Evaluating the Framework of Green Factories in China

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Abstract
China is the leading supply chain of the world and feed the whole world. The evaluation of Green Factories of China is very important. Traditionally, the factories are evaluated on specific aspects; energy conservation, efficiency, and environmental concerns. There are hardly any reports which emphasize on comprehensive and systematic evaluation methods for green factories. This study analyzes the current scenario of various countries and regions; and on the basis of emerging scenario, this research paper precisely understands the framework of Chinese Green Factory. This research paper highlights the relevant and updated research regarding the evaluation of Chinese Green Factories. This research paper assesses the effects of Chinese Green Factories and suggests future perspective and guidelines for making them more effective.

Key Words: - **China, Green Factories, Efficiency, Energy, Conservation**.

1. Introduction

Resources constraints, depletion of water table, pollutant air problem and other environmental degradation are the major problems for industrial development. Sustainable development becomes the main concern of all over the world. The companies and businesses started to adopt conservation of resources, environmental protection, green marketing, green manufacturing mechanism, recycling of wastages, and production of green product. Low carbon emission is one of the main aims of green factory concept. The adoption and implementation of green practices is the main factor for solving these problems. It takes into account external environmental problem, political will power and economic factors to find out the solutions of the problem. Factories are responsible for environmental problem as wastages, dust, smoke, and other particles are released by factories while making products and items. Factories are main point where green manufacturing and green practices are implemented. The essential way of optimize industrial structure is to establish green factories and making the whole system eco-friendly from production to distribution. It leads to transformation and upgrading as well as improvements in qualities and efficiency. The evaluation of framework of green factories facilitates for setting standards in the industrial world, guiding and standardization of the implementation of green manufacturing process. It facilitates corporation to take up responsibilities for implementing the green framework. China is the hub of manufacturing industry and accounted for 20% of the

world's annual manufacturing total. This research paper study the green framework of Chinese industry and trying to find out how its green factories should be evaluated.

2. The Concept of the Chinese Green Factory (CGF)

The factories all over the world has started to pay attention to the problems of limited resources and environmental degradation in 21st centuries. The concept of Green factories revolves around Zero-emission or low carbon emission. The factories are adopting different types of green practices in terms of "energy-saving factory," "low-carbon factory," "zero-emissions factory," "harmless factory," "environmentally protective factory," "ecological factory," "recycling factory," "sustainable factory," and more. However, there are not in agreement regarding the concepts and practices of green, but they are in agreement with adopting of green practices in different manner. Green Manufacturing brings the aspect of sustainability, harmony of economic productivity, safer environment, social benefits, and saving future resources. The main objectives of green practices to minimize the impact of factory practices on environment, save earth, lessening pollutant level, save resources for future by formulating environmental strategy.

China had designed a comprehensive plan for the implementation of green manufacturing in 2015. The major objective of this policy was the designing and construction of Chinese Green Factories. China has designed the first National Standards for CGFs in 2018 entitled *GB/T 36132-2018 General Principles for the Assessment of Green Factories.* This document has been defined CGFs as factories that engage in "*the intensification of land, the decontamination of raw materials, clean production, waste administration, and the reduction of carbon and energy*." CGFs should be introduced to Life Cycle Thinking (LCT) to ensure the quality and functionality of products and also maintaining health and safety in the production process. This would facilitate them to choose green raw materials, as well as green processes, technologies and equipment and ensuring that they can continue to meet their requirements regarding infrastructure, management systems, energy, resources, products, environmental emissions, green performance, and more. CGFs should try to make continuous improvement in these areas.

Research Methodology:-

Statement of the Problem: - The purpose of this study is to assess the green factory concepts and practices and framework adopted by the factories.

Scope of the Study

This study was limited to Taiwan, China, European Union, USA, Thailand, Japan, and South Korea to assess the Green Factory Framework and evaluation of Green Factory research and practices in these countries and regions.

Objective of the Study:-This research paper consists of the following objectives:

1. This research paper study the green framework of Chinese industry and trying to find out how its green factories should be evaluated.
2. To study the framework of Green factories framework in Taiwan, China, European Union, USA, Thailand, Japan and South Korea.
3. To find the drawbacks of the Green Factories framework
4. To suggest measure to make it more effective.

