

# 中国华能燃烧后CO<sub>2</sub>捕集工程示范

## POST-COMBUSTION CO<sub>2</sub> CAPTURE DEMONSTRATION IN CHNG

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□ 华能清洁能源研究院 Introduction of CERI

□ 华能燃烧后CO<sub>2</sub>捕集中试和工程示范

Pilot Plant and Demonstration Project of PCC in CHNG

□ 示范项目经验总结 Experience of Demo Project



# 中国华能集团公司 Brief Introduction of CHNG

- 世界最大的发电公司，装机规模超过1.54亿千瓦，电厂超过300个  
The biggest power generation capacity in the world.  
Total installed capacity is more than 154GW; Holding more than 300 power plants
- 2015年世界五百强企业排名224位，营业收入474亿美元  
A Fortune 500 Company: 224 rank in 2015
- 华能在澳大利亚、缅甸、新加坡、荷兰和墨西哥等国家拥有电厂。  
CHNG has assets distributed in Australia, Burma, Singapore, Netherlands and Mexico





# 中国华能集团清洁能源技术研究院有限公司 Huaneng Clean Energy Research Institute

## □ 中国华能集团直属清洁能源前沿技术研发机构

Institution focused on the frontier technology research and development of clean energy.

## □ 主要研发领域 Mainly focuses on research of the following aspects

- 近零排放燃煤发电、煤气化及煤基清洁转化 (Nearly zero emission for coal-fired power generation; Coal gasification and clean coal-based energy conversion)
- 大型循环流化床锅炉、低质煤利用 (Large-scale circulating fluidized bed boiler; Low-quality coal utilization;)
- 可再生能源发电、发电新材料、能源系统设计优化 (Renewable energy power generation; Design and optimization of energy system)
- CO<sub>2</sub>捕集、利用和封存 (Capture, utilization and storage of CO<sub>2</sub>)





# 中国华能集团清洁能源技术研究院有限公司 Huaneng Clean Energy Research Institute

## □ Authorization R & D institutions

- “国家能源煤清洁低碳发电技术研发（实验）中心” National Energy Technology R&D Center of Clean and Low-carbon Coal-fired Power Generation Technology
- “国家能源水能高效利用与大坝安全技术研发中心” National Energy Technology R&D Center of Efficient Hydro-power Utilization and Dam Safety
- “煤基清洁能源国家重点实验室” State Key Laboratory of Coal-based Clean Energy
- “北京市低质燃料提质与清洁高效利用工程中心” Beijing Engineering Research Center of Qualify and Clean Efficient Utilization of Poor Fuel
- “二氧化碳捕集与处理北京市重点实验室” Beijing Key Laboratory of CO<sub>2</sub> Capture and treatment





## 立项背景

# Background of Demonstration Project

### □ 碳减排形势需求 Greenhouse Gas Emission Control

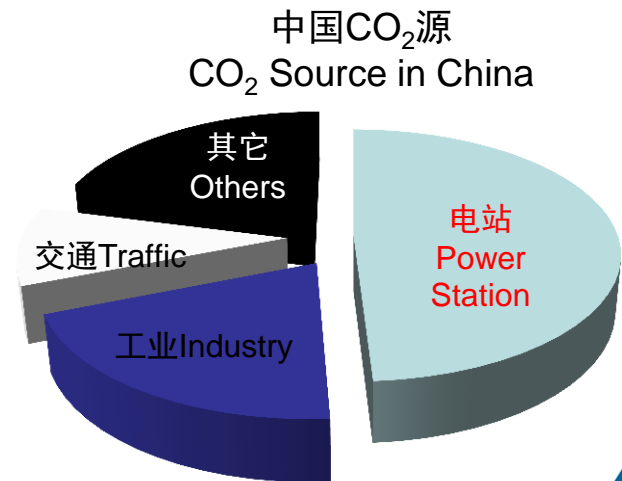
- 温室气体是造成温室效应、气候变化等问题的主因

Greenhouse gases cause global climate change

- 中国是CO<sub>2</sub>排放最多的国家之一，其中40%~50%的CO<sub>2</sub>排放来自于电厂

China is one of the largest CO<sub>2</sub> emission contributors

In China, 40%~50% CO<sub>2</sub> emission is from power stations





## 立项背景

# Background of Demonstration Project

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### □ 国家政策支持 Government Policy Support

