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Exploring the classification and characteristics of China's hydropower resources based on the UNFC

Bo Huang
Jiangsu University
Jiangsu, China
1650898548@qq.com

Zhe Zhang
Jiangnan University
Jiangsu, China
976339036@foxmail.com

Siyuan Liang
Beijing Wuzi University
Beijing, China
liangsiyuan96@163.com

Minxing Fu
China University of Geosciences, Beijing
Beijing, China
2297766380@qq.com

Yuxuan Xia
Jiangnan University
Jiangsu, China
2647987617@qq.com

Kaiqiang Zhou
Jiangnan University
Jiangsu, China
1546493857@qq.com

Xing Zhang
Yanshan University
Hebei, China
2189818430@qq.com

Abstract—Sustainable Development of energy is a problem that every country in the world needs to consider, which is a huge challenge to the adjustment of energy structure of every country. In China, hydropower is a high-quality and renewable energy source, and the key to the implementation of the Paris Agreement and the implementation of China's emission reduction commitments lies in China's hydropower. At present, the application of UNFC in the field of water energy resources is still in the preliminary stage, the research group on water energy resources established by the United Nations is in the research and development stage, and there are no examples of application in the field of water energy resources on its website. In this paper, we collected the data of China's hydropower projects, which have been put into operation and are being surveyed and exploited, is preliminarily based on the core theory of UNFC, through the actual reference indicators of some projects, the impact of the impact has been identified, pros and cons of such information, classified assessment. On the basis of the 2019 revised UNFC, the classification and evaluation system is analyzed and summarized in the light of the hydropower resources utilization projects that have been put into operation and are being surveyed and developed in China. The basic three-dimensional framework of UNFC and some applicable terms are retained in the analysis process, in combination with the actual situation of China's projects, the inappropriate parts are modified to adapt to the application of China's hydropower resources utilization projects. The purpose of this paper is to find out the key points that need to be paid attention to when using the UNFC, and how to evaluate the project reasonably, so that it can be used as an evaluation tool to evaluate the water energy resources utilization projects .As a decision-making tool that has been put into operation, it can provide decision-making and reference guidance for hydropower resource utilization projects under research and development and projects to be developed in the future, and provide a certain reference for countries to achieve their goals. it can provide decision-making and reference guidance for the water energy resources utilization projects being investigated and developed and the future projects to be developed, it can provide some reference for countries to achieve the goal of sustainable, environment-friendly, carbon-neutral and efficient development.

Keywords—Hydropower resources, Project benefits, Stage evaluation, UNFC

I. Introduction

The United Nations Resource Framework Classification (UNFC) was developed under the auspices of the United Nations Economic Commission for Europe by a group of experts from various fields. The latest revision of the UNFC aims to meet the needs of different resource industries and applications and actively implement the 2030 Agenda for Sustainable Development. And make the UNFC fully respond to the Parliament's demand for sustainable resource management Their common goal is to develop a global, principles-based resource classification system, as well as the classification, management and reporting of resources used for solid minerals, oil and gas, renewable energy and human activities. At the 2018 Geneva Conference, China's standard "Classification for Resources/Reserves of Solid Fuels and Mineral Commodities (GB/T 17766-1999)" and "Classification for Petroleum Resources/Reserves (GB/T 19492-2004)" were released bridging documents with UNFC.

In China sustainable energy development is an important issue related to economic and social development. In order to reach the peak by 2030 and achieve the goal of carbon neutrality by 2060, it is urgent to optimize the energy structure and accelerate the transition of energy consumption to low-carbon and clean energy [1]. China's hydropower resources reserves amount to 680 million kilowatts, ranking first in the world, and the rate of hydropower resources development is relatively high. Moreover, there is no fundamental opposition between the utilization of hydropower resources and the environmental protection of resources. The use of electric energy instead of fossil energy as the terminal to develop and utilize hydropower, a renewable energy source, conforms to the strategic requirements of sustainable development worldwide. In China, research on the classification system based on UNFC is limited, and its application in hydropower resources is still not yet available. The original content of UNFC is not

applicable to some of the content of water energy resource utilization, and China also has some unique industry terms.

