



中国小水电绿色发展与实践

China's Green Development of Small Hydropower

国际小水电中心

International Small hydropower Center

徐锦才 2023.9

Prof. Dr. Xu Jincai SEP. 2023

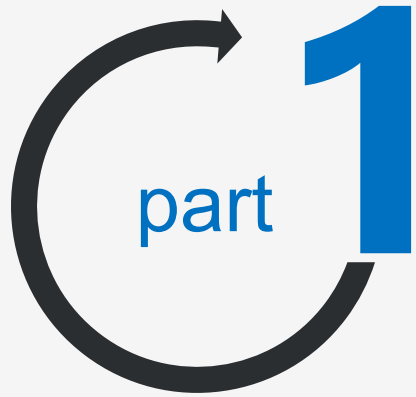


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气候变化与小水电现状

The climate change and SHP in China

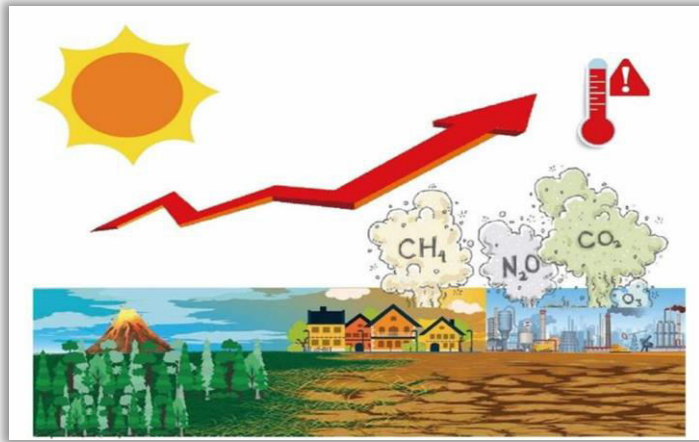
应对气候变化 tackle climate change

There is no doubt that human activity is causing global warming.

Climate change leads to more frequent extreme weather.

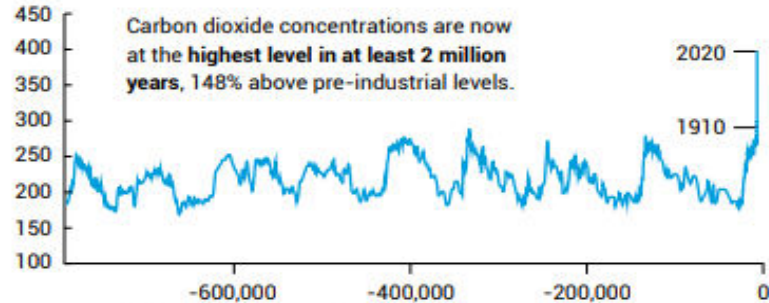
Weather-related disasters have increased over past 50 years.

Climate change urges the world energy consumption to move toward a lower-carbon and cleaner manner.



Trends in atmospheric carbon dioxide concentration over 800,000 years

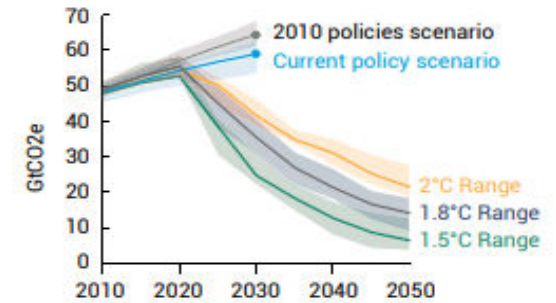
Mean carbon dioxide concentrations globally ppm



Source: United States Environmental Protection Agency, 2020.

Projections for global GHG emissions under different scenarios

Note: Projections do not take into account commitments announced in early 2021.



Source: UNEP, 2020.

能源与排放 Energy and emissions

- 气候危机要求我们必须严格控制温室气体排放。

The climate crisis calls for actions on reducing greenhouse gas from now.

全球温室气体排放70%以上与能源相关。

More than 70% Global greenhouse gas emissions are energy-related.

By the end of 2022, the installed capacity of global renewable energy was 3372GW.

中国非化石能源消费占比达到**17.5%**，与世界平均水平基本持平；非化石能源消费总量与增量稳居世界第一。

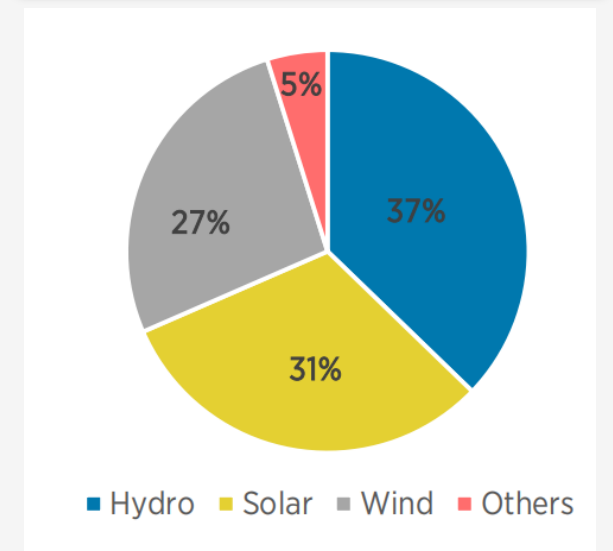
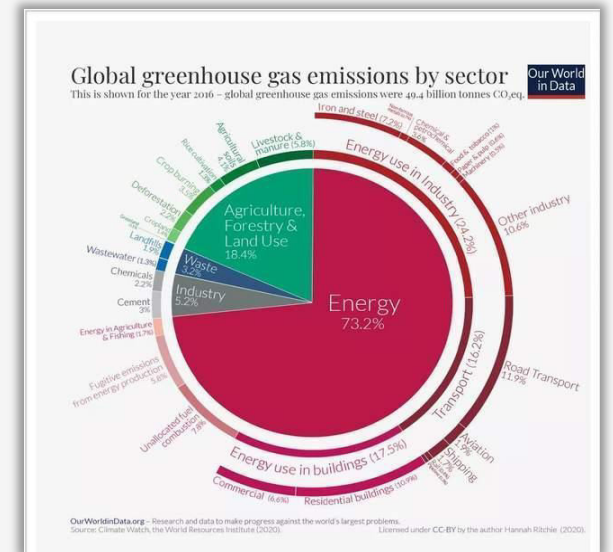
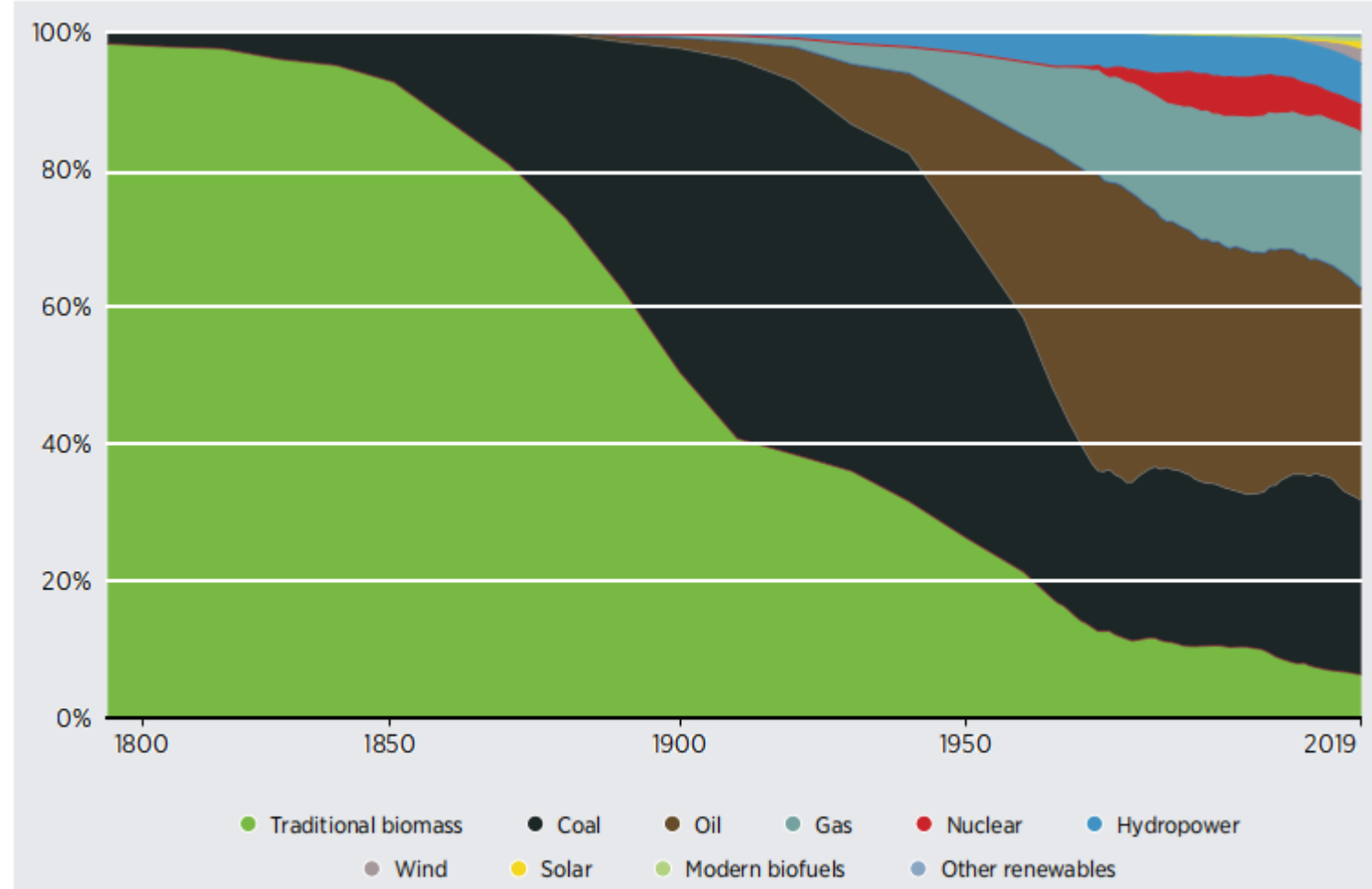


