THE GENERAL SECRETARIAT OF THE NATIONAL COUNCIL FOR SUSTAINABLE DEVELOPMENT
MINISTRY OF ENVIRONMENT

CASE STUDY ON OPPORTUNITIES OF INSTALLING SOLAR PV SYSTEM 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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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 pproach 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. Overview of solar situation in Cambodia

Solar cells and photovoltaics (PV) were first invented in 1954 after a lot of research around photoelectric technologies and beginning to use the sun's energy for other purposes. Solar panels contain solar cells that collect heat energy from the sun. Once, this energy is trapped, an inverter is used to convert the energy to power or electricity in which is useable for your home or businesses. Solar PV is considered as the clean energy as its energy comes from the renewable resource and it is more less affected to the environment. Now, solar has been around for many decades, and has been proved to consistently work well. Like most other technology, solar has improved immensely over time, gaining more efficiency and becoming a more viable option for homes and businesses.

Cambodia has abundant solar resources and high degree of solar irradiation and potential. Around 134.500 km^2 of land area in the country is suitable for photovoltaic (PV) which is estimated to produce energy potential of 12 TWh/year (MME, 2019). There are currently no official targets for solar PV in Cambodia. However; according to UNDP's report in 2019 on the Cambodia: De-risking Renewable Energy Investment, for on-grid solar PV, the illustrative investment target is set at 700 MW by 2030, split equally between utility-scale PV and rooftop PV. The investment target for rooftop PV is further equally split between the commercial and industrial (C&I), and the residential sector.

With those abundant solar resources, Cambodia is well positioned for investment in solar PV projects with illustrative long term to promote private sector to do this kind of investment. Solar PV provides the opportunity to meet Cambodia's rapidly growing electricity demand, improve energy security, to advance Cambodia's electrification via innovative off-grid technologies and business models, and can also support Cambodia's contributions to addressing climate change under the United Nations Framework Convention on Climate Change (UNFCCC) such as Nationally Determined Contribution update (NDC update).

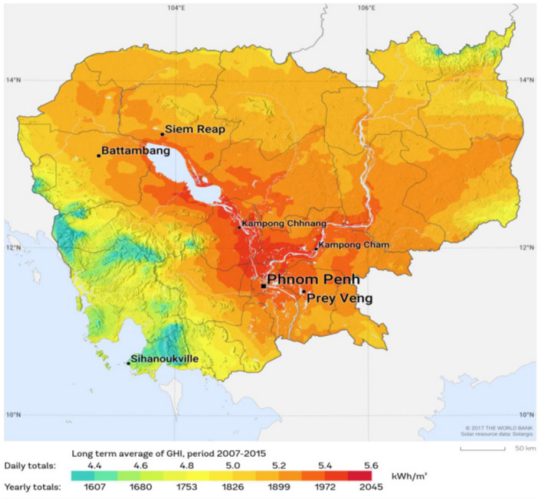

Figure 2: Solar resource map

Source: World Bank Group

There were two existing solar PV farms in Cambodia. SchneiTec Renewable Co., Ltd built its own first solar farm in Kampong Speu with total land 200 hectares completely and fully operational since late December 2019, which produced 60 megawatts. In April 2020, this company, a joint venture of Chinese and local partners, announced that the first phase of the project had been completed, supplying 20 MW to the national grid. Another solar PV farm was built in Bavet city of Svay Rieng province with the installed capacity of 10 megawatts, which is the first solar farm project connected to the national grid.

Table 4: Solar station in Cambodia

No.	Name of Investment	Location	Install Cap. (MW)	Type	Year Operation	Tariff (USD/KWh)
1	Sunseap Asset (Cambodia) Co., Ltd	Svay Rieng	10	Solar farm	2017	0.091
2	SchneiTec Renewable Co., Ltd	Kampong Speu	80	Solar farm	Dec. 2019	0.076
Total			90			

Source: MME, 2019

Presently, there are 7 more projects and companies are interested in investment on the solar PV farm with installed capacity 320 megawatts in total. Most of solar PV farms are under construction right now, hope most of them will be operated by the end 2021 this year.

Table 5: Solar PV Development plan 2019

No.	Name of Investment	Location	Install Cap. (MW)	Type	Year Operation	Tariff (USD/KWh)
1	Risen Energy Co., Ltd	Battambang	60	Solar farm	2020	0.076
2	SchneiTec Sustainable Co., Ltd	Kampong Chhnang	60	Solar farm	2020	0.076
	Green Sustainable Ventures Co., Ltd	Svay Rieng	20	Solar farm	2020	0.076
	SchneiTec Sustainable Co., Ltd	Pursat	60	Solar farm	2021	0.076
	Ray Power Supply Co., Ltd	Banteay Meanchey	30	Solar farm	2021	0.076
	SchneiTec Infinite	Pursat	30	Solar farm	2021	0.076
	ADB &EDC	Kampong Chhnang	60	Solar farm	2022	N/A
Total			320			

Source: MME, 2019

V. Why solar is a best choice for garment factories in Cambodia?

Cambodia's garment manufacturing industry is largely export-oriented and highly integrated into global supply chains. The European Union (EU) represents the largest market for Cambodian garment exports, accounting for approximately 40 percent of the total manufacturing, followed by the United States (30 percent), Canada (9 percent), and Japan (4 percent). Many companies in the country operate as contract manufacturers for major multinational brand such as Adidas, Gap, H&M, Marks & Spencer, and Uniqlo.

