2050 by 2050
What are the energy scenarios?

Cao Junhua
CPI Yunnan International Power Investment Co., Ltd.

For more information: www.hydropower.org/congress
Hydropower Development and Integrated Utilization of River Basin

——Experience from Hydropower Development and Integrated Utilization of Upper Yellow River

CAO Junhua
CPI Yunnan International Power Investment Co., Ltd.
1. Yellow River Overview

2. Integrated Development and Utilization of Upper Yellow River

3. Experience and Recommendations on Integrated Development
The Yellow River is the mother river of China. With its origin in the Yueguzonglie Basin north of the Bayankala Mountain on the Qinghai Plateau, it winds its way east, through the Loess Plateau and the Yellow River-Huaihai Plain, and into the Bohai Sea. Its main stream has a length of 5464km and a fall of 4480m. The Yellow River Basin is about 1900km long from east to west, and about 1100km wide from north to south. It has a total catchment area of 795,000km².
The Upper Yellow River covers the river section from its source to Hekou Town in Tuoketuo County in Inner Mongolia Autonomous Region. It is 3471.6km long and has a catchment area of 428,000 km², accounting for 53.8% of that of the whole river. It has a fall of 3496m and an average gradient of 1‰. Its runoff accounts for 54% of that of the whole river. Its annual sediment inflow is only 8.7% of that of the whole river. With more water and less sediment, it forms the source of clean water of the Yellow River.

Depending on its river course characteristics, the Upper Yellow River can be divided into three sections, namely, river source section, valley section and alluvial plain section. The valley section, which is from Longyangxia in Qinghai Province to Qingtongxia in Ningxia Province, has favorable conditions for building high dams and large reservoirs. It is one of China's major bases for hydropower development, and has created many beautiful ecological conservation zones after hydropower implementation.

The alluvial plain section, which is from Qingtongxia to Hekou Town, covers the famous Yinchuan Plain and Hetao Plain. The Hetao Plain is famous as an irrigated area of the Yellow River, with a long history of irrigation. As an old saying goes, the Yellow River causes many disasters, only leaving the Hetao Plain abundant.
Middle Yellow River (From Hekou to Taohuayu valley)

The Middle Yellow River is from the Hekou Town to the Taohuayu valley in the city of Zhengzhou, Henan Province. It is 1206.4km long, and has a catchment area of 344,000 km², accounting for 43.3% of that of the whole river. It has a fall of 890m and an average gradient of 0.74‰.

Most of the tributaries in the Shanxi-Shaanxi valley from the Hekou Town to Yumenkou flow through the Loess Plateau, causing serious soil erosion. The Yellow River has an annual average sediment discharge of 1.6 billion tons, among which 900 million tons come from this section of the River, forming the main source of sediment of the Yellow River. This section has a very great gradient and is rich in waterpower resources. It is the second largest hydropower base of the Yellow River.

After the Xiaolangdi water control project from Yumenkou to the Taohuayu Valley was completed, it has played a good role in flood prevention and sediment reduction. The flood control standard of the downstream Yellow River has been improved from the less than 60-year return to the 1000-year return, and the downstream river course can be prevented from silting up for a period of 20 to 25 years.
The Downstream Yellow River is from the Taohuayu Valley to the estuary. It has a catchment area of 23,000 km², accounting for only 3% of that of the whole river. It is 785.6 km long and has a fall of 94 m. It is steep in the upper reaches and flat in the lower reaches, with an average gradient of 0.12 ‰.

The downstream river course runs through the North China Plain, with most of the river sections being restrained by embankments. Due to heavy sedimentation, the river course rises year after year, thus forming the world famous “aboveground river.” In history, the River in the lower reaches burst its banks frequently, and the river course shifted dramatically, causing serious disasters to the people along the banks. After the founding of the People’s Republic of China, many water control projects have been built in the upper and middle reaches of the Yellow River for water and sediment regulation, and great efforts have been made in dredging and embankment protection in the lower reaches (the total length of embankments reaches over 1400 km), so the outburst and the river course change of the Yellow River are suppressed to protect the life and property of the people.
Agricultural civilization——Let people thrive for generations