Based on the above situations, the classification and evaluation of hydropower resources, scientific and reasonable analysis of the environmental-social-economic vitality and technical feasibility of existing hydropower resource development projects play an important role in promoting the optimization and upgrading of the energy structure. This paper analyzes and studies two representative hydropower projects, the Three Gorges Project that has been put into operation and the Medog County Hydropower Station in the survey stage. According to the core theoretical ideas of UNFC, the relevant content and data of two hydropower resource projects are collected, and comprehensive analysis and analysis are carried out according to the characteristics of different projects. 1. Take the China Hydropower Project as an example, and apply UNFC based on its unique terminology. 2. Look for the differences between hydropower projects and other energy projects, and conduct in-depth analysis of the differences. 3. Explore the environmental-social-economic vitality (E-axis), technical feasibility and maturity (F-axis) of the hydropower project in the process of UNFC application, and which aspects should be paid attention to. As the key point, the final classification is carried out. I hope to provide some references for other scholars to study hydropower resources and UNFC, and provide analysis, evaluation and guidance for decision-making on the utilization of hydropower resources in China and even other countries in the world.

II. CASE 1: THREE GORGES PROJECT

The Three Gorges Project is currently the largest water conservancy project in the world. It took 74 years from Sun Yat-sen's proposal in 1918 until the proposal for the construction of the Three Gorges project was voted through at the Fifth Session of the Seventh National People's Congress in 1992. During the period, the Three Gorges Project was started several times, but due to social unrest, it was placed again. After several surveys and demonstrations, the Three Gorges Project took 17 years and was finally completed in 2009 in three phases [2]. The Three Gorges Project has a significant impact in China and the world, with complex social, economic, humanistic, ecological and other impacts. So far, many local scholars and overseas scholars have carried out various researches on the project. Therefore, this paper believes that the study of China The case of the Three Gorges for hydropower resources is representative and necessary.

1. *Project Overview*

The Three Gorges Project is composed of a barrage dam, power station buildings, navigation buildings, and Maoping River protection project. The seismic design intensity of the main buildings is VII. Details are shown in Figure I.

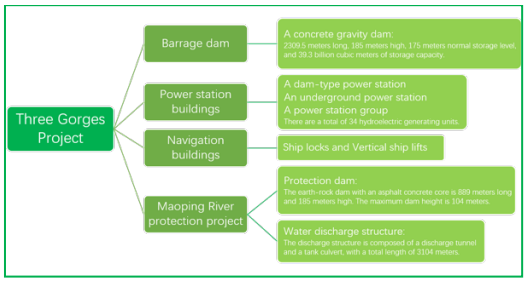

Figure I. OVERVIEW OF THE THREE GORGES PROJECT

2. *Method*

In the case of the Three Gorges Project, based on the UNFC three-dimensional framework system, literature research methods are used. First, quantify the various types of products of the project, and then analyze the three aspects of environment-society-economic vitality (E-axis), technical feasibility and maturity (F-axis), and product confidence (G-axis). When explaining the analysis, list the key points that need to be paid attention to, and evaluate through these key points.

3. *Product Type*

In the study of the utilization of hydropower resources, we found that the project products are expressed through project benefits, which can more fully reflect the utilization of hydropower resources. Compared with other energy sources such as the sun, wind, geothermal, minerals, and nuclear fuel energy, hydropower resources have the same characteristics and particularities. It is a kind of energy, a kind of clean and renewable energy, and it also has the characteristics of single benefit. Other energy utilization projects focus on energy production, possibly through various collection methods to achieve higher energy efficiency. However, when hydropower resources are used, their energy output may only be part of the project benefits, and there are more social and ecological benefits, including flood control, shipping, water supplementation, and ecological environment benefits, which are particularly reflected in major national projects. Just as in the analysis of the utilization of hydropower resources by China's Three Gorges Project, its flood control function is the first, followed by power generation, and it can also carry out the functions of drought resistance, irrigation, and shipping.

4. *Parameters*

(1) Electricity benefit parameters

Dam-back power station: 26×700,000 kilowatts, installed capacity 18.2 million kilowatts.

Power station: 2×50,000 kilowatts, with an installed capacity of 100,000 kilowatts.

Underground power station (commissioned for power generation in 2012): 6×700,000 kilowatts, with an installed capacity of 4.2 million kilowatts.

