水电水利规划设计总院
China Renewable Energy Engineering Institute

发挥区域资源优势、面向新型电力系统的水电发展展望：以黄河上游为例

Prospects of Hydropower Development in Building New Type of Power System by Leveraging Regional Resources:A energy integration case in the upper reaches of the Yellow River

China Renewable Energy Engineering Institute—Xue Lianfang

水电水利规划设计总院

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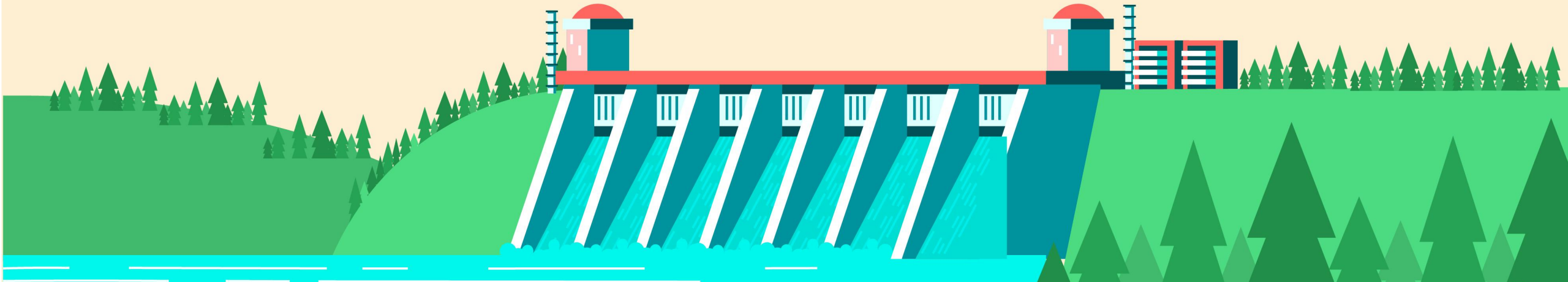
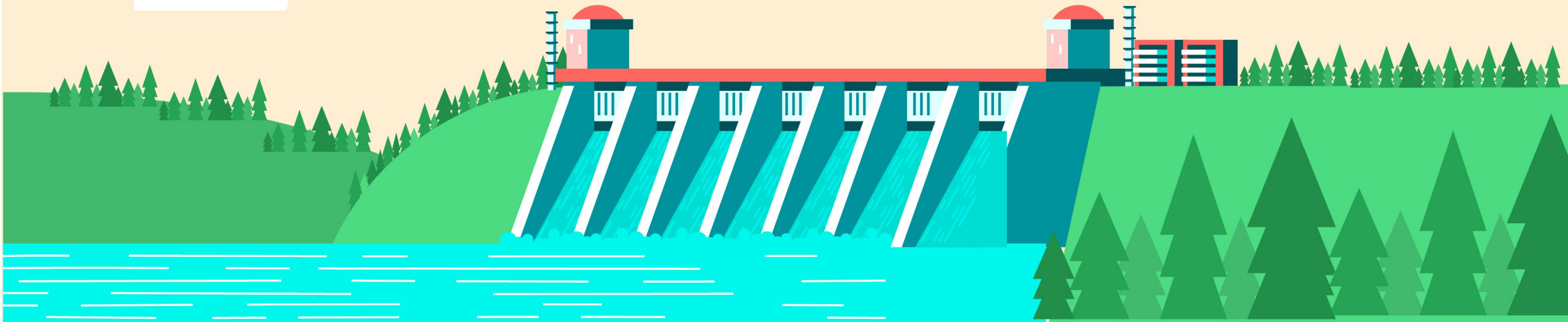


01

水风光清洁能源发展形势

Development status of clean energy in hydropower, wind, solar energy



“碳达峰，碳中和”的提出 Introduction

我国实现“碳达峰碳中和”，需要大力推动清洁能源发展。2020年12月，中国在气候雄心峰会上宣布：“2030年，我国**非化石能源比重**将达到**25%左右**，风电、太阳能发电总装机容量将达到**12亿千瓦以上**。”

To achieve "carbon peaking and carbon neutrality", China needs to promote the development of clean energy. In December 2020, China announced at the Climate Ambition Summit that by 2030, the proportion of non-fossil energy in China will reach about 25%, and the total installed capacity of wind power and solar power will reach more than 1.2 billion kilowatts.

2020 年

- ✓ 双碳目标**开局之年** The first year of the dual carbon goals
- ✓ 非化石能源消费比重达到**15.9%** The proportion of non-fossil energy consumption reached 15.9%

2025 年

- ✓ 绿色低碳循环发展的经济体系**初步形成**
- ✓ The economic system of green and low-carbon circular development has initially taken shape
- ✓ 非化石能源消费比重达到**20%左右**
- ✓ The proportion of non-fossil energy consumption has reached about 20%.

