offered a free energy audit in which that company owners can be able to understand and get to know electricity consumption breakdown, what the issues and their locations are in their compressed air system, their expense on the electricity consumption and the financial saving from fixing those issues in the compressed air system, the scope and size of their investment cost to fix those issues, and the payback period of their investment cost, etc. With that, those companies' owner will be able to build the concreted business plan holistically and can realize what the challenges for their production processes' cycle are, and things they need to invest and improve as well as to enable their decision making quickly and in the right way.

Moreover, there are a lot of energy improvement opportunities have been identified and studied during the on-site energy audit would be recommended along with the repair all of compressed air leakages. Below are the several examples that every factory or company is able to apply:

[6] https://iges.or.jp/en/publication_documents/pub/data/en/1215/IGES_GRID_EF_v10.5_20190828.xlsx

- Establish Energy Management System as per ISO 50001 or Environmental Energy Management System as per ISO 14001;
- Create a centralized data base for energy related information;
- Behavior change for energy conservation;
- Develop a maintenance standard operating procedure (SOP) and implement it;
- Turn off electrical equipment when is not in use especially in the dormitory and during lunch time;
- Replace the auto transfer switch control with a new one as the current one is already broken or has a problem;
- Seal the electrical cabinets; and
- Plant more trees in the east, west and south areas.

Beside this; for better or optimizing the compressed air system, the VSD air compressor is a smart choice for all factory owners to be invested in as it offers a lot of benefits in returns, more particular, it is the modern technology for this industry 4.0 revolution and commonly used in Cambodia's industrial production processes and all over the world. The VSD air compressors can be cost more expensive, but they can be paid back the added investment through energy savings. The greater the variation in demand, the greater the potential savings!

By implementing this measure on Optimize Compressed Air Usage by Repairing the Compressed Air Leakage, Optimizing Compressor Operating, and energy improvement opportunities, the above factory A could save a total of 42,059 kWh per year of electricity which is around 30% of total power consumed in 2018. The saving is worth 7,360 USD per year, which is approximately 40% of total expenditure on investment cost in 2018 with average payback period of 0.41 year (around 5 months). This factory A could also reduce 28 tons of CO2 emission per year. The factory B could save a total of 413,060 kWh per year of electricity which is around 34% of total power consumed in 2018. The saving is worth 69,983 USD per year, which is approximately 40% of total expenditure on investment cost in 2018 with average payback period of 0.17 year (around 2 months). This factory A could also reduce 274.73 tons of CO2 emission per year.

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