Industrial civilization——Living standards improve gradually

There is total 2.44 million hectares arable land in the Yellow River Basin and the arable land is 3.5 acres per capita in its rural areas which is 1.4 times of the national per capita arable land. Most areas in the basin have adequate light and heat resources so that and the agricultural development potential is great. The North China Plain, Fenwei plains and Hetao Irrigation is our country's major grain producing areas. Yellow River flows through 9 provinces (regions), 66 prefecture-level cities (city, state, AU) and 340 counties (cities, flags). In 2010, the total population in the basin is about 11,368 million, accounting for 8.6% of the total national population, including 454.3 million urban population whose urbanization rate reaches to 40.0%. Since 1980, the average annual growth rate of GDP in the basin reaches to 11% and the per capital GDP grows more than 10 times.
Splendid culture——Yellow River civilization formed in several thousand year time period

Modernization ——Boosting regional economic and social development

At Xihoudu human activity site of Ruicheng county in Shanxi Province, people found 1.6-million-year-old fossils of burned animals and antlers, and multiple carbon accumulations of 1 million years ago were found at Lantian human site in Shanxi Province. After that, Lantian Man, Dali Man, Dingcun Man, Hetao Man thrived at the Yellow River arms. About 6000 years ago, Banpo culture appeared as a representative of the matriarchal culture on the Loess plateau. More than 4000 years ago, the first nation in Chinese history—Xia Dynasty was established. The Yellow River river basin is the main source of the Chinese nation, gave birth to the ancient, splendid civilization in the Yellow River. In the future, modern scientific development and protection will keep the healthy life of the Yellow River, continuing to support the sustainable development of economy and society in the river basin.
1. Yellow River Overview

2. Integrated Development and Utilization of Upper Yellow River

3. Experience and Recommendations on Integrated Development
Responsibilities and duties of YRCC:
1) River basin master plan and review.
2) Direct and coordinate Integrated development and utilization of water resources in the basin, including water and hydropower facilities on its main stream and tributaries, lakes and control of sea shore and beach etc.
3) Plan and coordinate water uses for domestic, production and ecology in the basin, and supervise and manage the water uses.
4) Protect water resources in the basin, direct and coordinate the prevention and control of soil erosion.
5) Prevent and control floods and droughts in the basin, overall command and coordinate flood control and drought relief efforts.
6) Supervise water administration and law enforcement, inspect and punish violations in water affairs.

The Yellow River Conservancy Commission was started in 1933 with the original purpose of “being responsible in promoting the benefits and preventing disasters in the Yellow River Basin”. It was adjusted in the course and started to play comprehensive and coordination functions after founding of PRC.
1) Concentrated resources

From the normal high water level 2600m of Longyangxia reservoir to Sigouxia, the water level difference is 860m, on the average, the installed capacity of 28.9MW can be acquired at every kilometer channel, and the total annual generation is 107 million kW·h;

2) High development and utilization rate is feasible

The ratio of the available installed capacity and theoretical hydropower potential of the upper reach of the Yellow River, is 150% of the national average, and annual average generating capacity that can be utilized is about twice of the national average;

3) Great reservoir regulation capacity ensures power generation

The leading reservoir of the upper reach—Longyangxia reservoir, with a storage capacity of 24.7 billion m³ and a regulating storage capacity of 19.35 billion m³ which is 94% of annual average runoff, possesses over-year regulation function, ensuring power generation.
Properly plan and build water control complex

Reduce inundation loss
Build high dams in high mountain and gorge areas in upper reach, and build low dams in plain area.

Improve water volume regulation capability
Try to raise reservoir capacity and enhance water storage capability.

Pay equal attention to development and protection
Avoid nature reserves and improve environment protection measures.