Data Collection: - This study is based on secondary data which have been collected from the reports of respective government of different countries. This study has collected the data from journals, magazines, newspaper, books, internet, and other secondary reports published by the international agencies.

3. Evaluation of Research on Green Practices in Other Countries and Regions

3.1.The Organizational Environmental Footprint (OEF) developed by the European Union (EU)

The Environment and Sustainable Development Department of the European Commission's Joint Research Center investigated the assessment strategy in 2012 known as the Organizational Environmental Footprint (OEF). The European Commission issued *Recommendation 2013/179/EU,*[1] *on 9th April 2013* officially starting the promotion of OEF assessments for organizations (including manufacturing factories). OEF measures the environmental performance of an organization at multiple stages of its life cycle. Its primary purpose is to reduce the environmental impact related of an organization's activities by considering the entirety of its supply and logistics system (relating to extraction of raw material, development and usage of products, and waste management). This involves many related parties such as manufacturers, public institutions, and more. The OEF can be used for benchmark management, performance tracking, low-environmental-cost procurement, disaster mitigation, and other voluntary or mandatory programs. That said, the OEF system is still not ideal, since the evaluation process is very complex and contains many uncertainties.

3.2 The Green Certification System in South Korea

South Korea approved and introduced in 2010 the *Framework Act on Low Carbon Green Growth*[2] that introduced a green certification system. This system was introduced and implemented by South Korea's Ministry of Industry, Commerce and Resources. It was carried out in collaboration with eight other ministries and commissions. South Korea promoted four kinds of certifications through the

scheme: green technology, green endeavours, green products, and green enterprises. Among them, the green enterprises certification relates to the assessment and accrediting of green factories. However, the core of the green enterprises certification still focuses on green technology and zero carbon emission. It specifies that, if 20% of the products sold by an organization adopt green technology, then the organization can be called a green enterprise.

South Korean Enterprises that obtain a green certification benefit from a number of preferential policies, including green industry financial support, awards for environmental protections issued by the government, green manufacturing performance testing concessions, priority dispatch for overseas talents and senior talents, priority transfers for technologies, introductions to investment, consulting services, government procurement benefits, and more. As a result of the certification system, South Korea has greatly improved its energy conservation and reduced its emissions. South Korean Government provides lots of relief and benefits to those industries or enterprises that follow green practices in strict manner.

3.3 Environmental Accounting and Environmentally Protective Factories in Japan

As early as 2000, Japan put forward the idea of establishing a zero-waste society and adopted relevant environmental protection measures as a result. Japanese government develops and implements Environmental Accounting as one of measures to adopt the green concepts and practices. The Japanese firms prepare the Environmental Accounting report which shows how many these firms adopting the practices of green concepts and practices. In terms of evaluation methods, Japan implemented the *Environmental Accounting*[3] system to measure, analyze and publicize investments in environmental protections and their resulting economic benefits. This system focused on seven costs related to environmental protections, such as business costs, upstream/downstream costs, management activity costs, R&D cost, social activity costs, costs from environmental damages, and other miscellaneous costs. Japanese enterprises also actively promote various works for the protection of the environment. For example, in 2011, the Hitachi Group implemented the *Excellent Environmental Protection Factory*[4] certification system. In this system, factories could be certified every year and awarded a "crystal heart." After gathering five crystal hearts they would become a excellent environmental protection factory.

3.4 Eco-factory Certifications in Thailand

The Federation of Thai Industries introduced the eco-factory certification in 2011. The certification documents include details about the framework, scope, definitions, standards, rules and guidelines for the development of eco-factories. They state that there are five aspects that make up an eco-factory: zero emissions; efficient resource and energy use, effective environmental management systems; product activities that are green, safe, and transparent; and community cooperation. There are also 14 specific evaluation indicators: raw materials, energy, water and wastewater, air pollution, greenhouse gases, waste management, community, chemical

management, health and safety, transportation, and green supply chains. They measure the green factory concepts and framework on the basis of fourteen specific criteria. These criteria measure the impact of these practices on green house effect.