Cambodia's garment industry contributes approximately 19 percent to the national GDP and 72 percent of the country's exports. The garment industry is therefore Cambodia's most important manufacturing sector. However, inefficiencies in the production process and disproportionate consumption of high cost energy may lead the Cambodian garment industry to lose its competitive edge in a global market characterized by fierce competition. Even though actors in the garment industry are aware of their comparatively high energy costs and the significant market potential for industrial energy-efficient product and services, they have so far failed to achieve energy efficiency of any scale because of insufficient technical

capacity, lack of human and financial resources, lack of qualified local suppliers, and financing constraints (UNDP, 2015).

Electricity is the main source used by all factories for their production processes and facilities. Mostly, electricity in each garment factory is used towards lighting and maintaining optimal temperature on the shop floor including the running of sewing, finishing, embroidery, air conditioners, ventilation fan, air compressors, boiler/steam generators, and other equipment, greatly contribute to the cost of products manufactured in that factory. For more detail, please refer to the figure 3 below. The garment factory's owner has been looking out for alternate sources of energy or renewable energy for a long time, like windmill, biogas plants or solar panels. Among these sources, solar panels are easier to maintain and install, and also require much less space, but with constraints of high initial capital investment.

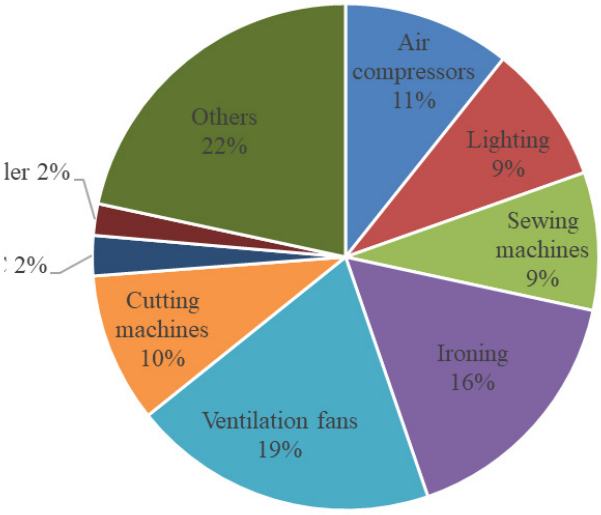

Figure 3: Electricity consumption by equipment type in the garment industry, 2018

Garment factories with abundant roof space, providing ample free space for panel arrays. Panels act as a form of insulation against the sun and can help keep buildings cooler. In other words, panels can be designed and installed for the car park that is also another best option apart from installing them on the roof of the buildings. As such, having solar panels can increase the factory's negotiating power with some buyers. When national gird power cuts off, factories can also use solar systems in-sync with diesel generators. Therefore, solar PV is the best option for every garment factory owner to look for.

VI. Benefits of installing solar PV

Cambodia enjoys some of the highest solar resources in the Greater Mekong Sub-region (GMS), with solar irradiance measuring on average 1,400–1,800 kilowatt-hours (kWh) per square meter per year throughout the country, for an estimated technical potential of over 8,000 MW. In the middle of Cambodia, including the load center of Phnom Penh, which is responsible for approximately 70% of national electricity demand, the peak solar resource measures over 1,900 kWh per square meter per year. Solar is a good option for remote rural households that do not currently have access to the grid and also good option for industrial sector that heavily relies on national grid or other renewable energy sources.

In 2013, the Royal Government of Cambodia (RGC), with support from development partners, began to seriously consider solar energy. Since 2015, the government has been prompted to explore solar power as a generation option because of the rapid reduction in global prices for renewable technologies such as solar power. In earlier 2018, the RGC adopted the regulation on General Conditions for connecting Solar PV generation sources to the electricity supply system of national grid or to the electrical system of a consumer connected to the electricity supply system of national grid in which it allows medium and big consumers to install solar PV systems for their own use in the business investment process, also allow their solar PV system to connect to the national grid, but need to comply with the technical safety requirements as stated in the article 7 and 8 of the regulation.

The main advantage of the solar PV systems connected to the national grid is its simplicity, relatively low operating and maintenance costs as well as reduced electricity bills. In other words; by looking for the advantages of installing solar PV, the industrial sector such as garment, textile, and other sector will receive many benefits in a return, not only because it will reduce GHG emissions but also because it will increase the competiveness of the industry, and improve energy security and the affordability of electricity.