2030 年

- ✓ 经济社会发展全面绿色转型取得**显著成效**
- ✓ The comprehensive green transformation of economic and social development has achieved remarkable results
- ✓ 非化石能源消费比重达到**25%左右**
- ✓ The proportion of non-fossil energy consumption has reached about 25%.

2060年

- ✓ 绿色低碳循环发展的经济体系**全面建立**
- ✓ An economic system for green and low-carbon circular development has been fully established
- ✓ 非化石能源消费比重达到**80%以上**
- ✓ The proportion of non-fossil energy consumption has reached more than 80%.

面临的主要挑战 Challenges

01

电源结构错配问题：以风电、光伏为代表的新能源占比逐年提升，调节资源日趋紧张。电化学储能作为配套储能方式，难以满足新型电力系统建设亟须的大规模、长时储能需求。

Power supply structure mismatch: The proportion of new energy represented by wind power and photovoltaic is increasing year by year, and regulatory resources are becoming increasingly tight. As a supporting energy storage method, electrochemical energy storage is difficult to meet the large-scale and long-term energy storage needs urgently needed for the construction of new power systems.

02

资源与需求分布不匹配：清洁能源资源富集地区用电负荷小，经济发展较好地区清洁能源资源条件差，需要研究通过外送通道将新能源送至缺电的省份消纳，打破省间交易壁垒。

Mismatch between resource and demand distribution: The electricity load in clean energy resource-rich areas is small, and the clean energy resource conditions in areas with good economic development are poor, so it is necessary to study the transmission channel to send new energy to provinces lacking electricity for consumption, and break the barriers of inter-provincial transactions.

03

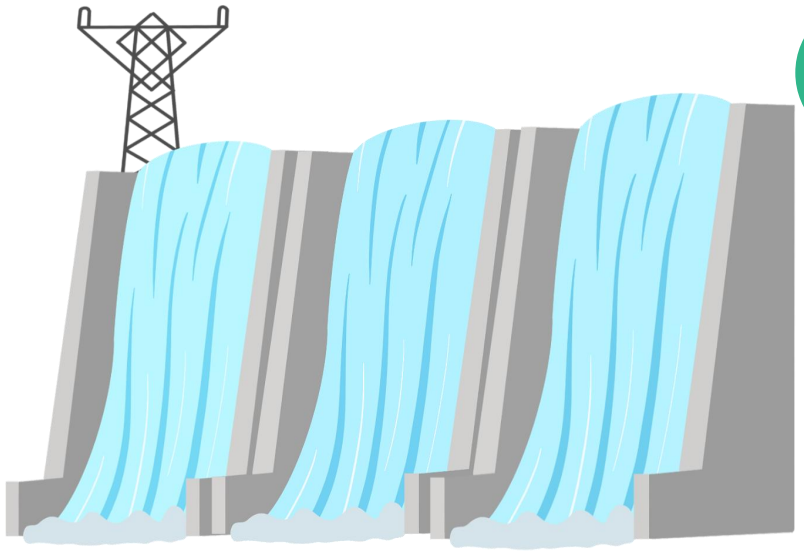
电力系统安全保障问题：新能源出力的随机性、波动性强，亿级新能源其出力波动可达数千万千瓦级，大幅度出力变化引发电力系统安全稳定、新能源脱网、电网大面积停电等问题。

Power system safety guarantee problem: the randomness and volatility of new energy output, the output fluctuation of 100 million new energy can reach tens of millions of kilowatts, and the large change of output causes problems such as power system safety and stability, new energy off-grid, and large-scale power outage of the power grid.

水电的作用 The Role of Hydropower

■ **新能源发电的间歇、波动和随机性，需要可调节电源以多能互补形式对其补偿调节。**

The intermittent, fluctuating and random nature of new energy power generation requires adjustable power supplies to compensate for them in a multi-energy complementary form.



01

水电是助力新能源消纳的有效途径：提供有效容量，保障电力需求；调节能力强、响应速度快，可配合新能源运行；当系统调节电源不足时，可以采取扩建常规机组、储能工厂、可逆机组等措施。

Hydropower is an effective way to help the absorption of new energy: Provide effective capacity and ensure electricity demand; Strong adjustment ability, fast response speed, can cooperate with new energy operation; When the system regulation power supply is insufficient, measures such as expanding conventional units, energy storage plants, and reversible units can be taken.

02

抽水蓄能是最具实践价值的大规模储能技术：抽水蓄能是当前技术最成熟、全生命周期碳减排效益最显著、经济性最优且最具大规模开发条件的电力系统灵活调节电源

Pumped storage is the most valuable large-scale energy storage technology: Pumped storage is the most mature technology, the most significant carbon emission reduction benefits in the whole life cycle, the most economical and the most large-scale development conditions of the flexible regulation power supply.