3.5 Green Factory Mark in Taiwan, China

In January 2012, the Taiwan Ministry for the Economy released a list of key points for promoting its *Green Factory Mark* system. It officially launched its program for evaluating green factories in April of the same year.[5] Taiwan designed a framework of integrated system which addresses energy conservation, reducing wastages and minimizing pollutants, green production and operating system. In Taiwan, a green factory is defined as: A series of mechanisms integrating green building and cleaner production, aiming to reduce the energy and resource consumption and environmental impact of factory buildings in construction and operation, as well as in all stages of a product's life cycle. This is intended to improve the environmental friendliness of industries and products, thereby creating low-carbon industries. The key requirement points of the Green Factory Mark include the green building assessment system and the clean production evaluation system. Organizations can obtain the Green Factory Mark only if they pass both the two evaluations above.

4. Research on the Evaluation Method for CGFs

In the past, the evaluation of CGFs has tended to focus on one specific aspect, such as products, management systems or buildings. The evaluation modes have tended to be one-sided, as was the case with the following three environmental directives of the European Union: the *Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC)*;[6] *Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (2011/65/EU)*;[7] and *Energy-related Products (ErP) Directive (2009/125/EC) (Formerly EuP).*[8] In the United States, the energy star program and the Electronic Product Environmental Assessment Tool (EPEAT) for rating green electronics are similar. The same could be said of China's system for labeling products as energy efficient and non-pollutive, as well as of its control certification system, its environmental management system, its energy management system certification, and its green certification system for civil buildings. Although the European Union, Japan, South Korea, Thailand, Taiwan and other countries and regions have carried out green factory evaluations, some of their evaluation methods are too cumbersome and have limited operability, as these frameworks are too difficult to implement and does not consist of simple steps to be implemented in the simple manner. Furthermore, some are too simplistic for carrying out a systematic evaluation of green factories. In order to develop a comprehensive and systematic framework of evaluation, it is necessary to establish a common green factory evaluation model which can be adapted to the entire manufacturing industry. The whole world also needs to have a comprehensive and global perspective framework which can be adopted by the entire world in the same manner.

First, in order to build a model that is widely applicable, it is necessary to identify the common elements of the manufacturing industry. All industrial manufacturing is a process that moves from input to production through to output.

Figure 1. The Basic Model for Manufacturing

With regard to resources and the environment, the production activities of all kinds of manufacturing factories can be summed up as follows. Based on its infrastructure and management system, a factory puts energy and resources into production and manufacturing. This leads to the creation of products and causes certain environmental emissions.

We can divide the general model for CGFs into six modules: infrastructure, management system, energy and resource input, products, environmental emissions, and overall performance. Previously, evaluations of CGFs have been one-sided, based either on products, processes, or services. The CGF assessment model presented here develops comprehensive and systematic requirements from the six modules outlined above. By analyzing the factors related to green manufacturing involved in each dimension, it is possible to develop a comprehensive CGF assessment system. The framework for this is shown in Table 1.

Table 1: CGF Assessment System Framework

No.	Dimension	Green Factory Factors

1	Infrastructure	Construction, lighting, special equipment, General equipment that uses energy, Measuring equipment, Pollution treatment equipment, etc.
2	Management System	Quality management system, Environmental management system, Occupational health and safety management system, Energy management system, Social responsibility, etc.
3	Energy and Resource Input	Energy input, Resource input, Green purchasing management, etc.
4	Product	Eco-design, Harmful substances use, Energy saving, Carbon footprint, Recycling, etc.
5	Environmentalism	Wastewater control, Exhaust control, Industrial solid waste control, Noise control, Greenhouse gas control, etc.
6	Performance	Land intensification, Raw materials decontamination, Clean production, Waste utilization, Energy and carbon reduction, etc.

Dimension 6, “Performance” refers to the overall results, corresponding to the objectives of CGFs. These results can be expressed

through a series of quantifiable indicators (see Figure 2) such as the intensification of land, the decontamination of raw materials, clean production, waste administration, and the reduction of carbon and energy. These represent the achievements of a CGF during the evaluation period. The other five dimensions are process-oriented, concerning infrastructure, management system, energy and resource input, and product and environmental emissions. They include a series of qualitative or quantitative indicators, showing the characteristics of the various processes and helping CGFs to meet their requirements. CGFs should also be set certain basic conditions, such as basic compliance, requirements for relevant parties, management responsibilities, and more.