- 2007年，国务院发布“中国应对气候变化国家方案”，明确将“CO<sub>2</sub>捕集、利用与封存”作为“加大先进适用技术开发和推广力度”重点内容

In 2007, the State Council issued “China ‘s Climate Change Counter-Plan”, in which, the government has promised to increase effort on development and promotion of CCUS technology.

- 2015年巴黎大会期间，中国承诺将于2030年左右使CO<sub>2</sub>排放达到峰值并争取尽早实现，且2030年单位国内生产总值CO<sub>2</sub>排放比2005年下降 60%－65%。

In 2015, China is to peak its CO<sub>2</sub> emissions “around 2030” and will make “best efforts” to peak early, and reduce its carbon intensity by 60%-65% of 2005 levels by 2030.





## 立项背景

# Background of Demonstration Project

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### □ 企业积极响应 High Motivation in Power Industry

- 华能是世界上碳排放最大的发电公司之一，煤电占比大，面临减排压力。

Huaneng is China's largest power company dominated by coal-fired units, facing the pressure of emission reduction.

- 华能积极倡导低碳发展战略，开展CCS技术研发和示范，不仅是发电企业义不容辞的社会责任，也是企业未来发展的过程中的必然选择。

Huaneng actively promote low-carbon strategy, develop and demonstrate CCS technology. It is the duty of social responsibility, and the inevitable choice of power generation enterprises.





# 华能集团CO<sub>2</sub>捕集技术发展历程

## Brief Review of CO<sub>2</sub> Capture Progress in Huaneng

China's first CO<sub>2</sub> capture facility in Huaneng Beijing Cogeneration Power Plant, 3000t/a

在华能北京热电厂建成我国第一个燃煤电厂碳捕集示范装置，规模为3000吨/年



2008

Lab-scale Study

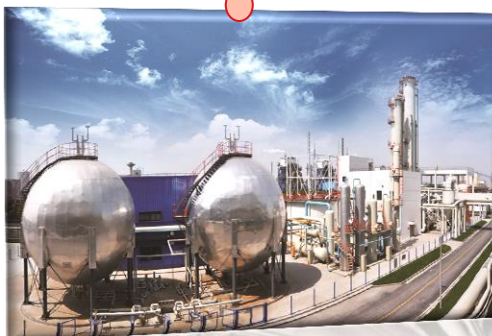
实验室规模测试与筛选实验



2007

The largest CO<sub>2</sub> capture facility in Huaneng Shanghai Shidongkou NO.2 Power Plant, 120000t/a

在华能上海石洞口第二电厂同步建成当时世界上最大的燃煤电厂碳捕集示范装置，规模为12万吨/年



2009

The first removable CO<sub>2</sub> capture facility in Huaneng Qinling Power Plant, 300t/a

在华能秦岭电厂建成第一套可移动式燃煤电厂碳捕集测试平台，规模为300吨/年



2011

The first CO<sub>2</sub> capture facility for NGCC in 密云建成第一套燃气烟气CO<sub>2</sub>捕集中试平台，规模为1000吨/年



2013

A removable CO<sub>2</sub> capture and compression facility in Huaneng Changchun Power Plant, 1000t/a



2014

在华能长春热电厂建成一套可移动、带CO<sub>2</sub>超临界压缩的碳捕集测试平台，规模为1000吨/年

Advanced Laboratory in Beijing

在北京未来科技城建成世界领先的碳捕集技术开发实验室



2011 ~ 今 ~ .....