水电的作用方式 The Way of Hydropower

水电助力新能源消纳

无调节性能水电

No regulating performance hydropower

- **无调节能力的水电可以承担基荷，提高多能互补系统的稳定性**

Unregulated hydropower can take on the base load and improve the stability of multi-energy complementary systems

有调节性能水电

Hydropower stations with regulatory performance

- **有调节性能的水电可以平抑新能源的波动，提高新能源消纳比例**
- **Hydropower with regulating performance can smooth out the fluctuation of new energy and increase the proportion of new energy consumption**

调节规模不足

Insufficient regulation scale

常规机组扩机

Installed capacity expanded

- **提高水电站调峰能力，使其更好地配合新能源运行**
- **Improve the peak shaving capacity of hydropower stations to better cooperate with new energy operation**

扩建可逆机组（储能工厂）

Expansion of reversible units (energy storage plants)

- **将剩余电能以水的势能储存，实现剩余电能的时移**
- **The remaining electric energy is stored with potential energy of water to realize the time shift of the remaining electric energy**

抽水蓄能电站

Pumped storage power stations

常规抽水蓄能

Conventional

- **可以削峰填谷，平抑新能源的波动，保障电网平稳运行**
- **It can cut peaks and fill valleys, smooth the fluctuation of new energy, and ensure the smooth operation of the power grid**

与常规水电站结合混合式抽水蓄能

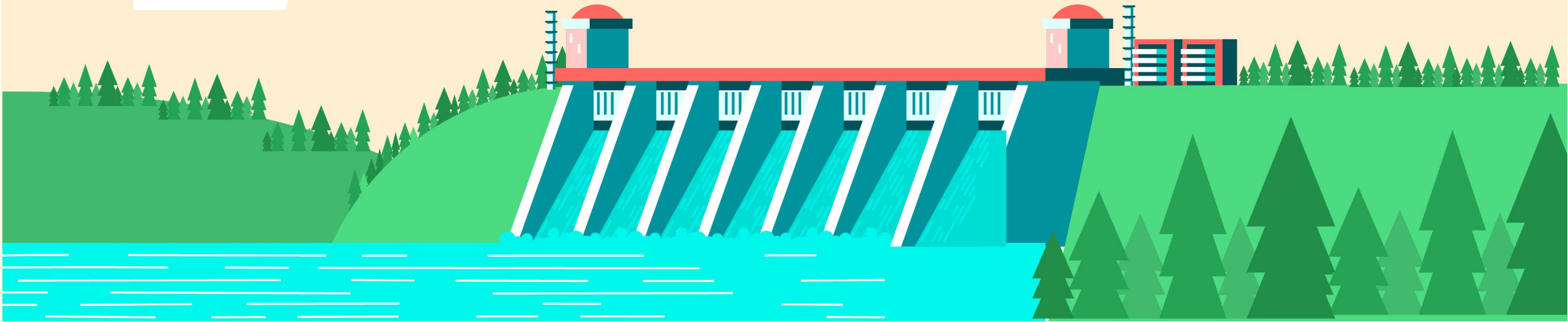
Hybrid

- **具有节约投资和缩短工期的优点**
- **It has the advantages of saving investment and shortening the construction period**

02

黄河上游水风光一体化能源结构与规划

Structure and planning of hydropower-wind-photovoltaic integrated system



全国水电及清洁能源发展现状

The current situation of hydropower and clean energy development in China

水电是推动能源绿色转型发展的重要抓手 》》 风光大规模跃升发展阶段 》》 抽水蓄能加速发展初步显现

- 2004年之后，我国水电装机容量居世界第一，大型机组位居世界首位，调度水平大幅提升。截至2022年底我国水电装机总容量41.4万MW
- 水电流域一体化开发，大力推动一体化开发
- 截至2022年底，我国风电装机36.5万MW，光伏发电装机39.3万MW，均居世界首位。风光电新增装机容量快速增长
- 预计2030年，新能源装机达120-160万MW
- 截至2022年底，抽水蓄能电站投产总规模4.58万MW，在建12.1万MW
- 预计2025年抽水蓄能规模将达到6万MW 以上；2030年将达到12万MW

Hydropower is an important starting point for promoting the development of green energy transformation 》》 Large-scale leapfrogging development stage of wind and solar 》》 The accelerated development of pumped storage has initially appeared

- After 2004, China's hydropower capacity and large-scale units ranked first in the world, and the dispatching level was greatly improved. By the end of 2022, China's installed hydropower capacity will be 414 GW.
- Integrated development of hydrocurrent domain, promote integrated development
- By the end of 2022, China's installed wind power capacity was 365 GW and photovoltaic power generation was 393 GW, both ranking first in the world. The new installed capacity of wind photovoltaics is growing rapidly.
- It is estimated that in 2030, the installed capacity of new energy will reach 1200-1600 GW.
- By the end of 2022, the pumped storage power station has a total scale of 45.8 GW and 121 GW under construction.
- It is expected that the scale of pumped storage will reach more than 60 GW in 2025; It will reach 120 GW in 2030