The total installed capacity is 22.5 million kilowatts, and the average power generation for many years is 88.2 billion kW·h. The annual power generation in 2020 is the highest in history of 111.8 billion kW·h.

(2) Shipping benefit parameters

Double-line five-stage continuous ship lock: 50 million tons of ship passing capacity.

Vertical ship lift: 3000 tons of ship capacity

(3) Other benefit parameters

The normal storage level of the reservoir is 175 m, with a storage capacity of 39.3 billion m^3.

The flood control limit water level during the flood season is 145 m, and the flood control storage capacity is 22.15 billion m^3.

The water retaining structure is designed according to the once-in-a-millennium flood, with a peak flow of 98,800 m^3/s.

5. Quantification of benefits

Electricity benefits. China's power grids generally face great pressure for peak shaving. Hydropower units have the characteristics of rapid start and stop and flexible operation. To a large extent, the peak shaving of the power grid system needs to be achieved through hydropower. Hydropower generation needs to cooperate with the grid system peak shaving and its own maintenance and repair, so it does not have a fixed operating time and power generation [3]. Based on the analysis of the total installed capacity of the hydraulic turbine units of the Three Gorges Project and the electricity output over the years, based on the calculation of 365 days a year, each unit of the Three Gorges Project has an average of 10.74 hours per day, and the maximum average operation of each unit is 13.61 hours per day. Comparing the Itaipu Hydropower Station with a total installed capacity of 14 million kilowatts and an average annual average of 90 billion kilowatt-hours, each unit runs an average of 17.61 hours per day. We can find that as China's electricity demand rises and the energy structure is adjusted, the Three Gorges Project will obviously Increase power generation year by year.

Shipping benefits. After the completion of the Three Gorges Project, the one-way passage capacity of the channel will be increased from 10 million tons to 50 million tons, and the 10,000-ton fleet can directly reach Chongqing from Shanghai. Since the impoundment, the accumulated freight volume through the gate has reached 1.26 billion tons over the years, and the annual maximum freight volume has reached 140 million tons.

Flood control benefits. The Three Gorges Reservoir can intercept floods, regulate the water level in the middle and lower reaches, and reduce the inundation of arable land, the affected population, and economic losses. Since 2003, the Three Gorges Reservoir has stored a total of 150.7 billion m3 of floodwater over the years, and no major danger has occurred in the main dike. Among them, in 2010 and 2012, they successfully dealt with floods with the largest flood peak of 70,000 cubic meters per second. In the event of a major flood, it can reduce the inundation of cultivated land by 2,400 square kilometers, reduce the disaster-affected population by 600,000 people, and reduce economic losses of 78.7 billion yuan.

Benefits of water resources regulation. Through the dispatch and operation of the Three Gorges Reservoir, it has provided water for drought relief and emergency water replenishment. As of 2018, it has provided more than 240 billion cubic meters of water to the downstream. In 2011, during a severe drought in the middle and lower reaches of the Yangtze River in 100 years, the Three Gorges Reservoir provided 5.47 billion cubic meters of water for drought relief in the middle and lower reaches. In 2014, during the salt tide intrusion of the Yangtze River Estuary, the Three Gorges Reservoir made an emergency water supply of 17.3 cubic meters.

Ecological and environmental benefits. Adjusting the discharge flow can effectively reduce the serious damage to the ecology and environment of the middle and lower reaches of the Yangtze River by flood disasters, and avoid the spread and spread of plagues and infectious diseases caused by floods. The cumulative green electricity generated by power generation is equivalent to saving 390 million tons of standard coal, reducing emissions of 1.04 billion tons of CO_2, 11 million tons of SO_2, and a large amount of waste water and waste residue [4].

6. Classification

6.1. *E Axis – Environmental-Socio-Economic Viability*

TABLE I. E CATEGORY CLASSIFICATION AND SUBCLASSIFICATION

Stages of project	***UNFC-2019 Class***		***Reasoning for classification***
	Category	***Sub-category***	
Survey stage	E2	/	During the survey stage, the project did not have sufficient reasons for construction at that time, but it is expected that construction will be carried out in the future in the future.
Construction stage	E1	E1.2	During the construction phase of the project, there have been problems in resettlement, environmental pollution, residential noise, and project quality management. It can be mitigated or even avoided after relevant measures are taken. Its expected future environmental, social, and economic benefits are significant, and its adverse effects are minor.
Operation stage	E1	E1.1	During the commissioning stage of the project, the benefits of flood control, power generation, shipping, and water resource regulation were realized as scheduled, and there were certain adverse effects on the ecological environment. Comprehensive considerations showed that the project has good vitality.