# CO<sub>2</sub>捕集中试平台（1）

## Pilot-scale Facilities for CO<sub>2</sub> Capture （1）

### □ 燃气烟气千吨级CO<sub>2</sub>捕集平台

1000t/a PCC for NGCC



- CERI建造的中国首套燃气电厂二氧化碳捕集测试系统（规模2.5吨CO<sub>2</sub>/天）

First CO<sub>2</sub> capture pilot plant for natural gas based power station in China, built by CERI in 2012 (2.5 tons CO<sub>2</sub> per day)

- 中标挪威CCM碳捕集工程的验证项目

This plant is served as a verification plant for Norway CO<sub>2</sub> Capture Mongstad (CCM) project

- 在保证84%捕集率的条件下，CCM验证项目已通过验收，连续稳定运行3000小时（捕集率84%~92%）

CCM Verification plant has been running stably for 3000 hours with capture efficiency >84%

- 新型MVR再生系统，可减少15%~20%能耗

Novel Regeneration System (MVR), Reducing 15%~20% Energy Cost Compared with Traditional Stripper.



## CO<sub>2</sub>捕集中试平台（2）

### Pilot-scale Facilities for CO<sub>2</sub> Capture （2）

#### □ 燃煤电厂千吨级CO<sub>2</sub>捕集平台

1000t/a PCC in coal-fired power plant



— 可移动实验平台，坐落于吉林省长春热电厂  
Transportable test plant built by CERI in 2014;  
Local in Changchun coal-fired power plant, Jilin province

— 在东北寒冷气候下，测试溶剂性能、评估操作工艺

The purpose is (1) to test the screened solvents;  
(2) to evaluate the operation of PCC plant under extreme cold conditions.

— 中澳100万吨/年PCC项目的重要组成部分

It is an important part of the China-Australia PCC Feasibility Study of 1 mt/a PCC in Changchun plant.

— 2015年完成3种溶剂测试，每种溶剂连续运行1000小时。

Tested 3 solvents with 1000hrs for each solvent in 2015.





# CO<sub>2</sub>捕集工业装置（1）

## Demo Projects of CO<sub>2</sub> Capture （1）

### □ 北京热电厂3000吨/年CO<sub>2</sub>捕集装置

3000t/a PCC plant in Beijing

- 2008年7月，华能建设的我国第一套电厂CO<sub>2</sub>捕集装置在华能北京热电厂投入运行，年捕集3000吨CO<sub>2</sub>气体。

China's first post-combustion CO<sub>2</sub> capture plant built by Huaneng in 2008 with a capture capacity of 3000t CO<sub>2</sub>/a.



3000 t/a PCC plant in Huaneng Beijing Thermal Power Plant



## CO<sub>2</sub>捕集工业装置（2）

### Demo Projects of CO<sub>2</sub> Capture （2）

#### □ 上海石洞口12万吨/年CO<sub>2</sub>捕集装置

120,000t/a PCC plant in Shanghai

- 华能在上海石洞口第二电厂建成12万吨/年烟气CO<sub>2</sub>捕集装置，已于2009年底投入示范运行，当时为世界上最大的燃煤电厂烟气CO<sub>2</sub>捕集装置。

China's largest post-combustion CO<sub>2</sub> capture plant built by Huaneng in 2009 with a capture capacity of 120000tCO<sub>2</sub>/a.

Captured CO<sub>2</sub> is used for food, dry ice industries, and CO<sub>2</sub> storage.



120,000 t/a PCC plant in Huaneng Shanghai Shidongkou NO.2 Power Station



## 执行过程

# Execution Process and Management

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### □ 项目支撑 Support of the Demo.

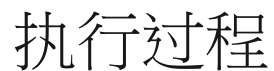
- 示范项目得到中国华能集团公司科技项目和上海市科技项目的支持。

The demonstration project got financial support by china huaneng group and shanghai government.

### □ 多家单位联合工作、广泛参与，共同开展12万吨/年CO<sub>2</sub>捕集示范项目

Six companies participated in the demo project.