Figure 1 Global primary energy consumption (1800-2019)

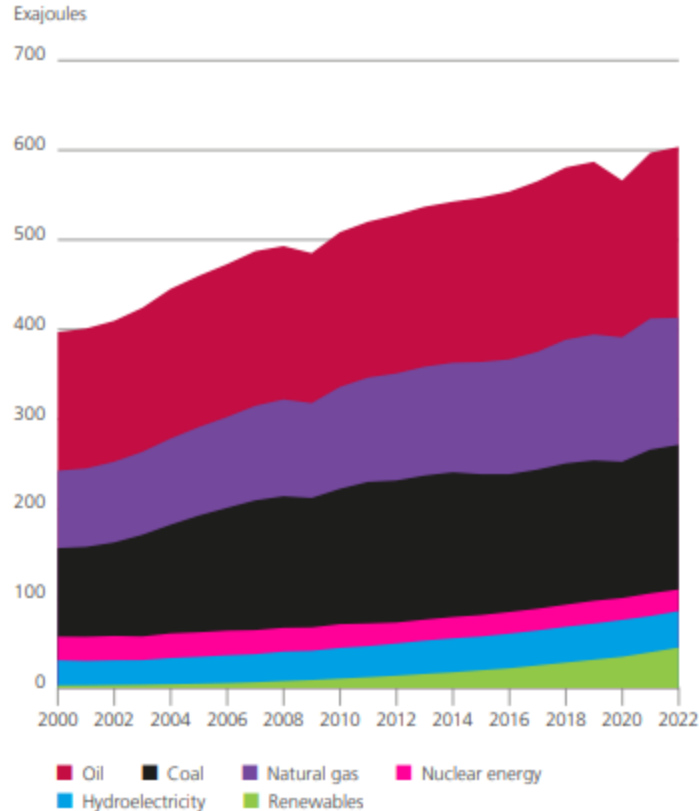


Note: In the figure above, primary energy is calculated according to the "substitution method", which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.

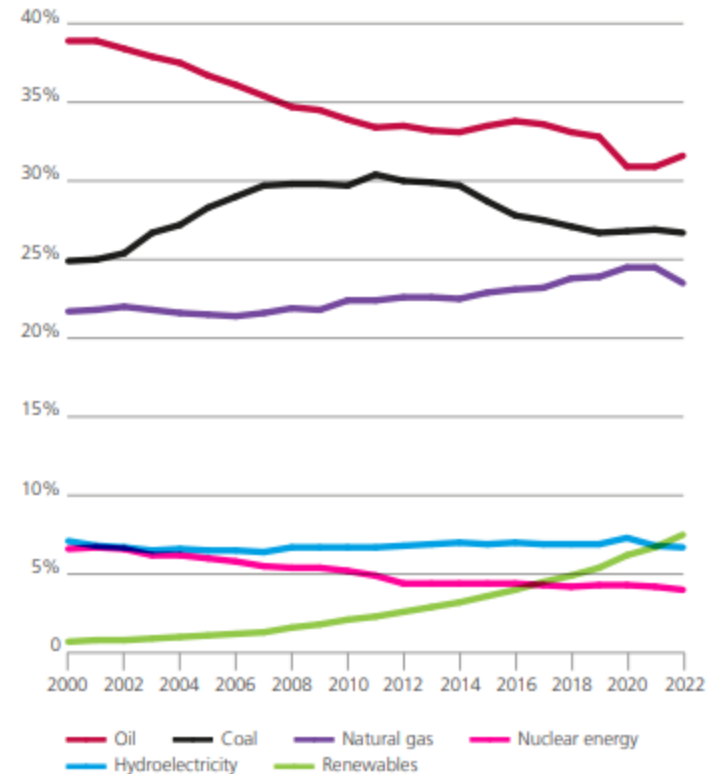
Source: Our World in Data (2021).