黄河上游青海段水电开发现状

Status of hydropower development in the upper reaches of the Yellow River (Qinghai section)

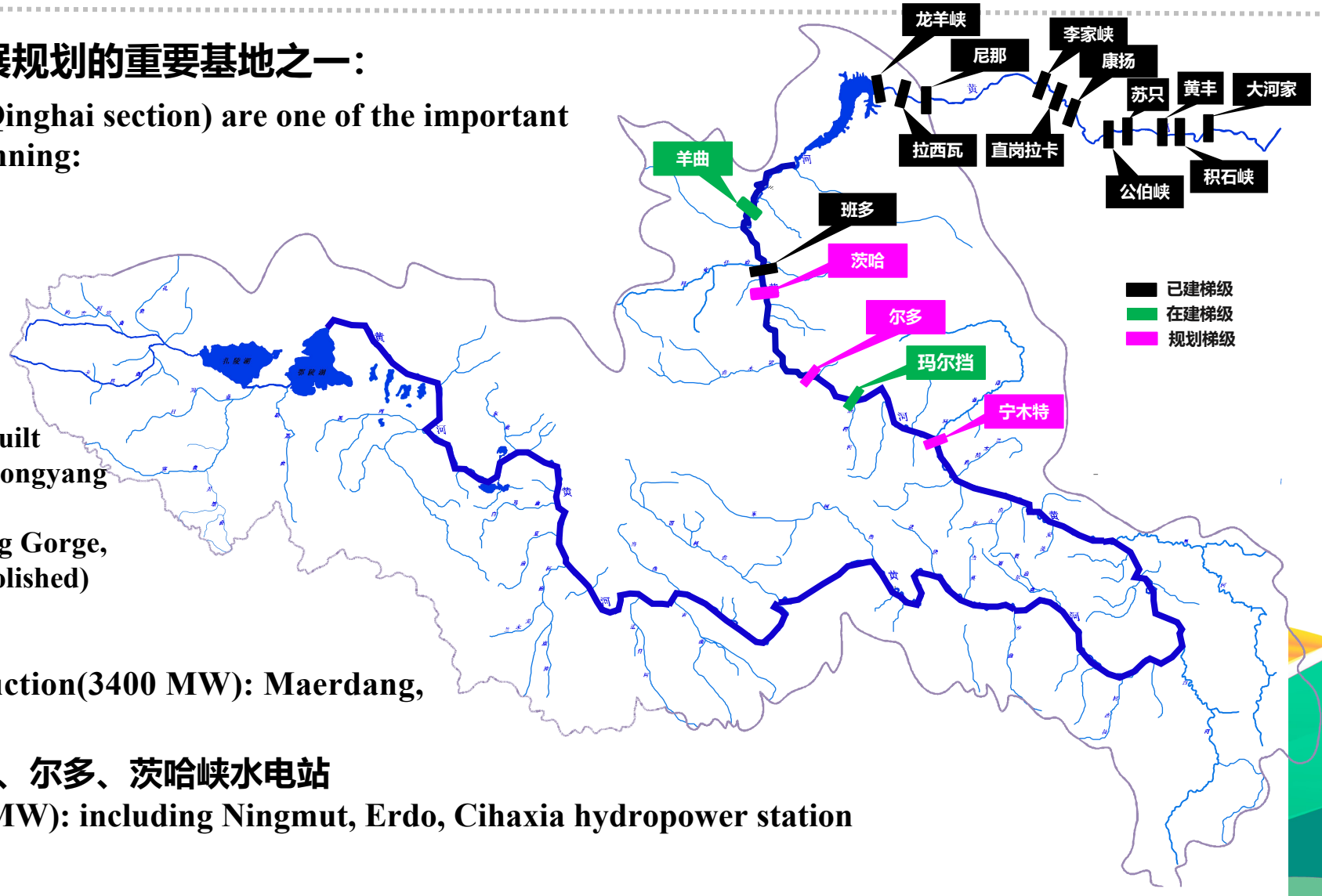
黄河上游（青海段）是我国能源发展规划的重要基地之一：

The upper reaches of the Yellow River (Qinghai section) are one of the important bases of China's energy development planning:

- **已建电站(1.123万MW)**
  - **龙羊峡及以下河段11个梯级电站**
  - **龙羊峡以上河段2个梯级电站，班多、黄河源（已拆除）**
- Hydroelectric power stations have been built
  - There are 11 cascade power stations in Longyang Gorge and the following river sections
  - 2 cascade power stations above Longyang Gorge, Bando and the Yellow River Source(demolished)

- **在建电站(3400MW): 玛尔挡、羊曲**
- Hydropower stations under construction(3400 MW): Maerdang, Yangqu

- **规划水电（6766MW）:包括宁木特、尔多、茨哈峡水电站**
- Planned hydropower station (6766 MW): including Ningmut, Erdo, Cihaxia hydropower station



青海省（黄河上游）抽水蓄能电站开发现状

Development status of pumped storage power station in Qinghai Province

■ **根据规划，青海省纳入抽水蓄能中长期规划共26个站点，其中22个站点纳入重点实施项目，4个站点纳入规划储备，总装机容量4.17万MW。**

■ **黄河干流附近共16个抽水蓄能站点，总规模约2.98万MW。**

■ According to the development plan, Qinghai Province is included in the national pumped storage medium- and long-term planning for a total of 26 sites, of which 22 sites are included in key implementation projects and 4 sites are included in planning reserve projects, with a total installed capacity of 41,700MW.