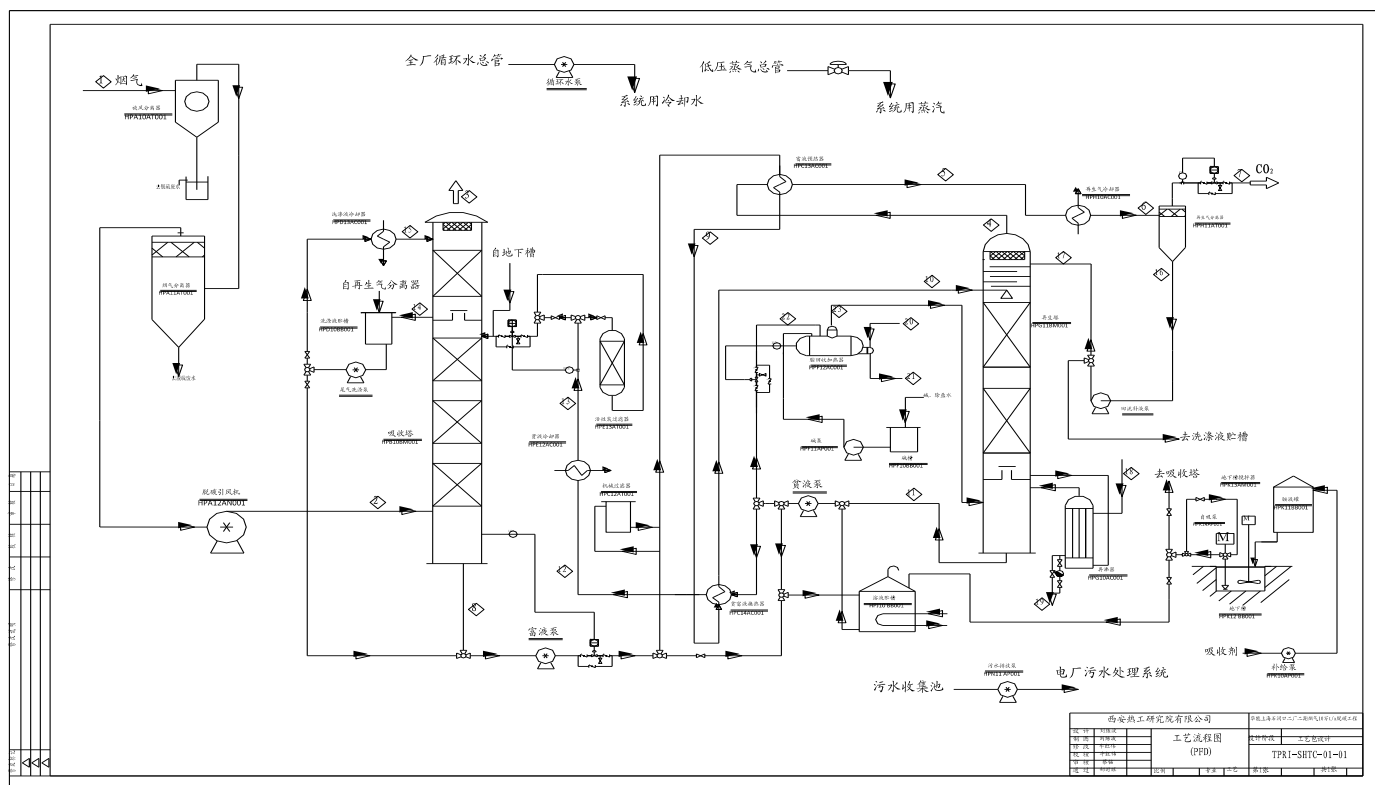
- 中国华能集团公司 China Huaneng Group
- 华能国际电力股份有限公司 Huaneng Power International Inc.
- 西安热工研究院有限公司 Xi'an Thermal Power Research Institute
- 华能上海石洞口第二电厂 Huaneng Shanghai Shidongkou No.2 Power Station
- 中国华能集团清洁能源技术研究院有限公司 Huaneng Clean Energy Research Institute
- 中国电力工程顾问集团华东电力设计院 East China Electric Power Design Institute



## Execution Process and Management

- 严格按国家相关标准进行设计，包括：工艺流程、管道流程及操作条件；物料平衡及消耗；设备规格；操作及化验程序及方法……

PID, operation conditions, mass balance, materials consumption, equipment, analysis methods ...







