FUTURE FACTORY: A CASE STUDY ON ENERGY AND CARBON REDUCTION IN A BIO-PHARMACEUTICAL PLANT

Hua Wang[1] and Jian Yu[2]
[1, 2] School of Information and Electronic Engineering, Zhejiang University of Science and Technology, China
Email: [1]wanghua96@126.com

Abstract
Manufacturing industry is recently facing many challenges such as shorter product life cycles, diversified demands and green manufacturing. According to the deployment of carbon peaking work in Zhejiang province of China, pharmaceutical and chemical companies must accelerate product upgrading and green technology transformation of production methods to promote the carbon emission peaking. To this end, the bio-pharmaceutical company named Conba optimizes, upgrades and innovates existing technologies and equipment when applying energy-saving and consumption-reducing processes, so that they can better meet the application conditions of energy-saving and consumption-reducing technologies in the actual production process. Using the key production parameters of the equipment and equipment monitoring technology, Conba improves the utilization rate of operating equipment and reduces unnecessary energy consumption through data analysis to build a future factory with high energy efficiency, green environment protection and comfortable work environment.

Key Words: Future factory, Bio-pharmaceuticals, Carbon peaking

1. Introduction

Today manufacturing industry is facing many challenges such as shorter product life cycles, diversified demands and green manufacturing [1-3]. By employing a series of automated control systems and digital technologies, the *Future Factory* [4,5] applies the concept of Internet of Everything, fully integrates and utilizes the information data of the production chain, to realize unmanned (or less human) automated manufacturing of products. The future factory visualizes the production process and makes it transparent, quantifiable and traceable. This could be realized by breaking through information silos. Endowing the future factory with an intelligent manufacture property can greatly improve production efficiency, enhance product quality control, and reduce production and operation costs. Through the implementation of the future factory project, companies can effectively enhance the sustainable development of enterprises, significantly strengthen their core competitiveness and improve the level of digital intelligent manufacturing in the industry. Conba is a comprehensive pharmaceutical enterprise producing antibiotics [6], semi-synthetic antibiotics, chemical synthesis and new formulations such as slow-release micro-pills and lyophilized powder injections. In recent years, relying on the resource advantages of Conba Stock Company (stock code: 600572), the company has been developing steadily and rapidly.

In applying energy-saving and consumption-reducing technologies, Conba also needs to optimize, upgrade and innovate existing technologies and equipment, so that they can better meet the application conditions of energy-saving and consumption-reducing technologies in the actual production process. Meanwhile digital systems need to be integrated to serve the project termed as Future Factory [7], which will centralize the future product development, manufacturing, sales and after-sales work in an enterprise-level IoT platform for unified management and optimization of various business processes [8].

The construction of this project meets the needs of the industry development of Conba. Given the myriads of key industry challenges arising out of the future factory convergence, the proposed project not only satisfies the requirements of Conba for the relocation of the fermentation and API (Active Pharmaceutical Ingredient) production line to ensure the stable supply of related APIs, but also improves the overall economic benefits of Conba. The relocation of APIs from other places is the demand for planning compliance, product line and industrial upgrading, as well as the requirement for compliance with safety and environmental protection related laws and regulations. At the same time, as the products are put into operation, the synthesized competitiveness of enterprise and industry will be comprehensively improved while meeting the domestic and foreign market demands. The construction and operation of the project will play a positive role in promoting the upgrading of the biomedical industry and the low-carbon development of the industry in Zhejiang province of China.

2. The proposed project

This project involves five products including spectinomycin hydrochloride shown as in Table 1.

Table 1. Product Name and Scale

No.	Production Name	Unit	Production Scale	Remark
1	Spectinomycin Hydrochloride	ton/year	150	
2	Spectinomycin Sulfate	ton/year	50	
3	Kanamycin	ton/year	300	raw material for Amikacin Sulfate
4	Amikacin Sulfate	ton/year	200	
5	Tazobactam Acid	ton/year	100	

The construction of this project includes Fermentation Workshop, Extraction Workshop-I, Extraction workshop-II, API Building-VII, API Building-VIII, Power Center-II, Comprehensive Warehouse (including grain storage), General Control Room, Hazardous Waste Storage of Category C, Waste-III Auxiliary Room, Accident Pond Expansion, Sewage Treatment, RTO, Solid Waste Incineration, Telecommunications Engineering and General Drawings, Plant External Pipe Rack, Plant Cable and Road Lighting, Plant Water Supply and Drainage and Fire Protection, Earthwork Excavation and Backfill, etc. The structural characteristics of the proposed single building are detailed in the list of buildings and structures in Table 2.