■ There are 16 pumped storage stations near the main stream of the Yellow River, with a total capacity of about 29,800MW.

序号	名称	地点	拟装机容量（MW）	前期工作进展
1	贵南哇让	海南州贵南县	2800	可研
2	共和	海南州共和县	3900	规划
3	龙羊峡储能（一期）	海南州贵南县	1000	可研
4	羊曲储能	海南州兴海县、贵南县	800	预可研
5	同德	海南州同德县	2400	可研
6	玛沁	果洛州玛沁县	1800	预可研
7	龙羊峡储能（二期）	海南州贵南县	4000	规划
8	贵德	海南州贵德县、贵南县	1000	规划
9	尔多储能	海南州同德县	600	规划
10	公伯峡储能	海东市化隆县	500	规划
11	化隆	海东市化隆县	1400	规划
12	李家峡混合式抽蓄	黄南州尖扎县	200	规划
13	茨哈峡储能	海南州兴海县	6000	规划
14	羊曲抽蓄1	海南州贵南县	1800	新增
15	羊曲抽蓄2	海南州贵南县	1000	新增
16	宁木特抽蓄	黄南州河南县	600	新增
	合计		29800	

青海省（黄河上游）风电、太阳能开发现状

Development status of wind power and solar energy in Qinghai Province

- 黄河上游流域青海段风电技术开发量约3.4750万MW，光伏技术开发量约196万MW。
- 截止2022年底，青海省风电、太阳能装机容量9720MW、1.842万MW，占全部发电装机容量的21.8%、41.2%。
- 黄河上游两岸的风电、太阳能累计装机容量达4510MW、 1.062万MW 。

- The Qinghai section of the upper reaches of the Yellow River basin has developed about 34.75 GW of wind power technology and about 1960 GW of photovoltaic technology.
- By the end of 2022, the installed capacity of wind power and solar energy in Qinghai Province was 9720 MW and 18.42 GW, accounting for 21.8% and 41.2% of the total installed power generation capacity.
- The cumulative installed capacity of wind power and solar energy on both sides of the upper reaches of the Yellow River is 4510 MW and 10.62 GW.

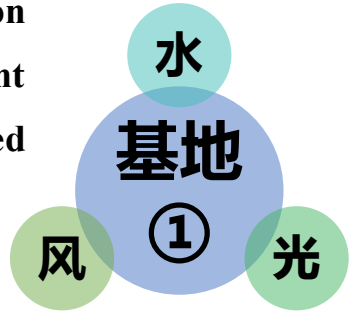
青海省（黄河上游）水风光一体化基地规划

Development status of hydro-wind-photovoltaic base in Qinghai Province

- 由来：为推进可再生能源高质量跃升发展，加快可再生能源替代行动进程，促进碳达峰碳中和目标实现。**2022年3月2日，国家能源局提出开展全国主要流域可再生能源一体化规划研究的要求。**
- 内涵：依托主要流域水电开发，充分利用水电灵活调节能力和水能资源，在合理范围内配套建设一定规模的以风电和光伏为主的新能源发电项目，建设可再生能源一体化综合开发基地，实现**一体化资源配置、一体化规划建设、一体化调度运行和一体化参与电力市场竞争。**

- Origin: In order to promote the high-quality leapfrog development of renewable energy, accelerate the process of renewable energy substitution actions, and promote the realization of carbon peaking and carbon neutrality goals. On March 2, 2022, the National Energy Administration issued the Notice on the Integrated Planning and Research of Renewable Energy in Major River Basins in China

- Connotation: Relying on the development of hydropower in major river basins, making full use of hydropower flexible regulation capacity and hydropower resources, supporting the construction of a certain scale of new energy power generation projects based on wind power and photovoltaics within a reasonable range, building an integrated comprehensive development base for renewable energy, and realizing integrated resource allocation, integrated planning and construction, integrated dispatching and operation, and integrated participation in electricity market competition.



黄河上游流域可再生能源一体化规划初步成果：拟打造4个一体化综合基地、11个一体化项目，规划总规模20.2万MW，其中新增水电及扩机容量2.059万MW、抽水蓄能容量3.360万MW、风电容量2.705万MW、光伏容量11.985万MW、光热0.1万MW以及配套的电化学储能0.3万MW.