## 执行过程

# Execution Process and Management

### □ 装置建造 Construction

- 项目工期: 2008.12~2009.12

Project Period: 2008.12~2009.12

- 与电厂紧密配合，控制施工标准、严把质量关、推动建造进度

Work tightly with power station. Control construction standard, quality and progress.





# 执行过程

## Execution Process and Management

### □ 制度管理 Management

- 编制开停车规则、操作指南、运行记录、人员轮转等规章制度
- 根据运行规律指导不同季节运行，编制操作卡片 Operation regulatory differs by seasons.

半工况运行关键参数指导操作卡

序号	参数名称	单位	数值	操作及说明
1	烟气流量	Nm <sup>3</sup> /h	35000	调节引风机入口挡板开度
2	循环流量	t/h	200	目标值在贫液流量调节器中设定
3	蒸汽流量	t/h	17	根据再生塔底温度自动调节
4	入吸收塔贫液温度	℃	≤42	调节贫液冷却器循环水入口手动阀门开度
5	入吸收塔洗涤液温度	℃	≤42	调节洗涤液冷却器循环水入口手动阀门开度
6	出口再生气温度	℃	≤40	调节再生气冷却器循环水入口手动阀门开度
7	吸收塔顶 CO <sub>2</sub> 浓度	%	<1	捕集率大于 90%
8	再生塔底温度	℃	110 ~ 114	
9	再生塔顶温度	℃	≤98	
10	再生塔液位	m	1.3	低于 0.8m，须通过地下槽向系统内补液

注：(1) 半工况指精制一台压缩机运行，一级循环回路关闭，捕集区 CO<sub>2</sub> 产量维持在 3800 Nm<sup>3</sup>/h；

(2) 以上数值基于入口 CO<sub>2</sub> 浓度为 12%，循环溶液总胺浓度 16%~20%；

(3) 不同季节工况唯一不同之处在于，各冷却器的循环水入口手动阀门开度不同，须就地手动调节以满足对应关键参数运行值的要求。

冬季半工况运行关键参数指导操作卡

序号	参数名称	单位	数值	操作及说明
1	烟气流量	Nm <sup>3</sup> /h	35000	调节引风机入口挡板开度
2	循环流量	t/h	200	目标值在贫液流量调节器中设定
3	蒸汽流量	t/h	17	根据再生塔底温度自动调节
4	贫液冷却器循环水入口阀门开度	度	15	一台循环水泵运行，就地根据循环冷却水温调节
5	入吸收塔贫液温度	℃	≤42	
6	洗涤液冷却器循环水入口阀门开度	度	20	一台循环水泵运行，就地根据循环冷却水温调节
7	入吸收塔洗涤液温度	℃	≤42	
8	再生气冷却器循环水入口阀门开度	度	25	一台循环水泵运行，就地根据循环冷却水温调节
9	出口再生气温度	℃	≤40	
10	吸收塔顶 CO <sub>2</sub> 浓度	%	<1	捕集率大于 90%
11	再生塔底温度	℃	110 ~ 114	
12	再生塔顶温度	℃	≤98	
13	再生塔液位	m	1.3	低于 0.8m，须通过地下槽向系统内补液

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(2) 以上数值基于入口 CO<sub>2</sub> 浓度为 12%，循环溶液总胺浓度 16%~20%。