Table 2. List of buildings and structures

No.	**Building (structure) name**	**Production/storage category**	**Structures Floor space(m^2)**	**Building index (m^2)**		**Structure Features**	**Architecture Number of layers**
				Area Covered	**Floor Area**		
1	Fermentation plant	Category C	/	3356	12884	Frame	4
2	Extraction workshop I	Class A	/	1320	5280	Frame	4
3	Extraction workshop II	Class A	/	1320	5280	Frame	4
4	API Building VIII	Class A	/	1320	5280	Frame	4
5	API Building VII	Class A	/	1575	6300	Frame	4
6	API Building IX	Class A	/	1320	5280	Frame	4
7	General Warehouse (including grain depots)	Category C	/	1408	5632	Frame	4
8	Power Center II	Category C	/	1408	2816	Frame	2
9	General control room	Class D	/	450	450	Frame	1
10	Class C hazardous waste storage	Category C	/	560	1680	Frame	3
11	Three waste auxiliary room	Category C	/	450	1350	Frame	3
12	Accident pool expansion		450	/	/		/
13	RTO, solid waste incineration		1241	/	/		/
14	Wastewater Treatment	Category C	/	3325	3325	Frame	1

2.1 Main equipment selection and engineering solutions

Each equipment in the production ensures the normal operation of the production while ensuring the safety of the production and reducing the pollution to the environment. Conba tries to use energy-saving equipment to fully consider the requirements of energy saving and emission reduction. According to the characteristics of the process, the *Fire Prevention Standard for Petrochemical Enterprise Design* (2018 version GB50160-2008 in China) [9], and the *Transport Design Specification for Pharmaceutical Industry* (GB51047-2014 in China) [9] are followed, combined with the current layout of the plant and the natural environment. There have been these attempts at meeting the requirements of smooth process flow, convenient transportation, safe fire separation and sanitation, save energy consumption and land, etc. The general layout strives to achieve clear functional zones, convenient pipeline routing, good environmental hygiene conditions, neat and beautiful plant appearance, and is conducive to production safety management.

2.2 Application and Adoption

After the implementation of Future Factory, unnecessary personnel have been reduced on the production line, production processes prioritized, production processes improved, and the overall work efficiency of the company raised. Finally, these measures have significantly improved the energy-saving use of the water, electricity, gas and other energy sources. After the technical transformation and relocation of the project, the energy consumption per unit product has decreased, mainly due to the elimination and updating of equipment, the upgrading of production process and the improvement of more reasonable layout of production lines. Among them, the energy consumption per unit product of spectinomycin has decreased significantly, mainly due to the upgrading of the sterilization technology of the culture medium in its fermentation workshop. The continuous sterilization technology is adopted, and the steam consumption is about 30% less than before. The comparative analysis of energy consumption before and after relocation of project is illustrated in Table 3 and 4.

Table 3. Comparative analysis of energy consumption before and after relocation of project

Item	Unit	Post-Relocation Indicators		Pre-Relocation Indicators	
		Spectinomycin	Amikacin sulfate	Spectinomycin	Amikacin sulfate
Annual production	*t*	200	200	200	200
Annual electricity consumption	10,000 *kWh*	1829.83	239.52	2181	240
Annual steam consumption	*t*	43299	18557	62500	19000
Annual water consumption	10,000 m^3	35.07	6.93	36	7.5
Comprehensive energy consumption and other values	t_{ce}	9315.18	2432.91	12118.52	2476.43
Comprehensive energy consumption equivalent value	t_{ce}	6349.02	2044.64	8585.90	2087.39