P Primary energy World consumption*

World consumption



Share of global primary energy



2022年：能源消费结构中，美国化石能源的占比达到79%，欧洲为71%。

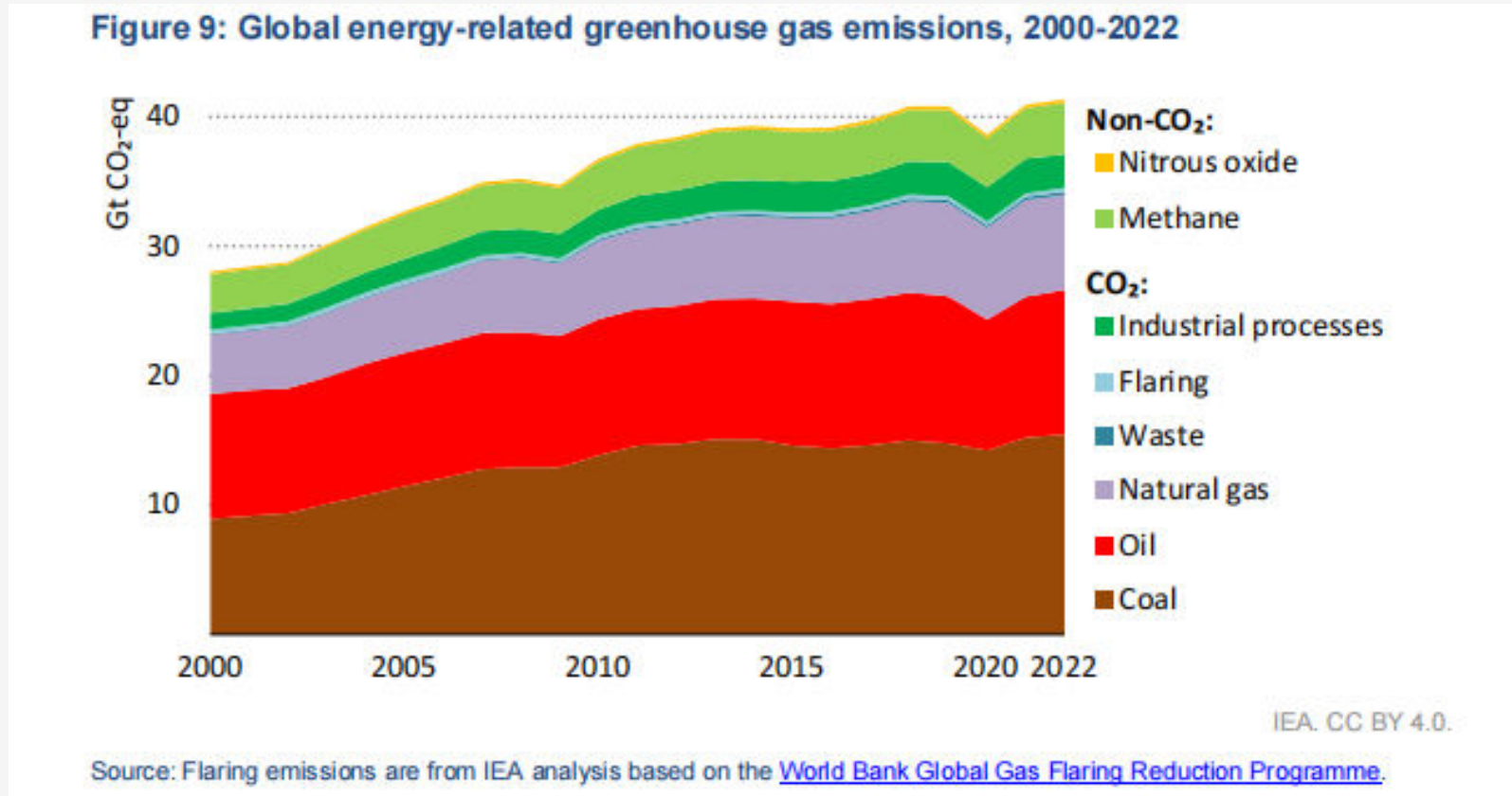
中国化石能源的占比达到82.5%(2030年75%)。

The proportion of fossil energy in the United States reached 79%, and Europe was 71% in the energy consumption.

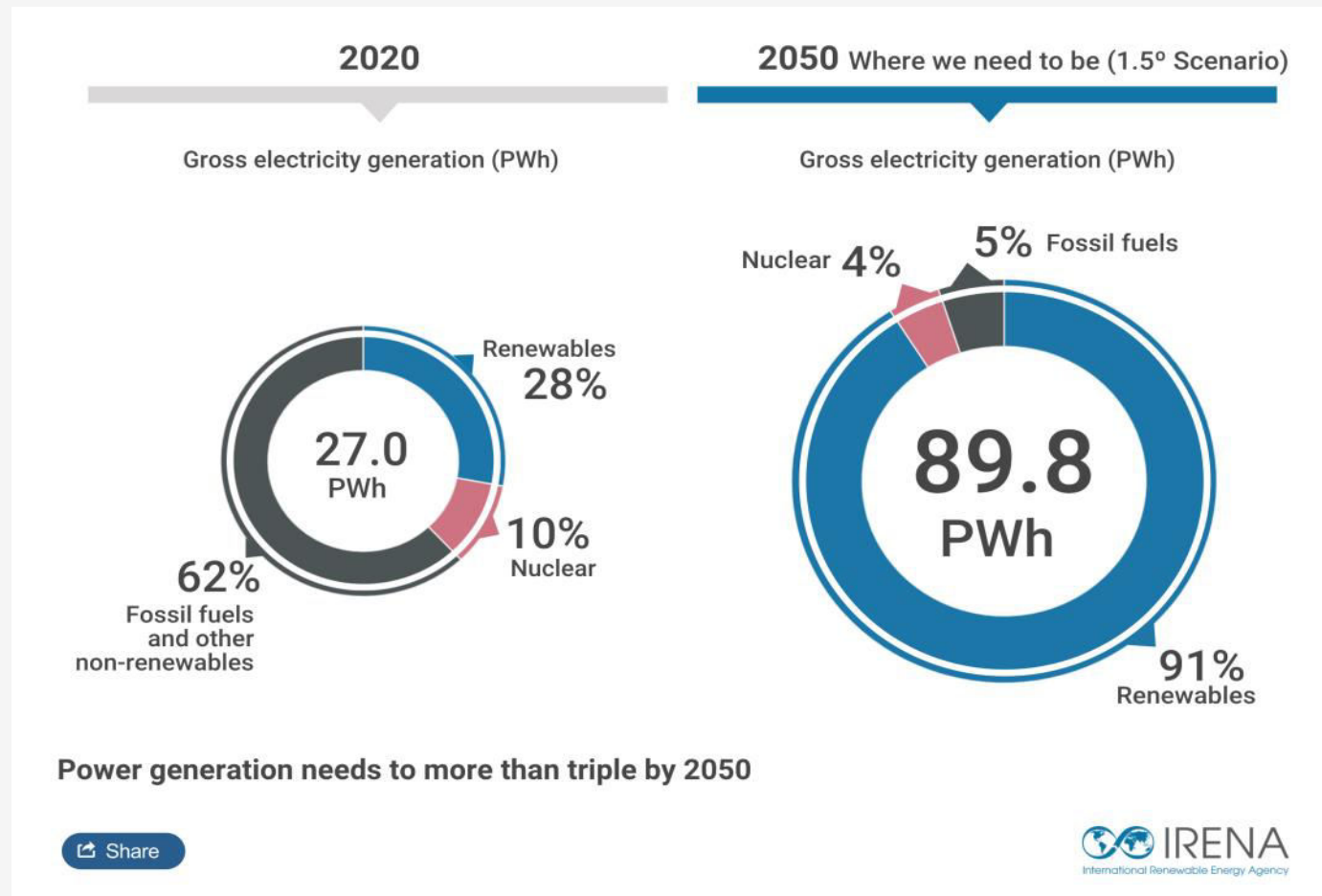
China reach 82.5%.

Energy-related greenhouse gas emissions reached

41.3 Gt CO₂-eq in 2022



Limiting global warming to 1.5° C requires cutting carbon dioxide (CO₂) emissions by around 37 gigatonnes (Gt) from 2022 levels and achieving net-zero emissions in the energy sector by 2050.