During the survey stage, the decision to construct the Three Gorges Project was greatly influenced by social, economic and national policies. Although huge hydropower resources have been proven to have clear power generation and flood control benefits, the decisions have been affected many times, including the country's excess electricity consumption. Key issues such as capital budgeting, social unrest, national policies, and disputes between experts belong to the construction that did not have sufficient reasons at the time, but it is expected that construction will be carried out in the future in the future. If it is classified at this time, it should be in E2.

During the he construction stage, the total investment actually completed for the Three Gorges Project is about 222 billion yuan, including 78.888 billion yuan for the pivot project, 93.960 billion yuan for the resettlement project, 34.428 billion yuan for the transmission and transformation project, and about 14.428 billion yuan for the underground power station and it's For supporting projects, it can be seen that the resettlement part accounts for about 42.3% of the investment in the project, which is also a key issue repeatedly demonstrated in the survey stage. The state has introduced relevant immigration policies to ensure that the living standards of immigrants cannot be lower than before, thus promoting the smooth development of the project. During the construction of each part of the building, there are some problems in quality management, construction noise and pollution, and the survival of animals and plants. After relevant measures are taken, they can be mitigated or even avoided. Its expected future environmental, social, and economic benefits are significant, and its adverse effects are minor, so the classification at this time should be E1.2.

During the construction stage, the Three Gorges Project has realized its benefits in flood control, power generation, shipping, and water resources regulation as scheduled, which has greatly promoted the society and economy. According to 2017 statistics, the Three Gorges Power Station has accumulated 1 trillion kilowatt-hours of power generation over the years, and the total power generation income has long exceeded the total construction investment of 222 billion yuan. As the project runs, its benefits will accumulate more [5]. However, due to the incomplete research on ecological and environmental issues in the early stage, the main problems are: first, clear water discharges to scour the river, causing intensified bank collapse and endangering the stability of the embankment; second, the storage of the reservoir after the flood causes the discharge flow to decrease, causing Dongting Lake and

Poyang. The water level of the two major lakes has decreased, the amount of water has decreased, and the water quality has deteriorated. Comprehensive consideration, the project has good vitality, and the classification should be E1.1.

6.2 *F Axis – Technical Feasibility and Maturity*

TABLE II. F CATEGORY CLASSIFICATION AND SUBCLASSIFICATION

Stages of project	*UNFC-2019 Class*		*Reasoning for classification*
	Category	*Sub-category*	
Survey stage	F2	F2.1	During the survey phase, the project development will be carried out in the future, but certain conditions must be met, and the classification should be F2.1. In the construction phase, the project has been demonstrated for phased construction, and the technology and funding have been determined, so it is classified as F1.3 at this time. In the commissioning stage, the project is in production and all aspects of the investment and income are realized as scheduled, so the classification is F1.1.
Construction stage	F1	F1.3	
Operation stage	F1	E1.1	

In terms of technical feasibility and maturity, from the survey to the commissioning stage, its technology meets the requirements in all aspects under the strict control of the country. But combined with the analysis of the above stages, the maturity of the project is different at different stages. During the survey phase, the project development will be carried out in the future, but certain conditions must be met, and the classification should be F2.1. In the construction phase, the project has been demonstrated for phased construction, and the technology and funding have been determined, so it is classified as F1.3 at this time. In the commissioning stage, the project is in production and all aspects of the investment in the income are realized as scheduled, so the classification is F1.1.

6.3 G Axis – Degree of Confidence

Product confidence is mainly combined with quantitative analysis of benefit parameters. According to the running time to evaluate:

TABLE III. CLASSIFICATION OF OPERATING PHASES

Classification	*Quality of benefits*		*Supplemental information*	*Reasoning for classification*
UNFC-2019 Class	*Hydropower benefits*	*Other benefits*		
E1.1; F1.1; G1	821.25×10^8 kW • h	Low case	Low estimate of project benefits	10 hours a day on average
E1.1; F1.1; G2	985.50×10^8 kW • h	Best case	Best estimate of project benefits	12 hours a day on average
E1.1; F1.1; G3	1149.75×10^8 kW • h	High case	High estimate of project benefits	14 hours a day on average

On a high confidence level, it runs an average of 10 hours a day and generates 82.125 billion kilowatt-hours of electricity annually.