Table 4 Comparative analysis of energy consumption before and after relocation

Item	Unit	Pre-Relocation Indicators	Post-Relocation Indicators	Addition Indicators
Annual electricity consumption	10,000 *kWh*	2421	4306.04	1885.04
Annual steam consumption	*t*	81500	131959	50459
Annual water consumption	10,000 m^3	43.5	91.34	47.84
Comprehensive energy consumption and other values	t_{ce}	14594.95	24754.61	10159.66
Comprehensive energy consumption equivalent value	t_{ce}	10673.29	17774.52	7101.23
Total industrial output	10,000 RMB	53750	90750	37000
Industrial value added	10,000 RMB	24187.50	46038.5	21851
Energy consumption of industrial added value (equivalent value) per 10,000 RMB	t_{ce}/10,000 RMB	0.60	0.54	0.46

2.3 Energy measurement and management

The company establishes the contract institution of energy consumption assessment for energy consumption measurement and assessment of workshops, sections and processes. Measurement and detection instruments are set up to implement energy consumption accounting so as to improve production efficiency. The company improves the energy management system, develops information communication control procedures, training and awareness control procedures, monitoring and measuring equipment control procedures. By employing measurements such as energy objectives and its indicators, control procedures of management implementation plan and other measures, Conba strengthens the effective management of energy measurement data collection, processing and use. In this way, the company gives full play to the role of energy measurement detection data in various tasks such as production and operation, cost accounting, energy balance and energy utilization statistical analysis. By using scientific and accurate measurement data to guide production and energy saving, the process defects and management loopholes could be found out through quantitative assessment. The potential of energy saving will be improved in a timely manner, and the energy conservation is implemented.

At the same time, the company establishes an intelligent energy management system. According to the requirements of the *Technical Agreement on the General Data Interface of Energy Metering Instruments* (GB/T 29871-2013) [9], the *Data Transmission Protocol on the Public Platform for Energy Metering Data* (GB/T 29873-2013) [9] and the relevant technical standards of Zhejiang province, data acquisition equipment of the energy source should be able to be directly accessed or be able to be accessed in line with the RS-485 interface standard [10], M-Bus interface standard [11] or the energy metering instrument with short distance wireless transceiver interface standard. Meanwhile, the data of metering terminals could be directly collected that comply with the *Communication Protocol for Multifunctional Watt Meters* (DL/T 645-1997) [9]. On the basis of ensuring the safety and reliability of energy and power supply, a real-time monitoring platform for enterprise energy management is established to improve the automatic monitoring and information level of energy and power system.

2.4 Calculation of energy saving and carbon reduction effect

(1) CO2 emission reduction

After the relocation of the project, the annual electricity consumption of spectinomycin and amikacin sulfate is 20,690,000*kWh* and the annual steam consumption is 61,856*t*. Before the relocation, the annual electricity consumption is 24,210,000*kWh* and the annual steam consumption is 81,500*t*. According to the *Greenhouse Gas Emission Accounting Methods and Reporting Guidelines for Enterprises in Other Industries* (for Trial Implementation in China) [12], the corresponding enthalpy is 2,777.3 kJ/kg at the pressure of 1.27 Mpa and the steam temperature of 170-180°C.

The formula for calculating the thermal consumption of an enterprise in terms of mass unit is $AD_{steam}=Ma_{st}*(En_{st}-83.74)*10^{-3}$, which gives the annual steam heat consumed before and after relocation as 219525.14GJ and 166612.85GJ, respectively. The CO_2 emission factor of the thermal supply is calculated as as 0.11t CO_2/GJ, and the annual CO_2 emissions of steam before and after the relocation are 24147.77t CO_2 and 18327.41t CO_2, respectively. So the CO_2 emission reduction is 5820.36t.

According to the default value in the *Accounting Guidelines* [12], the electricity emission factor is 0.7035t CO_2/MWh. The CO_2 emission formula implied by the net purchase of enterprises is $E_{CO2\ net\ power}=AD_{electricity}*Ei$. The CO_2 emissions of the annual electricity consumption before and after the relocation are 17031.74t CO_2 and 14555.42t CO_2 respectively, and the CO2 emission reduction of the annual electricity consumption is 2476.32t. Therefore, the total CO_2 emission reduction of steam and electricity before and after relocation is 8296.68t.