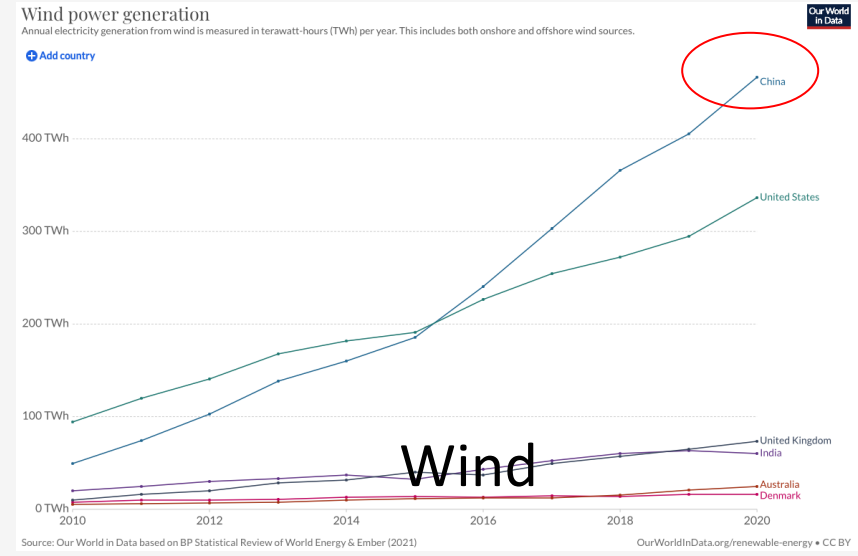
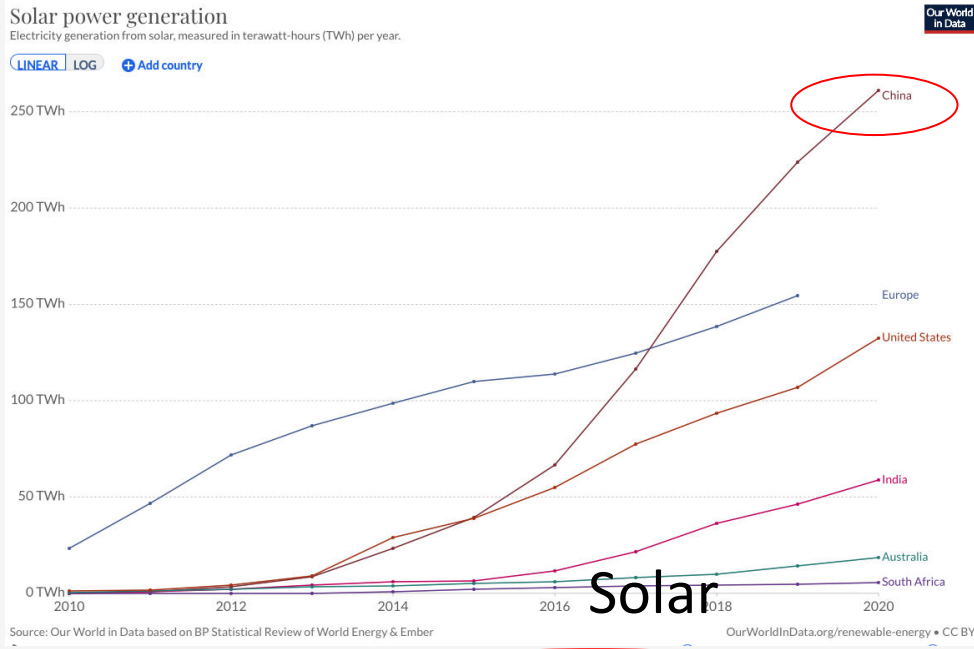


International Day for Clean Energy
January 26th

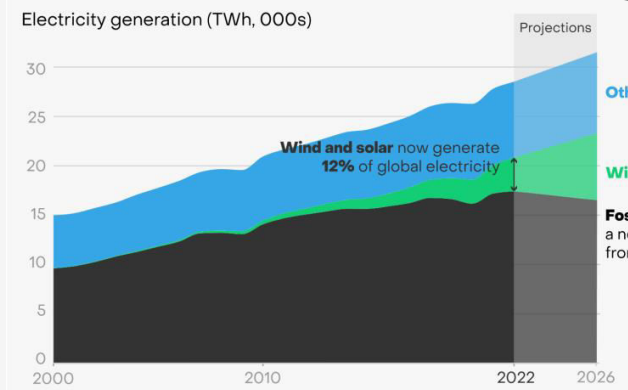
By the end of 2022, renewables accounted for 40% of global installed power capacity.

and 83 percent of new power generation installed globally last year was accounted for by renewables.

Who is doing the most?



Wind and solar hit 12% of global power: an era of fossil decline is about to begin



15% in China

Over the coming decades, solar PV and wind will dominate the growth of renewables in the power sector

双碳目标 Dual carbon goals

2020年9月22日，国家主席习近平在第75届联合国大会代表中国政府郑重承诺：

On September 22, 2020, at the General Debate of the 75th Session of the United Nations General Assembly, President Xi Jinping announced to the world China's new carbon peak goal and carbon neutrality vision:

中国将提高国家自主贡献力度，采取更加有力的政策和措施，二氧化碳排放力争于2030年前达到峰值，努力争取2060年前实现碳中和。

China will scale up the Nationally Determined Contributions, by adopting more vigorous policies and measures, **strive to peak carbon dioxide emissions before 2030, and strive to achieve carbon neutrality before 2060.**

中国可再生能源开发情况Clean and Renewable Energy

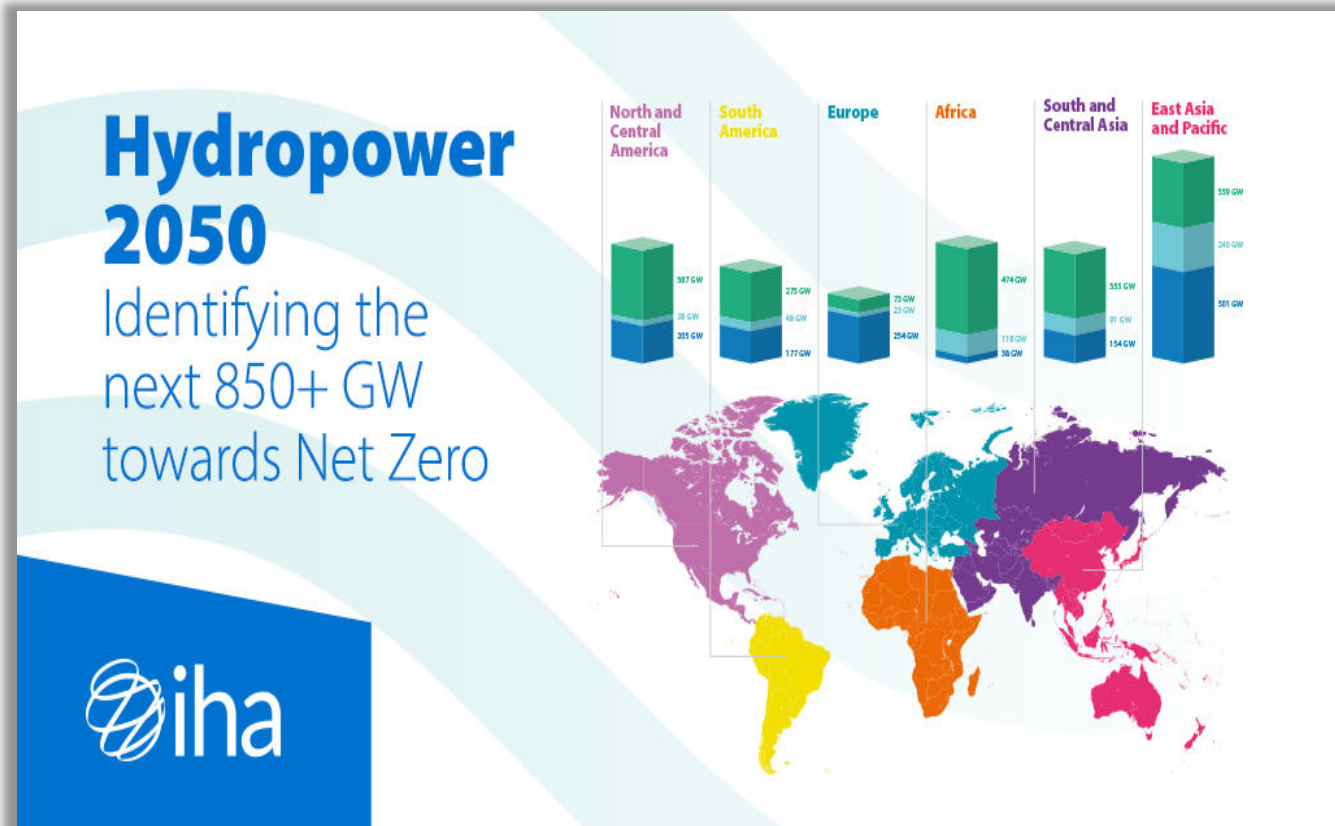
2022年末，全国发电装机容量25.64亿千瓦（可再生能源装机突破12亿千瓦，达到12.13亿千瓦，占全国发电总装机的47.3%，**超越煤电**），**全社会用电量8.6万亿千瓦时**（风电、光伏发电量首次突破1万亿千瓦时）。全国单位GDP电耗852千瓦时/万元；全国单位发电量二氧化碳排放约558克/千瓦时。（**可再生能源装机已占全球装机容量的40%**）