Preliminary results of the research on the integrated planning of renewable energy in the upper reaches of the Yellow River: it is planned to build 4 integrated comprehensive bases and 11 integrated projects, with a total planned scale of 202 GW, including 20.59 GW of new hydropower and expansion capacity, 33.6 GW of pumped storage capacity, 27.05 GW of wind power capacity, 119.85 GW of photovoltaic capacity, 1 GW of solar thermal and 3 GW of supporting electrochemical energy storage.

以水风光为主

黄河流域可再生能源一体化基地

总规模2020万kW

龙羊峡及以上河段	◆水电站单体水电装机规模较大 ◆河段沿线区域风光电资源较丰富 ◆6个一体化项目组成龙羊峡及以上水风光一体化基地	总装机规模14802万kW
拉西瓦~大河家河段	◆梯级电站均已建、作为区域调峰电源充分发挥作用 ◆以整体河段组成区域一体化项目	总装机规模4268万kW
炳灵~乌金峡河段	◆在新能源较丰富的河段依托水电、抽水蓄能形成一体化项目 ◆以整体河段组成区域一体化项目	总装机规模1394万kW
沙坡头~青铜峡河段	◆依托水电形成一体化项目 ◆以整体河段组成区域一体化项目	总装机规模45万kW

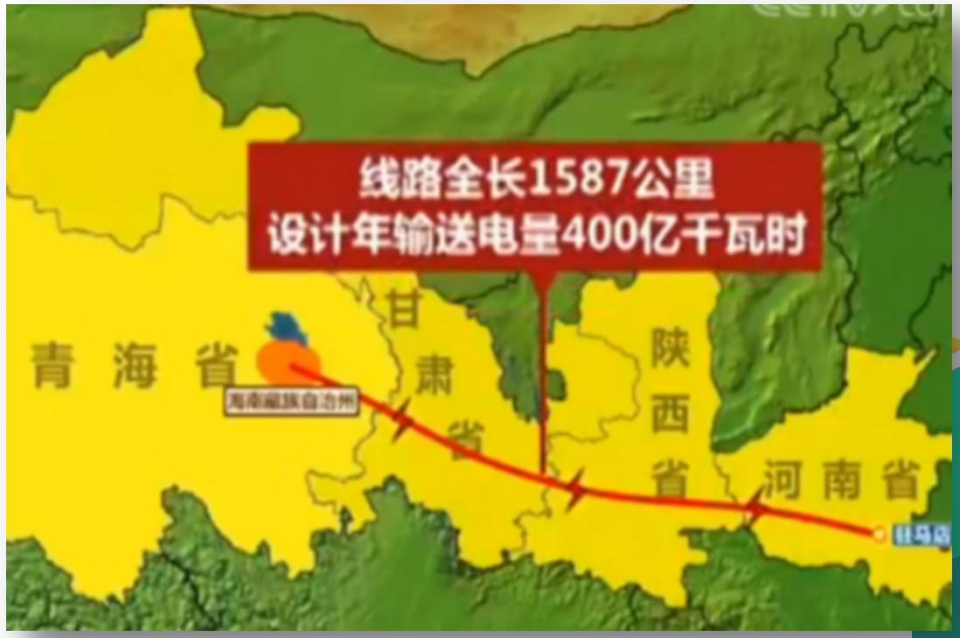
龙羊峡及以下河段

青海省（黄河上游）水风光清洁能源外送通道

Qinghai Province (upper reaches of the Yellow River) water, wind, solar energy delivery lines

- 现状：截至2022年底，青海电网通过7回750kV交流线路与西北主网相连，通过1回±800kV直流线路与河南电网相连，通过1回±400kV直流线路与西藏电网相连，以清洁能源发电能力满足各省用电需求。截至2022年底，青豫（青海-河南）清洁能源特高压输电通道已累计外送“绿电”300亿千瓦时。
- 规划：全力推进青海至江苏清洁能源特高压输电工程建设；开展高比例新能源接入、远距离输电的特高压柔性直流输电技术研究，创新应用“新能源+抽水蓄能+柔性直流电网”送电方案，满足青海省大规模新能源外送需求。