VII. The different ranges of Solar PV capacity's cases

Cambodia's electricity tariffs are the highest in the region and in the world. The tariffs for industrial consumers range from US$ 11.71-14.63 per kWh and are the most expensive in ASEAN region. The high rates of electricity tariffs make Cambodia less competitive in global and regional trade and investments. The high tariff is because Cambodia's domestic electricity generation is highly dependent on oil while Cambodia is a net oil importer country. By addressing these challenges, switching to renewable energy such as solar PV is the crucial way that may concern in the present and near future. Below are lists of Solar PV installation's cases and its benefits.

Table 6: Case 1: Install 50 kWp Solar PV with 200 kWh Li-battery system

GHG saving	49 tCO_2/y
Potential Energy Generation from solar	4,914,000 kWh/y
Power produces from solar	73,000 kWh/y
Solar PV System	20,000 USD
Li-Battery	100,000 USD
Installation cost	5,000 USD
Financial saving	11,672 USD/y
Projected Payback Period	10.71 yrs

Table 7: Case 2: Install 100 kWp Solar PV on the roof of the factory's buildings [2]

GHG saving	122 tCO_2/y
Power produces from solar	161,600 kWh/y
Solar % of Consumption	15%
Grid Electricity % of Consumption	85%
Projected Payback Period	4 yrs
10 Year NPV	$93,300
Annual Savings	$31,500

Table 8: Case 3: Install 300 kWp solar PV with 500 kWh Li-battery system on the roof

GHG saving	291 tCO_2/y
Potential Energy Generation from solar	4,914,000 kWh/y
Power produces from solar	438,000 kWh/y
Solar PV System	120,000 USD
Li-Battery	600,000 USD
Installation cost	70,000 USD
Financial saving	76,542 USD/y
Projected Payback Period	10.87 yrs

[2] This information is retrieved from https://www.infiniteenergy.com.au/commercial/case-studies/manufacturing-engineering-transportation/plas-pak

Table 9: Case 4: Install 500 KWp Solar PV with 1000 kWh Li-battery system on the roof of the factory's buildings

GHG saving	485 tCO_2/y
Potential Energy Generation from solar	22,680,000 kWh/y
Power produces from solar	730,000 kWh/y
Solar PV System	200,000 USD
Li-Battery	500,000 USD
Installation cost	70,000 USD
Financial saving	121,188 USD/y
Projected Payback Period	6.35 yrs

Table 10: Case 5: Install 1000 kWp Solar PV on the roof of the factory's buildings

GHG saving	1,757 tCO_2/y
Potential Energy Generation from solar	10,915,170 kWh/y
Power produces from solar	2,641,687 kWh/y
Solar PV System	900,000 USD
Installation cost	100,000 USD
Financial saving	264,100 USD
Projected Payback Period	6.16 yrs

Table 11: Case 6: Increase Solar capacity from 640 kWp to 2000 kWp

GHG saving	1,320 tCO_2/y
Potential Energy Generation from solar	5,155,970 kWh/y
Power produces from solar	1,985,600 kWh/y
Solar PV System	952,000 USD
Installation cost	136,000 USD
Financial saving	496,400 USD
Projected Payback Period	2.19 yrs

VIII. Conclusion and Recommendations

The garment industry is the most important manufacturing sector in Cambodia. It contributes approximately 19 percent to the national GDP and 72 percent of the country's exports. However, inefficiencies in the production process and high rate of energy cost and energy consumption on manufacturing facility may reflect heavily on the costing of the products manufactured in that facility, and that may also lead the Cambodian garment industry to lose its competitive edge in a region and global market.

Cambodian garment industries generally consume electricity towards lighting and maintaining optimal temperature on the shop floor including the running of sewing, finishing, embroidery and other heavy machines, and that contribute greatly to the cost the electric bills. To cope with this issue, the garment industry's owners have been looking for alternate sources of energy such as biomass or biogas plants, windmills, or solar panels. Among these three categories, solar panels are easier to maintain and install, and also require much less space; but, of course, it constraints of high initial capital investment. Anyway, there have various ranges of solar capacities and choices that every garment industry's owner can take it into account.

As Cambodia has either abundant solar resources

and high degree of solar irradiation and potential or the regulations on general conditions for connecting solar PV generation sources to the electricity supply system of national grid or to the electrical system of a consumer connected to the electricity supply system of national grid, there is a huge opportunity for every garment industry's owners who want to install solar PV for their production processes. UNDIO TEST project's team had conducted energy audit for garment industrial sector and found that garment industry can install solar PV from 50 kWp capacity up to 1000 kWp with Li-battery system or connecting to the national grid. However, we found that most of garment factories commonly install 300 kWp solar PV with 500 kWh Li-battery system for their electricity consumption's purposes. Therefore, we recommended that every garment factory's owner should consider this if you interest. By looking for the advantages of installing solar PV, the industrial sector such as garment, textile, and other sectors will receive many benefits in a return, not only because it will save electric bills and reduce GHG emissions but also because it will increase the competiveness of the industry, and improve energy security and the affordability of electricity.

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