- **At the end of 2022, the installed capacity of power has reached 2564GW in China.**
 - of which the total installed capacity of **hydropower is 413GW**
 - the installed capacity of **nuclear power-generating units 55.53GW.**
 - The **wind power is 365GW (offshore 26GW)**
 - **solar power-generating capacity 393GW.**
 - the installed **biomass power-generating capacity is about 41.32GW.**

煤电以不足**50%**的装机占比（**43.8%**），提供了**58.4%**电量，**70%**的顶峰能力和近**80%**的调节能力。

水电在全球碳中和中的作用

Hydropower's Role in Global Carbon Neutrality



Hydropower, the world's largest provider of renewable energy.

GLOBAL HYDROPOWER DAY

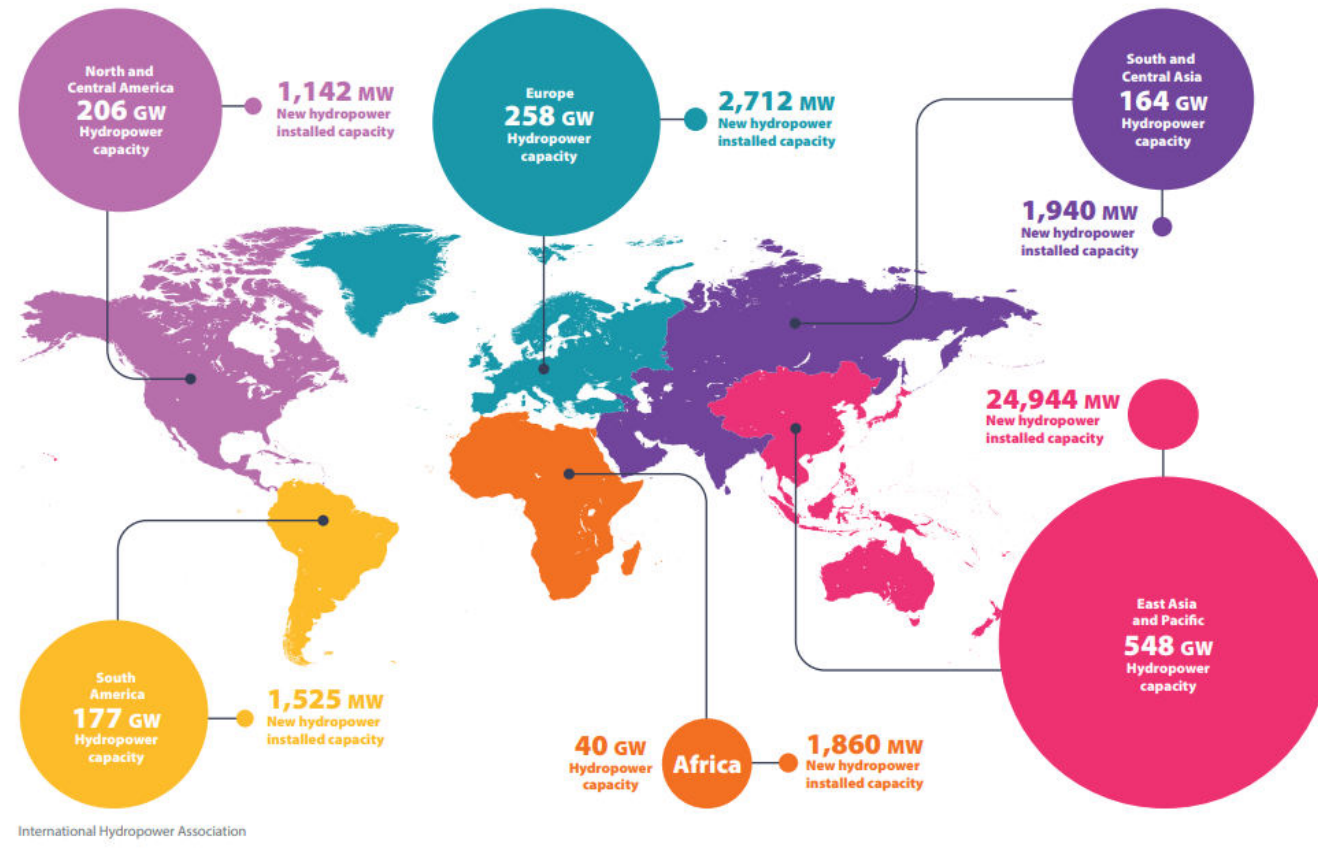
#GlobalHydropowerDay on 11 October 2022 celebrated the positive impacts of sustainable hydropower on people and communities around the world.



Hydropower also supports the rapid growth of solar and wind power

hydropower

Hydropower capacity by region in 2022



In east Asia and indeed globally, China continues to lead the way, with nearly 24 GW of new capacity brought into service in 2022.

尽管水电是最成熟的可再生能源技术，但它也面临着许多挑战，包括：

- 确保可持续性和气候适应能力；（2022年四川出现了罕见的电力短缺）
- 老化的机组及相关的投资要求；
- 运行和维护(O&M)需适应现代电力系统的要求；
- 过时的市场结构和商业模式没有认识到水电提供的全方位服务。



中国长江流域遭遇了60多年来最严重的干旱

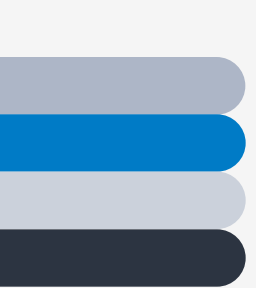
Despite being the most mature renewable technology, hydropower faces a number of challenges .

These include the **need to ensure sustainability and climate resilience**;

ageing fleets and related investment requirements;

the need to adapt operation and maintenance (O&M) to modern power system requirements;

and outdated market structures and business models that do not recognise the full range of services provided by hydropower.