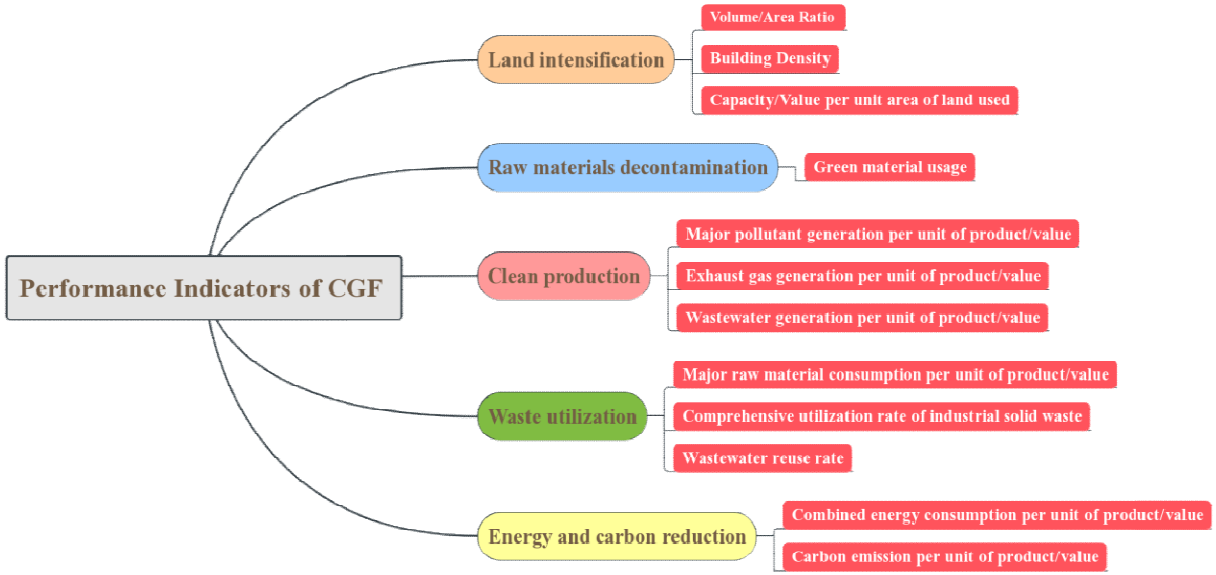

Figure 2:- CGF Performance and Detailed Indicators

When carrying out specific evaluations, the evaluator should formulate the evaluation scheme according to the different characteristics of each industry or enterprise. The evaluation scheme should include, at least, the basic requirements and the six dimensions (namely infrastructure, management system, energy and resource input, products, environmental emissions, and performance). The evaluation scheme should also track scores based on the requirements of the different dimensions to provide a comprehensive evaluation. This will demonstrate to industries or companies how they can achieve an advanced level.

The CGF evaluation would make it possible to obtain for a comprehensive evaluation result covering all the dimensions. This

avoids the incompleteness of a one-dimensional evaluation. A one-dimensional evaluation, as is well known, does not ensure that every factor of a company or industry is green.

On the one hand, the green factory model provides a benchmark for constructing new factories. At the initial stage of factory construction, considering all of the relevant factors helps factories make a good start to obtaining their green goals. On the other hand, the green factory model could also help improve already existing factories. By using a CGF index, factories could know the overall green level of their entire industry. They could keep striving for improvements. From the overall perspective of the manufacturing industry, the construction and evaluation of CGFs would generate experience that could be used for reference, thereby improving green manufacturing levels in the future.

5. Evaluation the framework of CGFs in China

Due to its rapid industrialization, China's overall industrial level has significantly increased. In a list of its 500 major industrial products, over 220 of them rank first in the world in terms of output. In other words, China has become a real industrial power. However, this rapid and large-scale industrialization also consumes a lot of resources and energy, which has placed great pressure on the environment. In 2018, China's total energy consumption was 4.64 billion tons of coal equivalents, 70% of which resulted from industrial energy consumption. In order to make its manufacturing factories more green, however, China has carried out a lot of useful work to try and develop CGFs in recent years.