Build water control project on the main stream in the upper reach where the comprehensive cost is lower so as to maximize the comprehensive benefits.
The Yellow River from Longyangxia of Qinghai, across Gansu to Qingtongxia section of Ningxia, the total length is 918km, natural water level difference is 1324m, theoretical hydropower potential is up to 11330MW, accounting for 28% of the whole Yellow River Basin, 1245m-water-head is utilized by 25 built and planning cascade HPPs, accounts for 94% of the water head, the total installed capacity is 16050MW, with an average generating capacity of 59.3 billion kW · H.
Since the reform and opening up, Qinghai province has taken the development of hydropower resources in upstream of the Yellow River as a leader, and Longyangxia, Lijiaxia, Gongboxia, Laxiwa and other large HPPs has been built successively, hydropower, thermal power and new energy electric power industry is developing rapidly. As of 2009, Qinghai Province, the per capita Installed Capacity has reached 1.9 Kw, 3.3 times of the national average. In 2012, hydropower generation of the upstream Yellow River hit a new record high, up to 44.9 billion Kw · H.
Electric energy supports social development

GDP of Qinghai Province

- Longyangxia HPP operational in 1989
- Lijiaxia HPP operational in 1997
- Liujiaxia HPP operational in 1974
- Gongboxia HPP operational in 2004
- Laxiwa HPP operational in 2009


- GPD总量 (万元)
- 人均GDP (元)
Longyangxia and Liujiaxia, the two main large reservoirs in the Upper Yellow River are in joint operation. According to the operation data from 1986 to 2005, a total of 21.42 billion cubic meters of water were stored in 19 years, and 1.13 billion cubic meters per year. Among which 5.37 billion cubic meters were stored from June to October period, 4.24 billion cubic meters of water were supplemented from November to July period. It plays a very significant role.
Since 2002, one water and sand regulation of the Yellow River has been performed each year with joint operation of Wanjiazhai, Sanmenxia and Xiaolangdi reservoirs. With joint operation of Wanjiazhai, Sanmenxia and Xiaolangdi Reservoirs, the scouring ability on the river bed in the downstream is increased by releasing water from the reservoirs and creating man-made flood peaks, and at the same time the engineering measures were taken to fight against the bank scouring so as to reduce the sedimentation of the Yellow River course. The minimum flow passing capability was increased from a pre-implementation level of 1800m$^3$/s to 3500m$^3$/s. This helps to gradually restore the basic function of the river course and safeguard the permanent safety of the downstream.
The operations of water and sand regulation have provided a favorable water condition for restoring wetland ecology, created large area of water surface and wetland, and effectively mitigated wetland reduction phenomenon due to the salt water intrusion. The wetlands in the Yellow River estuary are expanding at an average rate of 33.4 million square meters each year, and became the protected region with the fastest natural growth in terms of land area expansion in the world.

The rare aquatic animals such as the Yellow River knife fish on the brink of extinction and several national level rare bird species such as Saunders’ gull, oriental white stork, and red-crowned crane appear in the Yellow River estuary. The biodiversity resources are getting rich day by day, and the ecology is developing in the direction of diversification and stability.
Booming tourism industry

Laxiwa— The water of the Yellow River becomes clear at Guide County in Qinghai Province (downstream)

Liujiaxia— developed tourism industry of Binglin Temple Grottoes (reservoir area)

Xiaolangdi— a new tourist attraction (dam and reservoir area)

Yellow River Wetland Park
The hydropower development on the Upper Yellow River in 60 years has created tens of thousand direct job opportunity for the local people and immeasurable indirect jobs. The living standard of riparian residents is improving rapidly with a very remarkable social benefit.

During the course of development, an advanced management philosophy has been developed and the effective measures have been fixed in the form of law. The corresponding law and regulation or special by-law governing the management of water resources have been established. The management and control are put under normal operation. This helps the Integrated utilization of water resources, virtuous cycle of ecology and environment, and sustainable development of socio-economics.
1. Overview of Yellow River

2. Integrated development and utilization of Upper Yellow River

3. Experience and understanding from integrated development
Basis for setting up river management commission: relevant laws and regulations in the areas of river basin management, development, electric power, navigation, fishery, and environment protection in state and local level.

As many rivers in the Southeast Asia are cross several regions and countries, the development of river is not only the matter of one country. It requires establishment of coordination mechanism among the countries for negotiation and management so as to maximize the benefits of the rivers for the people.
Under the uniform and coordinated condition, the input and return complement each other and achieve a virtuous cycle.
In 2005, the hydropower in China reduced CO$_2$ emission by 340 million tons, and a further reduction of 99 million tons in 2009. A reduction of 342 million tons and 639 million tons for “12th Five Years” and “13rd Five Years” Plan periods. All the countries where the hydropower resources are abundant in the world give their priority in developing hydropower so as to save coal and oil resources, and reduce carbon emissions, reduce the pollution by thermal power on environment and air. Almost all developed countries give their priority to develop and use clean and renewable ----hydro power.