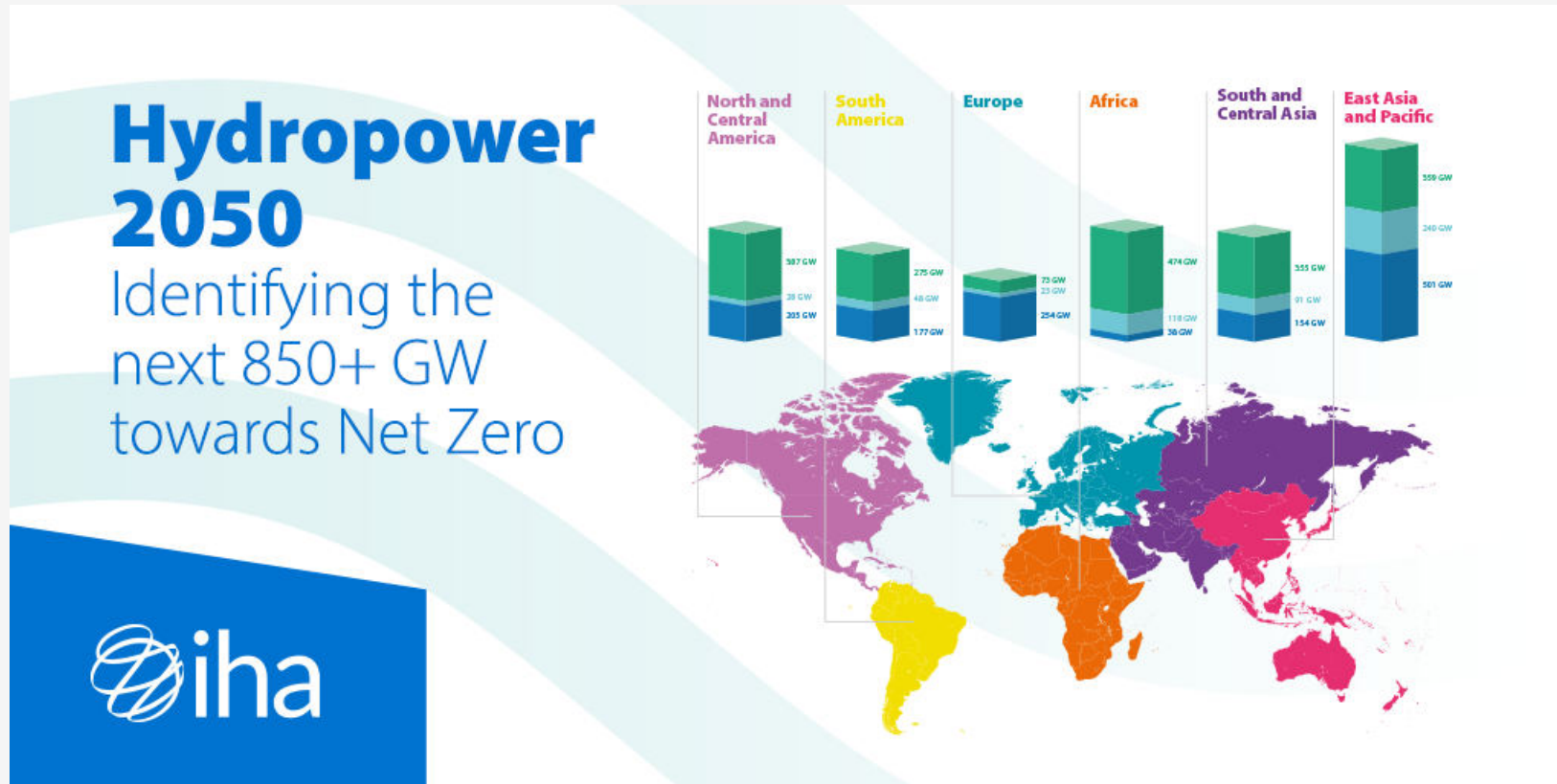
Hydropower provides clean electricity, with significantly lower greenhouse gas emissions than most other energy sources.

Hydropower is an important component of power systems worldwide. **It is the largest source of renewable electricity and can enable a higher penetration of variable renewables such as solar and wind by providing balancing and flexibility services.**

Beyond electricity, **hydropower also provides other services including storage for drinking and irrigation water,** increased resilience to flooding and droughts, and recreational opportunities.

Like other types of infrastructure, hydropower is however starting to experience negative impacts due to climate risks. Water availability and hydropower generation are affected by changes in hydrological patterns and extreme weather events.

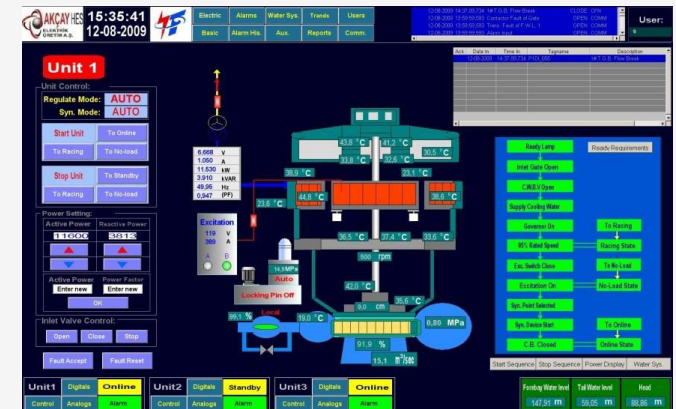
More than 500 GW of hydropower installations are in the pipeline worldwide, but this is far short of what is required to limit dangerous global warming.



中国小水电开发情况 SHP Development in China

China has the Small hydropower potential of 128 GW and ranks first in the world. By the end of 2020, we have constructed 43957 SHP stations, with the total installed capacity of more than 81 GW.

SHP plays a significant role in rural electricity accessibility, promoting the economic and social development, improving the living and working conditions for the people in rural areas.



小水电是独特的可再生能源

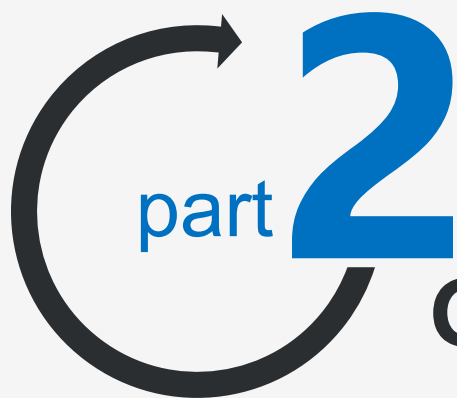
SHP, A Unique Renewable Energy

我国现有库容10万m³及以上的小水电1万余座，是独特的分布式发电资源。

In China, there are more than 10,000 small hydropower plants with storage capacity of 100,000 cubic meter or more, which is a unique distributed power generation resource.

Small hydropower cascade stations can regulate storage capacity and increase the flexibility of power grid.





中国小水电绿色转型发展实践

Green Transition Practice of SHP in China

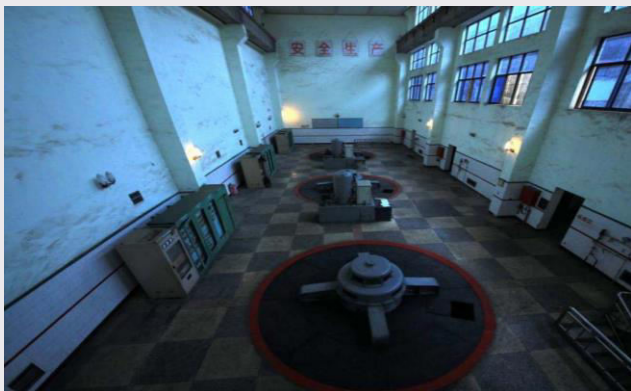
- The Capacity Expansion and Efficiency Increase,
- SHP reorganization and rectification,
- Establishment of Pilot Green Small Hydropower ,
- and the SHP modernization.

1、小水电增效扩容改造

Capacity Expansion and Efficiency Increase of SHP in China

改造前后对比 Before VS After

重庆宋农电站
Songnong SHP
in Chongqing



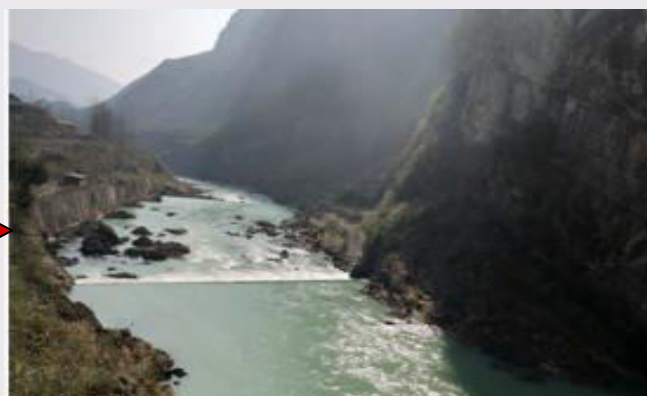
◀ 厂房改造前
厂房改造后 ▶
Powerhouse
Renovation



贵州省梅江河
(3座梯级电站)
Meijiang River
in Guizhou, 3
cascade SHPs



◀ 河道改造前
河道改造后 ▶
river ecological
restorations



2、小水电清理整改 SHP Reorganization & Rectification

长江经济带清理整改 (2018-2020)

Yangtze River Economic Belt

- 共2.5万余座，2.1万余座电站按规定落实了生态流量，并已接入各级监管平台。

Over 25 000 SHPs involved, 21 000 rectified with ecological flow and connected to regulatory platforms at all levels.