On a medium confidence level, it runs an average of 12 hours a day and generates 98.55 billion kilowatt-hours of electricity annually.

On a low confidence level, it runs an average of 14 hours a day and generates 114.975 billion kilowatt-hours of electricity annually.

III. CASE 2: MEDOG COUNTY HYDROPOWER STATION

After studying the Three Gorges Project which has been put into operation, this paper studies the Medog County

Hydropower Station which is in the survey stage. Medog County is located in the border area between China and India in the southeast of Tibet. Its abundant hydropower resources play an important role in the future energy structure of both sides, it is related to China's national security, international relations, energy structure, ecological environment, and the future social and economic sustainable development of Tibet. This is an even more magnificent and arduous, technically complex and significant hydropower construction task.

1.Project Overview

Medog County, along the Yarlung Tsangpo River that drains into India, is the last couty within Chinese territory, and the main part of the Yarlung Tsangpo Grand Canyon was in Medog County. During the survey period, the Medog County hydroelectric power station is located between the Mainling County River and the Great Bend Gorge of the Brahmaputra River in Medog County, with a drop of 2,350 meters and an average flow of 60 billion m^3. The river bend is a straight-line distance of about 35 kilometers, and it can be used to draw water from giant tunnels to generate electricity. It is planned to lay out six large hydropower stations with a capacity of 10 million kilowatts. The power stations can generate electricity by making use of the huge drop in water flow. The total installed capacity is 60 million kilowatts, the proposed Medog County Hydropower Station will have twice the installed capacity of the Three Gorges, making it the world's second-largest super-power station to generate electricity across the Himalayas and downstream from Medog.

2.Method and product type

For the case of the Medog County Hydropower Station, it is also based on the UNFC three-dimensional framework system, using literature research methods. Quantify various types of products of the project, and analyze from three aspects: E axis, F axis, and G axis. Its product types include energy, social, and economic benefits. The research methods and product types of Medog County Hydropower Station are the same as those of the Three Gorges Project, but the key points of analysis are different.

3. .Quantification of benefit

Electricity benefits. According to preliminary calculations, if the Medog County Hydropower Station is built at the big bend, the installed capacity could reach 60 million kilowatts, more than twice the size of the Three Gorges Project (the installed capacity of the Three Gorges Hydropower Station is 22.5 million kilowatts) and the annual power generation capacity is 200 billion kilowatts. By analogy with the Three Gorges Dam in the previous study and the Itaipu Dam in question, the estimated average unit operating time after commissioning of all turbines is expected to increase gradually, as is the case with the Three Gorges Dam.

Benefit to water resources regulation. To prepare for the Hongqi River Project, which will channel water from the Yarlung Tsangpo River basin all the way along the eastern contour line of the Tibetan plateau to Xinjiang, the investment is estimated to be 4 trillion yuan and will create an oasis of 200,000 square kilometers in the northwest, will radically improve drought conditions in northwest China.

4.Classification

4.1 E Axis – Environmental-Socio-Economic Viability

The Yarlung Tsangpo River, which can connect the already built South West Grid to the rest of the country, could replace 80m tonnes of standard coal or 40m tonnes of oil. That amount is equivalent to 56 per cent of China's annual imports of 71M tonnes of oil. It is a cheap, renewable and green energy source that does not consume fuel. It also has great benefits in ecological and environmental protection.Both the number of settlers and the inundation losses are small. Secondly, it can help to develop the economy of southern Tibet. But given the local geological and hydrological conditions, Medog County is mostly high mountains and canyons, and the natural conditions are extremely complex. The southern Tibet Region is located at the edge of the qinghai-tibet Plateau, where earthquakes, landslides, debris flows and other disasters occur frequently. If there is no reasonable plan for these problems, technological progress has been made, and after many demonstrations and construction of hydropower stations, these disasters will be further aggravated by the huge amount of water stored up. The project is at an early survey stage and should be rated E3.1 based on current assumptions about the future.