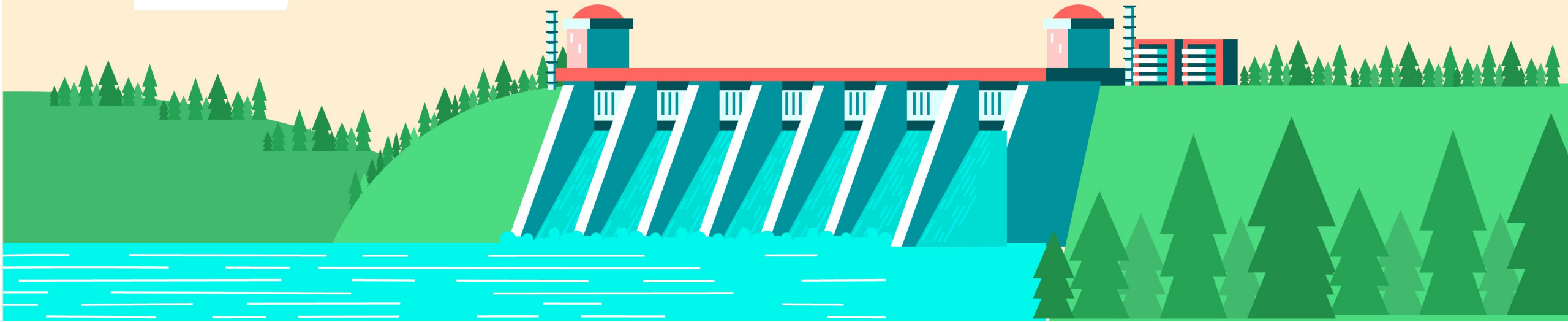
- Current situation: By the end of 2022, Qinghai Power Grid is connected to the northwest main grid through seven 750kV AC lines, Henan Power Grid through one ± 800kV DC line, and one ± 400kV DC line to meet the electricity demand of various provinces with clean energy power generation capacity. By the end of 2022, the Qingyu (Qinghai-Henan) clean energy UHV transmission channel has sent a total of 30 billion kWh of "green power".
- Planning: Fully promote the construction of clean energy UHV transmission project from Qinghai to Jiangsu; Carry out research on UHV flexible DC transmission technology with high proportion of new energy access and long-distance transmission, and innovatively apply the "new energy + pumped storage + flexible DC power grid" transmission scheme to meet the large-scale new energy transmission demand in Qinghai Province.



03

水风光清洁能源高质量发展

High-quality development of hydropower, wind and solar energy



The development time of the water elevator stage is earlier and the time period is relatively long, and the formulation of environmental protection measures for early development hydropower stations has certain historical limitations.

The implementation effect of ecological environmental protection measures lacks long-term observation, research and management, and the construction of environmental protection measures in some power stations lags behind

After the integrated dispatch, the hydrological situation and water temperature changes under the dam of the hydropower station are more severe, and the ecological environmental protection measures for hydropower development at the level of integrated joint operation are insufficiently coordinated.

水电梯级开发时间较早，时段较长，早期开发水电站环境保护措施制定存在一定历史局限性

生态环境保护措施实施效果缺乏长期观测、研究和管理，部分电站环保措施建设存在滞后

一体化调度后水电站坝下水文情势、水温变化更加剧烈，一体化联合运行层面水电开发生态环境保护措施统筹性不足

渣料场缺少治理
低温水影响
大坝阻隔影响

部分环保措施效果还不明显
环保措施运行缺乏监测手段

增殖站等措施总体布局不协调
水电梯级开发累积影响的应对问题
干支流协同保护欠缺等

There is a lack of treatment in the slag yard
Low temperature water effects
Dam barrier impact

Some environmental protection measures are not yet effective.
There is a lack of monitoring means for the operation of environmental protection measures

The overall layout of measures such as breeding stations is not coordinated
Addressing the cumulative impact of water elevator stage development
lack of protection of main tributaries, etc