5.1 The Construction of the CGF Standard Technology System

Standards help to support the overall establishment of CGFs. At present, under the leadership of China's Ministry of Industry and Information Technology (MIIT), CGFs have been increasingly standardized according to a three-level CGF evaluation system made up of general principles, guidelines, and detailed rules. The general principles are set out in *GB/T 36132-2018 General Principles for the Assessment of Green Factories*, drafted by the Chinese Electronics Standardization Institute (CESI) and officially released on May 14th, 2018. This document outlines the standard indicator system and technical top-level framework for CGF evaluation. In terms of the guidelines, the standards for key industries such as electronics, machinery, steel, synthetic ammonia, automobiles, and building materials have all been regulated. Based on the general principles laid out in *GB/T 36132*, the characteristics of various industries have been further highlighted separately, for example in documents detailing industry standards such as *SJ/T 11744-2019 Specification for the Assessment of Green Factories in the Electronic Information Products Manufacturing Industry*. Finally, through the overall planning of the Green Factory Promotion Alliance of China (GFAC), as well as other organizations, detailed rules for CGF evaluations have been formulated for some specific industries.

5.2. The Activities of CGFs

In the second half of 2016, China issued *The Notice on The Construction of a Green Manufacturing System,*[9] which clearly defined the principles, requirements, contents and evaluation methods for CGFs. It also successively carried out several CGF evaluations and selected some companies as CGFs.

According to relevant specifications, the framework for evaluating CGFs in China is divided into six dimensions: infrastructure, management system, energy and resources input, products, environmental emissions and performance. This is a systematic and comprehensive system, meaning that the establishment of CGFs is not unsystematic. That said, it could still be optimized.

By August 2020, the MIIT of China had organized four batches of CGF evaluations listed 1402 factories as CGFs. The industry distribution (Figure 3) shows that electronics (230), machinery (210), chemical (137), building materials (136) and food (124) make up the largest proportion of CGFs. They account for 16.41%, 14.98%, 9.77%, 9.70% and 8.84% of the total, respectively. Among them, the electronics industry and machinery industry are representatives of the discrete manufacturing industry CGFs, while the chemical industry and the building materials industry are representatives of the process manufacturing industry CGFs.

From the regional distribution (Table 2), it can be seen that Jiangsu Province (147), Shandong Province (140), Guangdong Province (129), Zhejiang Province (106), Henan Province (86) account for the largest proportions of the total. They account for 10.49%, 9.99%, 9.20%, 7.56% and 6.13%, respectively. As this shows, CGFs are relatively concentrated in the eastern and southern coastal areas of China.