夏季半工况运行关键参数指导操作卡

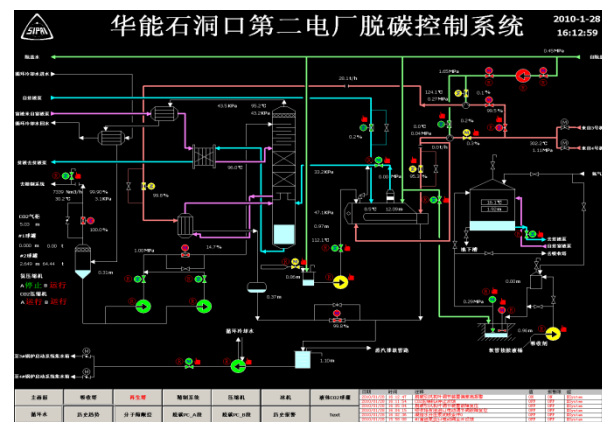
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4	贫液冷却器循环水入口阀门开度	度	25	两台循环水泵运行，就地根据循环冷却水温调节
5	入吸收塔贫液温度	℃	≤42	
6	洗涤液冷却器循环水入口阀门开度	度	30	两台循环水泵运行，就地根据循环冷却水温调节
7	入吸收塔洗涤液温度	℃	≤42	
8	再生气冷却器循环水入口阀门开度	度	30	两台循环水泵运行，就地根据循环冷却水温调节
9	出口再生气温度	℃	≤40	
10	吸收塔顶 CO <sub>2</sub> 浓度	%	<1	捕集率大于 90%
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(2) 以上数值基于入口 CO<sub>2</sub> 浓度为 12%，循环溶液总胺浓度 16%~20%。



Monitor the operational data online, and open to public.





# 运行监测 Operation & Monitoring

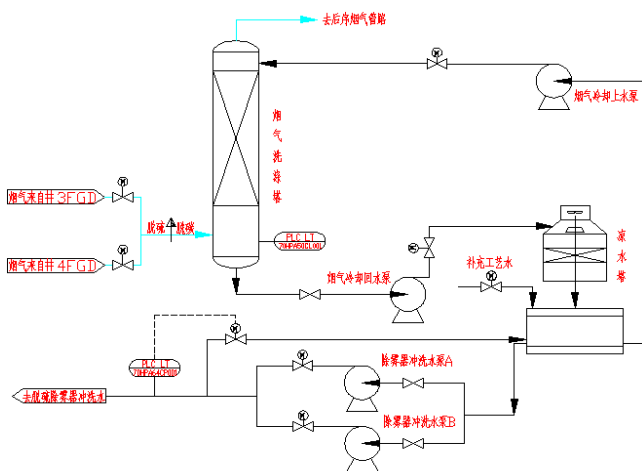
## □ 推动装置性能改造 Equipment & Performance Upgrade

- 后续不断提升技术水平，对示范装置性能进行性能优化和改造升级，如烟气预处理系统改造、吸收溶剂升级换代等

Improve technology level, upgrade the performance of demo project, like pre-treatment system modification of flue gas, using novel solvent.

- 将该示范项目打造成技术开发和验证平台

Also work as a technology development and verification platform.





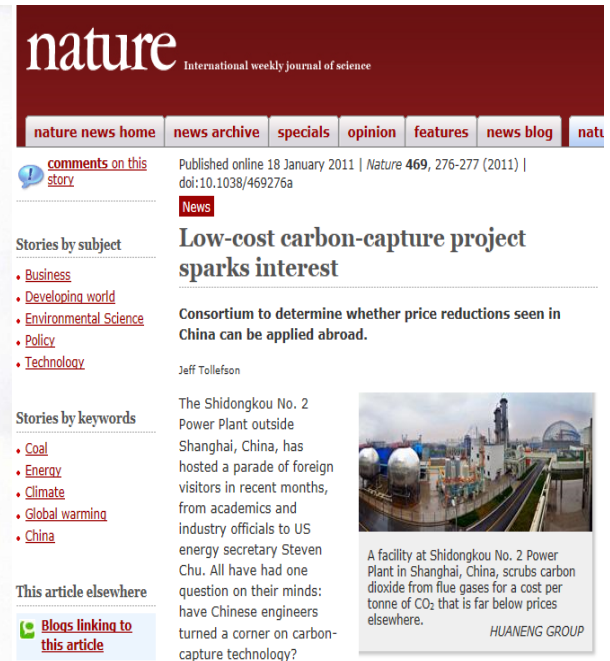


# 社会影响 Social Impact

## 国内外媒体广泛关注

- 作为当时世界上最大的CO<sub>2</sub>捕集装置，该示范项目得到国内外媒体的广泛关注和报道，社会影响巨大。

The demo project received widespread attention and media coverage.