注重生态保护与高质量发展

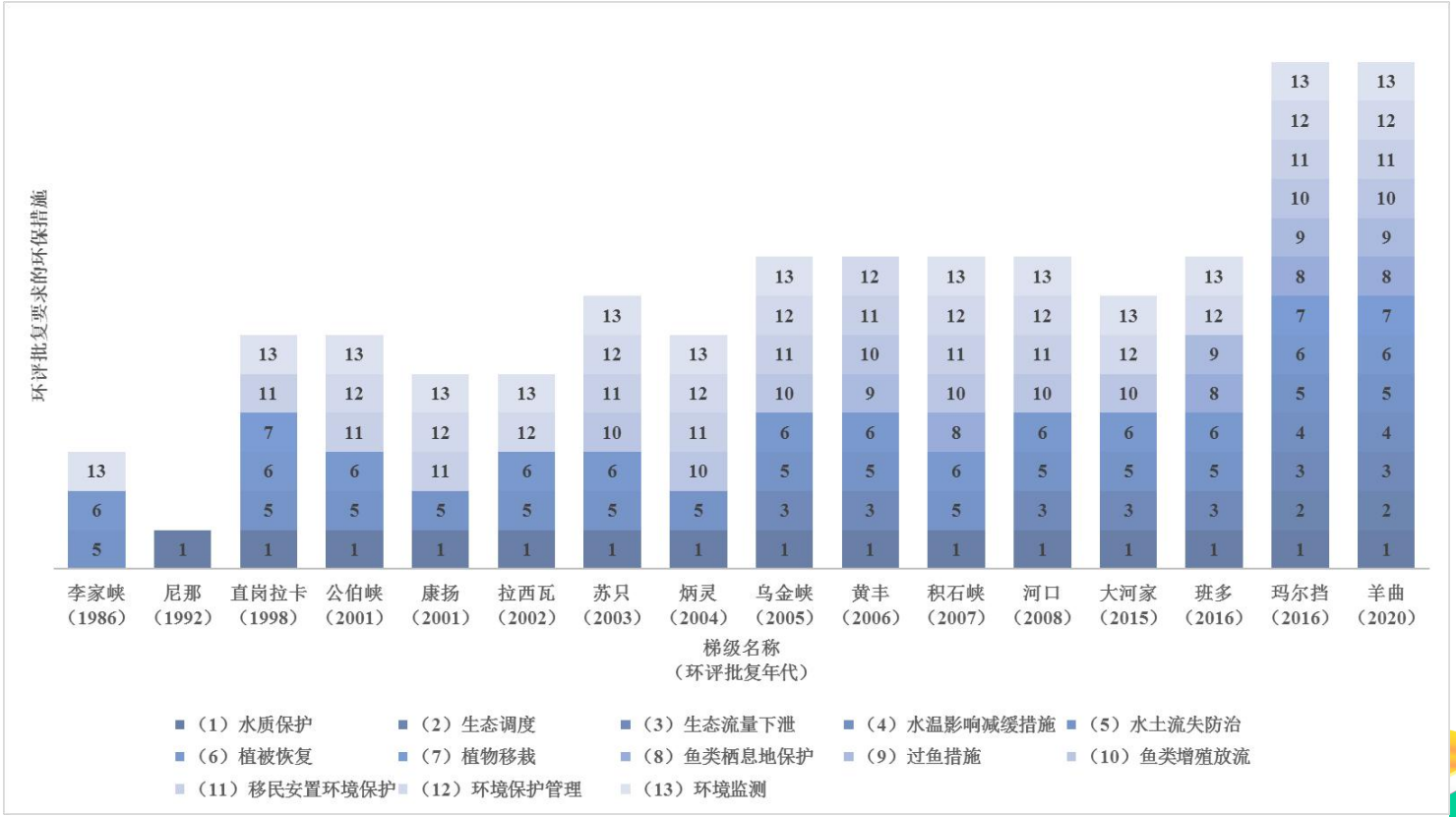
Pay attention to ecological protection and high-quality development

早期水电工程实施的环保措施多关注施工期的环境影响减缓，如水质保护、水土流失防治等

2002年以后，采取了陆生生态保护及水土流失防治、植被恢复、移栽等措施；水生生态保护实施了鱼类栖息地保护、过鱼措施、鱼类增殖站、生态放水设施、增殖放流等较为全面保护措施。

The environmental protection measures implemented in early hydropower projects mostly focused on the mitigation of environmental impact during the construction period, such as water quality protection and soil erosion prevention

After 2002, measures such as terrestrial ecological protection, soil erosion prevention, vegetation restoration, and transplanting were adopted. Aquatic ecological protection has implemented relatively comprehensive protection measures such as fish habitat protection, fish crossing measures, fish breeding stations, ecological water release facilities, and breeding and release.



黄河上游水电站不同年代环评批复要求

Environmental impact assessment approval requirements for hydropower stations in the upper reaches of the Yellow River in different eras.

展　望 Prospects

随着国际上对室温气体的控制要求和**国家双碳**目标的提出，能源的清洁化与可在生化已是大势所趋，清洁可再生发展将是今后能源发展的主流，**水电具有的特殊调节性质必将在后续发展中展现出特别优势和再发展空间**

- 1、加强水电与新能源调度运行研究。常规水电站本身承担较多综合利用任务，例如防洪、防凌、供水、航运、发电等，当需要配合新能源以及抽水蓄能电站运行时，调度运行方式将更加复杂，需要加强研究和论证
- **2、探索生态和谐的开发模式**。深入开展水电、抽蓄、一体化基地等工程环境保护工作；开展水电梯级环境综合监测及环保措施适应性管理；运用大数据、物联网等信息化手段，逐步实现**生态环境保护的智慧管控。**

- 1. Strengthen research on hydropower and new energy dispatch and operation. Conventional hydropower stations themselves undertake more comprehensive utilization tasks, such as flood control, pollution control, water supply, shipping, power generation, etc., when it is necessary to cooperate with new energy and pumped storage power station operation, the dispatching operation mode will be more complicated, and it is necessary to strengthen research and demonstration
- 2. Explore ecological and harmonious development models. Carry out in-depth environmental protection work in hydropower, pumping and storage, integrated bases and other projects; Carry out comprehensive environmental monitoring of water elevator level and adaptive management of environmental protection measures; Use big data, Internet of Things and other information means to gradually realize the intelligent management and control of ecological environmental protection.

谢谢您的倾听！

Thank you!