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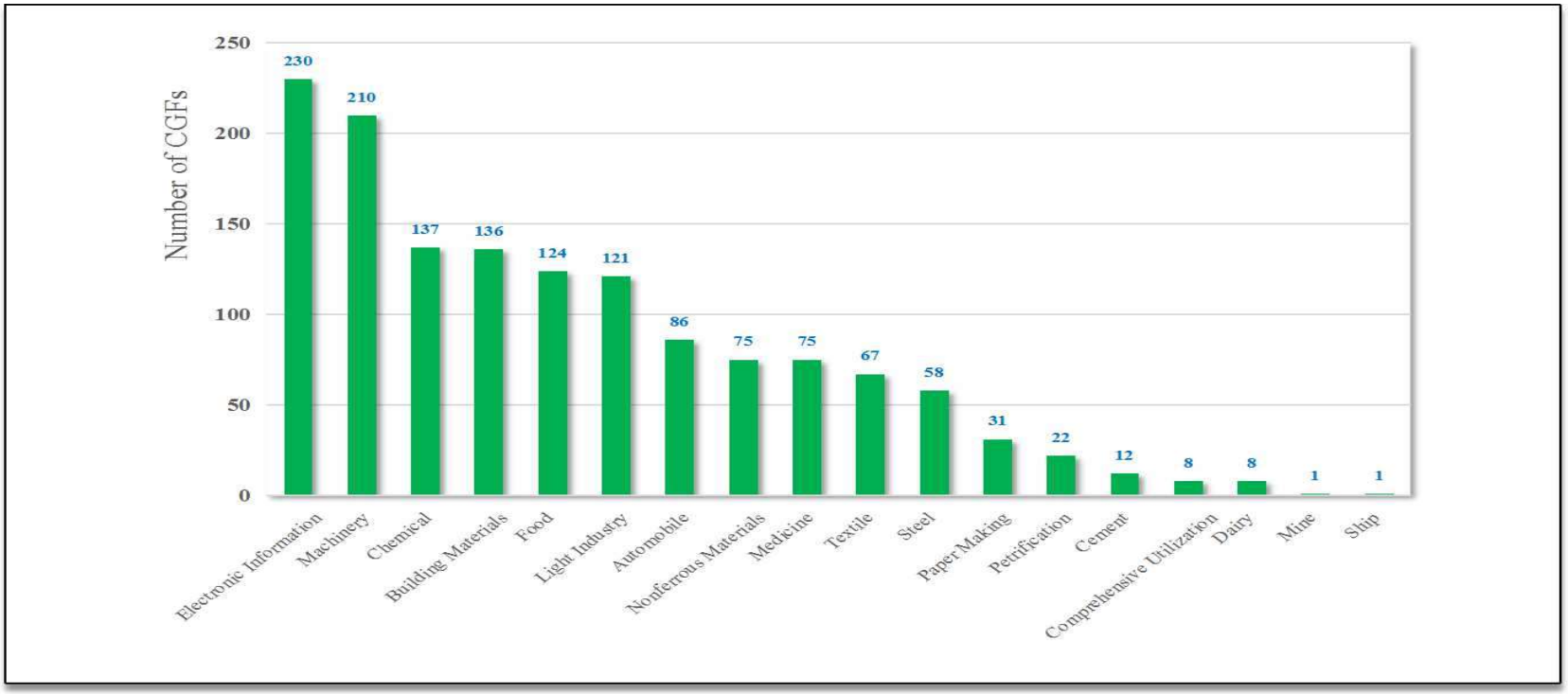

Figure 3: Industry Distribution of CGFs

Table 2 Chinese Region Distribution of CGFs

No.	Area/Province	Number of CGFs	Percentage	No.	Area/Province	Number of CGFs	Percentage
1	JIANGSU	147	10.49%	20	SHAN(3)XI	26	1.85%
2	SHANDONG	140	9.99%	21	SHENZHEN	24	1.71%
3	GUANGDONG	129	9.20%	22	CHONGQING	22	1.57%

4	ZHEJIANG	106	7.56%	23	HEILONGJIANG	21	1.50%
5	HENAN	86	6.13%	24	LIAONING	21	1.50%
6	ANHUI	79	5.63%	25	JILIN	19	1.36%
7	HUBEI	70	4.99%	26	NINGXIA	19	1.36%
8	HUNAN	48	3.42%	27	NINGBO	15	1.07%
9	XINJIANG	42	3.00%	28	QINGDAO	11	0.78%
10	BEIJING	40	2.85%	29	XIAMEN	11	0.78%
11	SICHUAN	40	2.85%	30	SHAN(1)XI	11	0.78%
12	JIANGXI	33	2.35%	31	GUIZHOU	10	0.71%
13	FUJIAN	30	2.14%	32	QINGHAI	10	0.71%
14	TIANJIN	30	2.14%	33	GANSU	8	0.57%
15	INNER MONGOLIA	30	2.14%	34	XINJIANG CORPS	6	0.43%
16	GUANGXI	29	2.07%	35	DALIAN	5	0.36%
17	SHANGHAI	28	2.00%	36	HAINAN	3	0.21%
18	YUNNAN	27	1.93%	37	TIBET	0	0
19	HUBEI	26	1.85%	_	IN TOTAL	1402	100.00%

5.3. The positive effects of CGFs

The creation of CGFs has left to significantly more efficient energy conservation as well as a reduction in emissions. According to (albeit incomplete) statistics, for those industrial enterprises above a scale designated by the state, the work of CGFs from 2016 to

2019 drove the average water consumption per unit of industrial value-added down by 27.5%. It also drove the energy consumption per unit of industrial value-added down by more than 15% in the same period. Thus, constructing a comprehensive green factory model to create CGFs based on certain model parameters has systematically improved the sustainability levels of several industries. The general green factory model covers the entire manufacturing process from input to output.