长江经济带小水电清理整改平台
Yangtze River SHP R&R Platform

黄河流域各省区清理整改 (2021-2024)

Yellow River Basin

- 共2800多座，正在进行中

A total of 2800 SHP involved underway.

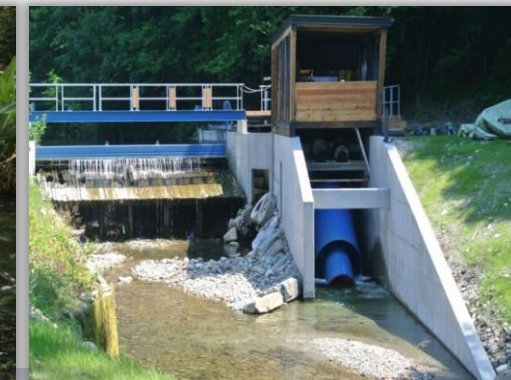


黄河流域省区小水电清理整改平台
Yellow River SHP R&R Platform

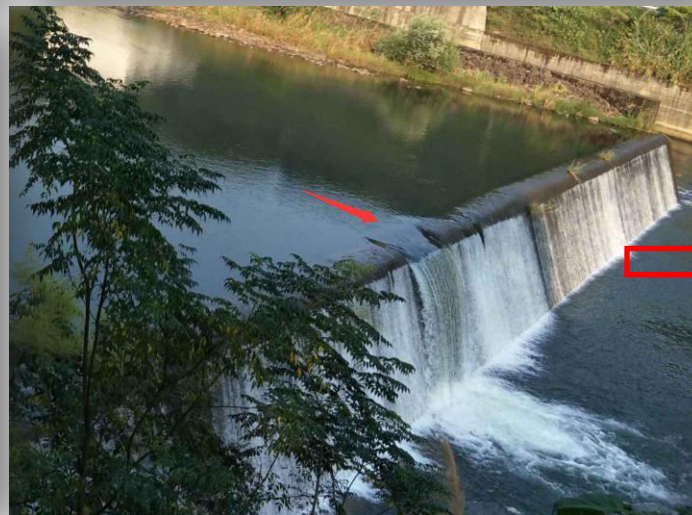
厂坝间河流生态修复

Ecological Restoration of River Channels Between Powerhouses and Dams

- 恢复河道连通性(取消拦河坝改用低堰坝、修建过鱼设施、改用鱼类友好型机组)
- Recover the river connectivity by using low dams, fish passing facilities, fish friendly units, and etc.
- 减脱水河段修复(生态跌坎、生态堰坝、阶梯-深潭系统、河道纵向深槽、河岸生态护坡)
- Restore the ecological environment of water reduction and dehydration river reach by ecological drop-step, ecological weir dam, step-pool system, longitudinal deep groove, river bank slope protection, etc.



泄放设施改造 E-flow facility renovation



3、绿色小水电示范电站

Pilot Green Small Hydropower Plant

聚焦生态环境、社会、管理
和经济等四个方面

The Evaluation of Green
Small Hydropower mainly
focus on four aspects:

- Ecological environment
- society
- management
- finance

绿色小水电
评价指标体系
Green SHP
Evaluation
Frame

Category	Element	Indicator
Environment (55)	Hydrology (15)	Ecological flow (15)
	River morphology (5)	Disturbance of river morphology (3)
		Sediment transport (2)
	Water quality (5)	Changes of water quality
	Aquatic and terrestrial ecology (10)	Impact on protected aquatic organism (6)
		Impact on protected terrestrial fauna and flora (4)
	Landscape (10)	Landscape coordination (5)
Landscape restoration (5)		
Energy-saving & emission reduction (10)	Substitution effect to fossil energy (5)	
	Efficiency of carbon emission reduction (5)	
Social (18)	Resettlement (6)	Performance of resettlement (6)
	Benefit sharing (8)	Improvement of public services (4)
		Guarantee of people's livelihood (4)
	Comprehensive utilization of water resources (4)	Comprehensive utilization of water resources (4)
Management (18)	Safety management (6)	Evaluation of safety standards (6)
	Construction of green hydropower (8)	Capacity building of green hydropower (4)
		Green hydropower facilities (4)
	Technical progress (4)	Automation (4)
Financial (9)	Stability of finance (6)	Profitability (3)
		Solvency (3)
	Regional economic contribution (3)	Rate of social contribution (3)

绿色小水电示范电站

Pilot Green Small Hydropower Plant

木瓜电站：
浙江淳安
引水式开发

Mugua SHP:

- **Location:** Chun'an, Zhejiang Province
- **Capacity:** 5000kW
- **Mode:** Diversion



Eflow facility



绿色小水电示范电站

Pilot Green Small Hydropower Plant

江滨电站，河床式开发

Jiangbin SHP :

- **Capacity:**1000kW
- **Mode:** Run-of-river



4、水电站现代化提升 **SHP Modernization**

改变单站独立分散运行的常规模式，以区域（流域）为单位建立电站集群统一运行模式。

The modernization initiative integrates the decentralized small hydropower plants into a virtual power station for **remote monitoring, integrated operation and management by a central control center.**



中华人民共和国水利部办公厅

办水电话〔2023〕596号

水利部办公厅关于印发《智能化小型水电站 技术指南(试行)》《小水电集控中心 技术指南(试行)》的通知

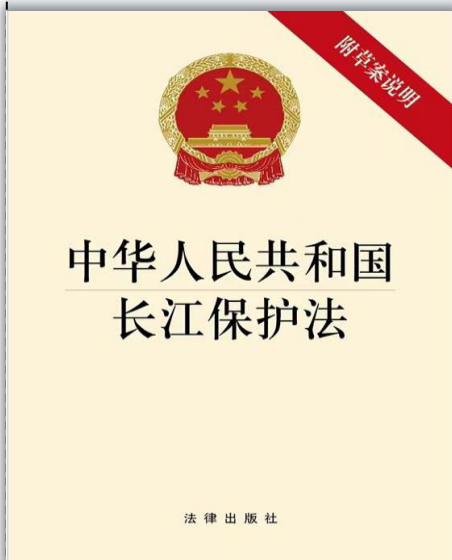
各省、自治区、直辖市水利(水务)厅(局),新疆生产建设兵团水利局,各流域管理机构,部直属有关单位:

小水电绿色改造和现代化提升是践行习近平生态文明思想,推进中国式现代化的具体举措。近年来,部分地区政府和市场两手发力,积极开展小水电绿色改造和现代化提升试点,通过设施设备除险加固、电站智能化改造、集控中心建设、生态修复、蓄能改造等方式,推进小水电智能化、集约化、标准化,取得较好成效,积累了经验。2023年全国水利工作会议明确要求实施小水电绿色改造和现代化提升工程,推进建设智能集约的现代化小水电。为加强对这项工作的指导,推广运用数字孪生、人工智能等新一代信息技术,我部编制了《智能化小型水电站技术指南(试行)》《小水电集控中心技术指南(试行)》,供各地参考。