4.2 F Axis – Technical Feasibility and Maturity

Traffic Inconvenience will be an important consideration in the operation and development of the project. Medog County is the last county in China to have access to the highway. The total investment in Medog County before and after the construction of the highway was more than 2 billion yuan. It took several decades to finally reach the present traffic conditions, and not yet open to traffic all year round. In addition, the difficulty of construction, because the Yarlung Tsangpo River is a plateau river, and located at the junction of plates, the construction zone will be earthquake-prone areas, plateau climate problems will also bring great difficulties to the construction workers; at the same time, the transportation of the materials needed for the construction of the hydropower station, especially the machinery and equipment, cannot be realized through the existing transportation network. At present, the only way to realize it is by air dropping. The investment is huge, the amount of funds needed to be raised is huge, and the project covers a wide range of areas, comprehensive Development is difficult, so the grade is F4.2.

4.3 G Axis – Degree of Confidence

PRODUCT CONFIDENCE IS MAINLY COMBINED WITH QUANTITATIVE ANALYSIS OF BENEFIT PARAMETERS. ACCORDING TO THE RUNNING TIME TO EVALUATE:

TABLE IV. CLASSIFICATION OF MEDOG HYDROPOWER STATION

Classification	Quality of benefits		Supplemental information	Reasoning for classification
UNFC-2019 Class	*Electricity benefit*	*Other benefits*		
E3.1; F4.2; G1	1752×10^8 kW·h	Low case	Low estimate of project benefits	8 hours a day on average
E3.1; F4.2; G2	2628×10^8 kW·h	Best case	Best estimate of project benefits	12 hours a day on average
E3.1; F4.2; G3	3504×10^8 kW·h	High case	High estimate of project benefits	16 hours a day on average

On a high confidence level, it runs an average of eight hours a day, generating 175.2 billion kwh a year.

On a medium confidence level, it runs for an average of 12 hours a day and generates 262.8 billion kilowatt hours of electricity annually.

On a low confidence level, it runs an average of 16 hours a day, generating 350.4 billion kwh a year.

IV. *CONCLUSION*

Hydropower resources play an important role in regulating the national energy structure, achieving emission reduction and sustainable development goals. This paper mainly elaborates the benefits of the Three Gorges Project that has been put into operation and the Medog County Hydropower Station in the survey stage. The focus is on quantitative analysis of its hydropower output, but in terms of social and ecological benefits, sufficient data and appropriate methods have not been found to quantify it. These aspects involve a wide range and many influencing factors, making analysis difficult, especially in the case of the Mo Dehydration Power Station involving national security and international relations. But from its statistical data, the benefits other than energy production are more important and will continue to accumulate with the running time of the project.

Hydropower resources are different from the utilization of resources such as oil, natural gas, wind energy, and solar energy. These energy projects focus more on the benefits of their energy products, but in hydropower resource projects, energy production is only part of the project benefits. There may be more social and ecological benefits (including flood control, shipping, water replenishment, ecological environment, local economy, etc.). These benefits should be taken into consideration when carrying out UNFC analysis. If indicators that cannot be quantified are found, but they have a position that cannot be ignored in the project, appropriate estimates can be combined with existing data and horizontal comparisons of similar projects to make the evaluation results. more realistic.

In some large hydropower projects, it usually takes a relatively long time from survey to commissioning. Especially when it involves a large-scale social economy and even national strategic deployment, many surveys and decision will be made. The focus of the project at different stages is different, and it will have a decisive influence on the classification of the entire framework. This also requires that in the classification of the resource framework, it is necessary to divide the project construction period into three stages for analysis and evaluation: the survey phase, the construction phase, and the commissioning phase. In the analysis and explanation of a specific project, some key issues should be paid attention to at different stages, as these cannot be solved, which may cause the project to be postponed or stopped. Here are some key points listed. In the survey stage, attention is paid to the issues of national policies, social stability, pros and cons of the plan, capital budget and later impact. In the construction phase, focus on quality management, the impact of construction on citizens' lives, and the impact on the ecological environment. In the commissioning stage, verify the degree of realization of project benefits, monitor the adverse impacts and file improvements, and contribute to the realization of its sustainable development. This article just lists some of the key points that appeared in the case study of this article. For other projects, these key points can be paid attention to, and at the same time, the key points unique to the project should be explored.

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