For certain specific factories, the green factory model has also produced very positive effects, leading to continuous improvement and enhanced green performance. Take the factory of a world-renowned automobile company as an example. Since 2017, this factory has carried out relevant evaluations and practical activities in accordance with the CGF model, and has been included in list of CGFs issued by China's MIIT. The factory organizes annual evaluations and reviews based on a "Plan-Do-Check-Act" cycle. It uses the results of these evaluations as input for the following year's green development decisions. According to the CGF model, the factory's evaluation scores for the past three years have been: 91.20 points (2018), 92.85 points (2019), and 93.85 points (2020). Thus, while its green manufacturing performance is already at a top level, it nevertheless continues to improve. Details of the factory's CGF scores and green manufacturing flash points for each of the past three years can be seen in Table 3.

Table 3 Summary of the Evaluation Results of a Typical Factory (2018-2020)

No.	Dimension	Evaluation Score 2018	Evaluation Score 2019	Evaluation Score 2020
1	Infrastructure	19.00 / 20.00	19.00 / 20.00	19.00 / 20.00
2	Management System	15.00 / 15.00	15.00 / 15.00	15.00 / 15.00
3	Energy and Resource Input	14.25 / 15.00	14.25 / 15.00	14.25 / 15.00
4	Product	8.80 / 10.00	9.05 / 10.00	9.05 / 10.00
5	Environmental Discharge	8.20 / 10.00	8.30 / 10.00	9.30 / 10.00
6	Performance	27.60 / 30.00	27.25 / 30.00	27.25 / 30.00

Total	91.20 / 100.00	92.85 / 100.00	93.85 / 100.00
	● Combined CGF work with daily production and management process		
Flash point	● A *Plan-Do-Check-Act* cycle used to continuously improve the construction of green factory		
	● Energy performance continues to improve		

6. Conclusion and Suggestions

Resources constraints, depletion of water table, pollutant air problem and other environmental degradation are the major problems for industrial development. Sustainable development becomes the main concern of all over the world. The companies and businesses started to adopt conservation of resources, environmental protection, green marketing, green manufacturing mechanism, recycling of wastages, and production of green product. The adoption and implementation of green practices is the main factor for solving these problems. Above all, after nearly four years of development, there have been many positive achievements resulting from the establishment and evaluation of CGFs. The evaluation indicator system has been shown to be scientific, rational and operable across various regions and industries. Under the impetus of China's MIIT, a number of advanced CGF models have been developed, leading to improvements in China's manufacturing industry, particularly with regards to efficiency and sustainability. At the same time, it has also provided practical experience for green development in manufacturing industries around the world. Therefore, it is suggested that the establishment and development of CGFs be encouraged and improved in the following ways.

1. Study the Threshold Value of Green Factory Related Indicators:- Basic data (regarding, for example, comprehensive energy consumption per unit product and water intake per unit product) should be collected to generate a basic database of energy conservation and emission reduction in each industry. This would provide a scientific basis for the threshold value of relevant standard indicators.

2 Enhance CGFs by Increasing Capacity in Underdeveloped Areas and Industries:-The number of CGFs in developed areas and advanced industries accounts for more than 40% of China's total. However, from the perspective of demand, underdeveloped areas and industries also need to move urgently towards green manufacturing. The establishment of CGFs in these areas would help

with this.

3 Learn from the Experience of Various Countries and Increase the Promotion of Government Policies:-China should learn from the experiences of the EU, South Korea and other countries and regions. It should establish a green manufacturing incentive mechanism with positive fiscal and tax policies for CGFs. This would encourage enterprises to assume social responsibility, carry out energy conservation, and reduce their emissions.

4. Strengthen International Cooperation and Promote: It the need of the hour to establish International Standards for Green Factories:-International cooperation and exchange should be improved to develop good practices in various countries. This should involve the establishment of international standards for green factories. This would lead to improvements in green development for manufacturing industries worldwide.

There is need of comprehensive framework throughout the world which address the environmental problems in more strict manner and standards requires to be ne devise in this direction to implement these standards on equal footage. Countries are devising their own standards and framework which suits their industries/factories and strict compliance to be followed. There is no compliance or penalties to be followed in these frameworks. Absence of compliance of standards and practices are the main drawback of green factories/ industries.

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