法律保障、技术指导、标准引领

Legal Assurance, Technical Support and Guiding Standards

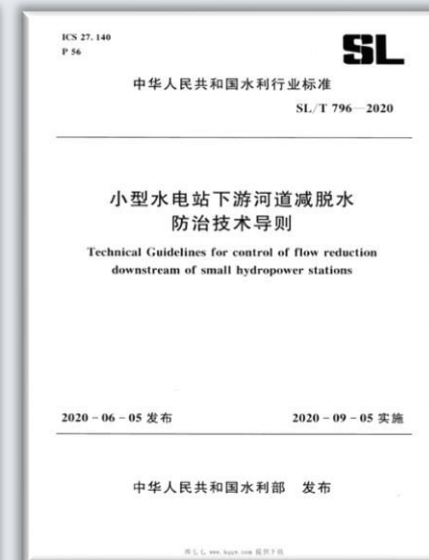
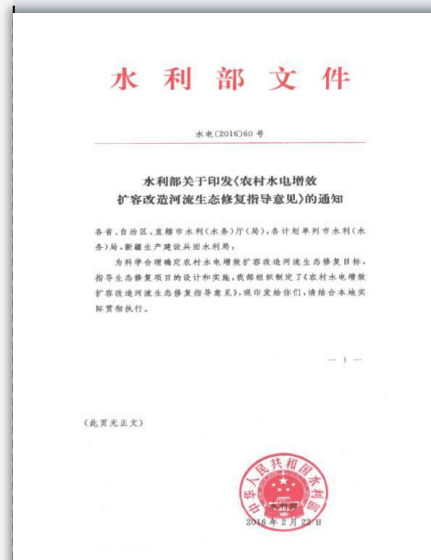
- 《水法》 《环境保护法》
- 《长江保护法》 《黄河保护法》 等



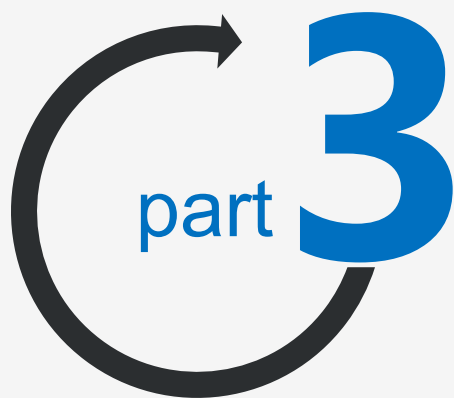
2021: Yangtze River Protection Law

2022: Yellow River Protection Law

- 《农村水电增效扩容改造河流生态修复指导意见》 《绿色小水电评价标准》 等技术指导文件



行业指导文件、技术标准
Industrial guiding documents, technical standard



中国小水电绿色发展面临的机遇

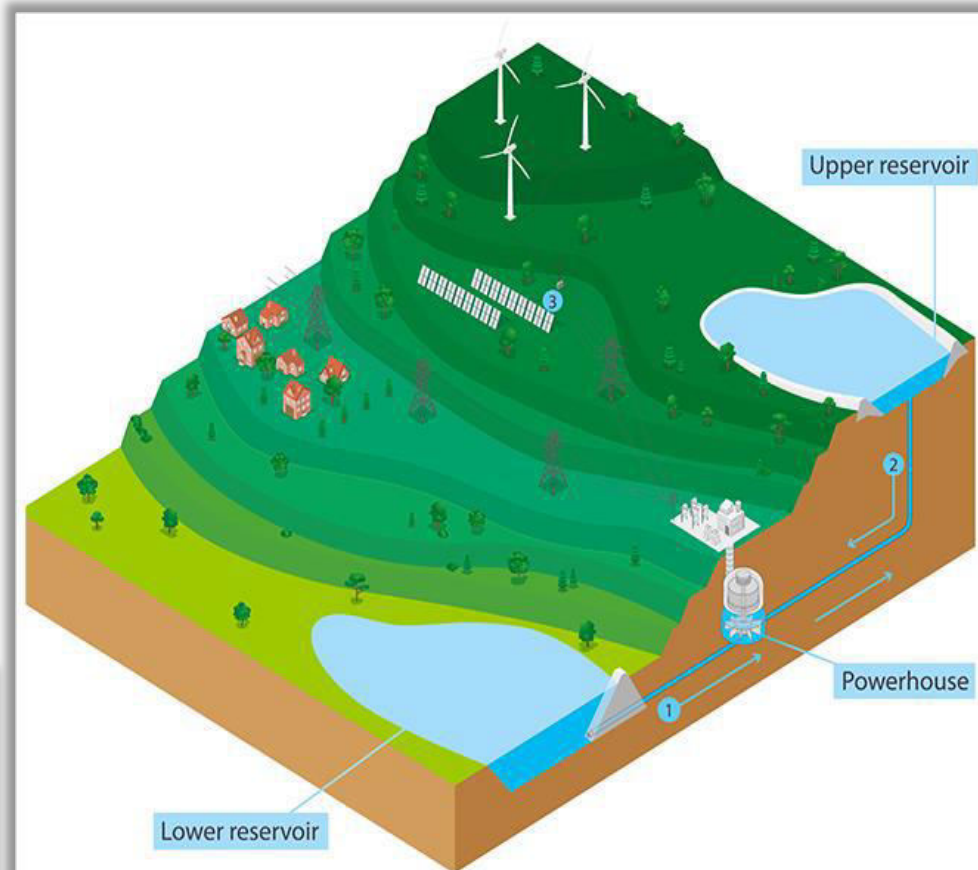
**Opportunities of the Green Development of
Small Hydropower in China**

1 梯级电站抽水蓄能改造

The Renovation of Cascade Pumped-storage Power Stations

将已建的小水电（群）梯级电站改造成抽水蓄能电站，可促进随机性可再生能源的消纳，实现小水电绿色转型。

Transforming the existing cascade small hydropower plants into pumped storage power stations, combined with wind power, solar power and other renewable energy can promote the consumption of random renewable energy.



- 1 During periods of low demand reflected by lower prices, renewable energy such as wind and solar is used to pump water uphill.
- 2 When demand increases, water from the upper reservoir runs downhill through the turbines to produce electricity.
- 3 Pumped storage combined with variable renewable energy can provide reliable, dispatchable and low carbon electricity to domestic and industrial consumers.

2、多能互补与虚拟电厂

Complementary Multi-energy & Virtual Power Plant

水电与新能源有很强的互补性，小水电站点多面广量大，很大部分没有发挥好调节电源作用。

Hydropower and new energy are well complementary to each other. China's SHP is dispersedly distributed in large number, and most of them do not contribute to regulating power supply.



虚拟电厂是新型电力系统不可或缺的新成员。

The virtual power plant is an indispensable part of the new power system.

4 电网辅助调节 Ancillary Regulation of Power Grid

电网辅助服务：有功平衡、无功平衡、事故应急

Active power balance, reactive power balance and accident emergency.

- 有功平衡：调频、调峰、备用、转动惯量、爬坡等

Active power balance: frequency regulation, peak shaving, standby, moment of inertia, climbing, etc.

- 无功平衡：自动电压调节、调相等

Reactive power balance: automatic voltage and phase regulation and equalization

- 事故应急：稳定切机、稳定切负荷、黑启动等

Accident emergency: stable machine cutting, stable load cutting, black-start, etc.

Hydropower has a unique role in power grid ancillary regulation on peak shaving, moment of inertia and black-start.

结论 Conclusion

小水电在实现能源安全和气候目标两方面有独特的潜在重要作用!

Small hydropower plays a unique and potentially important role in achieving energy security and climate goals

- 过去：建设小水电，提供电力供应，实现农村电气化。

In the past, SHP contributed to the power supply and rural electrification.

- 现在：改造小水电，提高效率、安全和生态效应，实现绿色转型。

Now, SHP renovation aims at improving the efficiency, security and ecological effects, and shifting to the green development.

- 将来：可持续发展，发挥独特的储能调节作用，助力实现双碳目标。

In the future, SHP will play its unique role in power storage and regulation to support sustainable development and the dual carbon goals.



感谢聆听！
Thanks for your attention!