(2) Energy consumption intensity

The energy consumption (equivalent value) of this project is 0.54tce/10,000 RMB of industrial added value, which is 0.06tce/10,000 RMB lower than before the technical transformation and relocation.

3. Conclusions

(1) *Comparison and selection of technological schemes.* Conba has its own fermentation and extraction process with independent intellectual property rights, which is simple in route, higher in raw material conversion rate and more suitable for industrialization. On the basis of preliminary research, the technological scheme of related products is finally selected, and all raw materials and reagents are made in China.

(2) *Principles and basis for determining the raw material route.* The selection of raw materials mainly considers green and environmental protection, convenient supply and low price. The process route is reasonable, easy to operate, suitable for industrialization, and has little pollution.

(3) *Characteristics of process technology*: The hydrochloric acid, spectinomycin sulfate and kanamycin products of the project are fermentation and extraction products. The production is divided into strain cultivation, fermentation, pretreatment, extraction, concentration, crystallization, drying, packaging and other processes. The production technology is advanced, and the production equipment, product quality and various technical indicators can meet the corresponding standards.

The project adopts fermentation extraction technology with independent intellectual property rights. We uses ordinary raw materials to save energy, reduce consumption and reduce costs. The usage of new solvents and reagents reduces the generation and treatment difficulty of *three wastes*, facilitates industrial production, also reduces environmental pollution of industrial production. Tazobactam acid and amikacin sulfate are synthetic products by avoiding expensive raw materials and reagents, thus, achieving energy saving and consumption reduction. Furthermore, ordinary raw materials are used to reduce the risk in the reaction process.

Through the construction of this project, a API production line conforming to Chinese GMP and European and American GMP has been established. The advantageous products of the enterprise has been effectively combined, which has greatly promoted the optimization and adjustment of product structure of the enterprise. At the same time, the technology and equipment level of the company has been greatly improved on the existing basis, with particular emphasis on improving the level of safety management and environmental protection. In this way, an international advanced pharmaceutical enterprise with industry demonstration level has been built, eventually to enhance the overall image of the company.

References

[1] Chen, Y., and Y. Liu. How Biased Technological Progress Sustainably Improve the Energy Efficiency: An Empirical Research of Manufacturing Industry in China[J]. Energy, 2021, 230(C).

[2] Mei-Rui Zhong, Meng-Yuan Cao, Han Zou. The carbon reduction effect of ICT: A perspective of factor substitution[J]. Technological Forecasting and Social Change, 2022, 181(C).

[3] Nwani, C., Effiong, E. L., & Matthew, E. T. Globalization-induced social changes and their environmental impacts: Assessing the role of information and communication technology in sub-Saharan Africa. Journal of International Development[J], 2022, 1–21.

[4] Xu L, Vrieze P D, Yu H , et al. Interoperability of the future factory: an overview of concepts and research challenges[J]. International Journal of Mechatronics and Manufacturing Systems, 2020, 13(1):3.

[5] McCreary, F., Petrick, I., Zafiroglu, A. Designing for the Future Factory: Exploring the Co-evolution of Manufacturing Digital Intensity and Personas[J]. Advances in Intelligent Systems and Computing, 2019, 793:127–137.

[6] www.conbapharm.com:9443/en, 2020.

[7] Level P. The Factory of the Future, Augmented Reality and Projection Mapping[M]. 2020.

[8] Uwiringiyimana, M.M., Nandagopal, G., Guan, Y., etc. IoT Platforms. In: Zivkovic, C., Guan, Y., Grimm, C. (eds) IoT Platforms, Use Cases, Privacy, and Business Models. Springer, Cham. 2021:21–49.

[9] http://www.gb688.cn. 2017.

[10] Buchanan, W.J. RS-422, RS-423 and RS-485. In: The Handbook of Data Communications and Networks. Springer, Boston, MA. 2004:627–631.

[11] Schneps-Schneppe, M.A. M2M communications based on the M-Bus protocol. Automatic Control and Computer Sciences, 2012(46):83–89.

[12] The National Development and Reform Commission. The Guidelines for Accounting Methods and Reporting of Greenhouse Gas Emissions by Chinese Power Generation Enterprises (for Trial Implementation)[J]. East China Power, 2013, 41(11):1-20.