Hydropower, a source of renewable energy

Hydropower schematic
Global Hydropower Development Rate

- Economic development rate = annual power output / economic potential
- Technical development rate = annual power output / technically feasible potential

Data source: World Energy Statistics Yearbook by BP
Per capita installed capacity in some developed countries and Southeast countries:

- **China**: 0.8 kW
- **Europe**: 1.3 kW
- **USA**: 3 kW
- **Japan**: 1.3 kW
- **Thailand**: 0.46 kW
- **Laos**: 0.26 kW
- **Vietnam**: 0.23 kW
- **Myanmar**: 0.05 kW
- **Cambodia**: 0.04 kW
The guiding principle for the Yellow River Basin Planning is to integrate development and protection, make full use of water resources, promote socio-economic development of the basin and relevant regions and ensure the safety of downstream plains.

The hydropower potential in the Upper Yellow River is 11330 MW with 16 cascade projects planned. The main objective for developing this river section is for power generation, providing reliable power supply for the Northwestern regions, while offering irrigation, flood control, ice flood control, water supply and other comprehensive benefits for Upper and Middle Yellow River. It is a strategic project for the northern corridor of west-east power transfer scheme.

- Head project: Longyangxia HPP, installed capacity 1280 MW, offering comprehensive benefits in flood control, ice flood control, irrigation, aquaculture, tourism and navigation.
- Lijiaxia HPP: installed capacity 2000MW, annual power generation 5.9 billion kwh, mainly for power generation, also for irrigation.
- Laxiwa HPP: installed capacity 4200 MW, largest in the Yellow River Basin in terms of project size, highest dam, unit capacity and total capacity, power generation, lowest unit cost, good investment climate and economic benefit.

### Storage and Regulation Capacity of Main HPPs in Upper Yellow River

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Total reservoir capacity ( 100 million m³ )</th>
<th>Regulation capacity ( 100 million m³ )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longyangxia HPP</td>
<td>247</td>
<td>194</td>
</tr>
<tr>
<td>Liujiexia HPP</td>
<td>57</td>
<td>41.5</td>
</tr>
<tr>
<td>Laxiwa HPP</td>
<td>10.79</td>
<td>1.5</td>
</tr>
</tbody>
</table>
There are 30 large tributaries joining the Middle Yellow River. The water volume added in this river section accounts for 42.5% of the whole river, and the sediments added account for 92% of the whole river, and is the main source of sediments in the Yellow River.

The main objective for the planning of this river section is to coordinate the water-sediment relationship, mitigate the sedimentation in the river course, properly handle the sediment and water regulation by large regulating reservoirs in the upstream, protect wetland, and maintain ecological balance.

Build flood control and sediment reduction engineering systems in the Lower Yellow River, control flood water, shape and maintain river channel of about 4000 cubic meters per second in the downstream, contain “second class suspended river. With large reservoirs in the upper section and ecological environment restoration in the middle section, achieve safety in the beach area and ensure the river empty into the sea via the planned route.

Shentianhu Lake, the largest national level wetland reserve in the middle and lower reaches, more than 230 bird species, an important stop for migratory birds, more than 20 rare bird species spent their winter here.
Basin development and utilization need to consider comprehensive benefits

Large benefits——Small impacts

- Stable regional geology
- Strong regulation capability
- High comprehensive benefits

- Small resettlement
- No block to main navigation channel
- Small flooded area
One of basic principles for dam site selection is to minimize the negative impacts.

Counter-measures against temporary negative impacts:

- Environment management
- Vegetation protection
- Animal protection
- Fish protection
- Water environment protection
- Project waste treatment
- Domestic waste treatment
- Air quality control
- Noise control
- Resettlement
- Environment monitoring
- Environment protection investment

Basin development and utilization need to consider comprehensive benefits.
Impacts of project construction

Environmental impacts

Social impacts

Basin development and utilization need to consider comprehensive benefits

animals
plants
river
residents in reservoir area
Residents in downstream area
Thanks!