## 示范工程的经验

## Experience of Demonstration Project

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- 碳减排形势的迫切要求和国家政策的大力支持，企业的社会责任感和勇于探索的创新精神，是华能集团进行CO<sub>2</sub>捕集工程示范的强大动力。

Urgent carbon emission reduction situation, government policy support, enterprises social responsibility and spirit of innovation are the high motivation of CHNG to demonstrate CO<sub>2</sub> capture projects.

- 2007年9月，中澳联合声明“中澳洁净煤工作组”第一个项目，由中国华能集团公司联合澳大利亚联邦科学与工业组织(CSIRIO)在北京华能热电厂建设3000t/a 燃煤电厂燃烧后捕集项目。

In September 2007, China and Australia governments announced the first joint project of “China-Australia Clean Coal Working Group”: China’s first CO<sub>2</sub> capturing facility with capacity of 3000 t/a in Huaneng Beijing thermal power station.

This project was jointly performed by CHNG and CSIRO.



## 示范工程的经验

## Experience of Demonstration Project

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- 华能集团成立了示范工程领导小组，集团领导的协调，推进了中国首个燃煤电厂CO<sub>2</sub>捕集示范装置的建设。后续示范项目得到了电厂的大力支持。

China Huaneng Group established a leading group of demo project to coordinate and promote the construction of China's first CO<sub>2</sub> capture facility in coal-fired power plant.

Follow-up demonstration projects got strong support by huaneng beijing thermal power station.

- 科技部、发改委、华能集团、北京市和上海市的经费支持，保证了示范项目的持续运行和改进。

Sufficient financial support, which are from Ministry of Science and technology, National Development and Reform Commission, Huaneng Group, Beijing and Shanghai, ensure the continued operation of demonstration projects and performance improvements.

- 华能上海和华能长春示范项目，分别得到了当地政府电厂上网小时数提高的奖励。

The local government allows huaneng's relevant power plants to increase their power generation time because of the CO<sub>2</sub> demo projects in Shanghai and Changchun





## 示范工程的经验

## Experience of Demonstration Project

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- 好的组织形式和任务分工，在示范工程的建设和后续运行中至关重要。

Advanced organization form and task arrangement are essential in the construction of demonstration projects and subsequent runs.

- 研究院CO<sub>2</sub>捕集团队技术总负责，电力设计参加初步设计并负责施工设计，电厂负责基建和后期运行。各单位优势互补。

Research institute manages working group and directs CO<sub>2</sub> capture technology; Electric power design institute is responsible for construction design; Power station is responsible for construction and subsequent run.

- 1000t/a的中试装置由研究院投资，并直接运行，电厂仅提供公用工程。3000t/a和120kt/a的工业示范装置，由电厂投资和运行，研究院提供技术支持，避免了示范工程随科研项目结束而停止运行的命运。

Research Institute directly invest and run 1000t/a pilot plant, power plant only provide steam, water and electricity.

Power plants are responsible for the investments and operation of 3000t/a and 120kt/a demo facilities with technique support by research institute.

This cooperation model can avoid the stop of demo project with the finish of research project.



## 示范工程的经验

## Experience of Demonstration Project

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- 电厂运行CO<sub>2</sub>捕集装置，减轻了CO<sub>2</sub>捕集团队的工作。为了减少能耗，促使电厂和研究院密切合作，持续运行和改进示范装置，积累了丰富的工程经验。

Operation of CO<sub>2</sub> capture facility by power station can reduce workload of CO<sub>2</sub> capture team.

To reduce energy consumption cost, power plants is willing to cooperate closely with research institutes, run the facility continuously, improve its performance by the application of new technique and accumulate rich experience in engineering.

- CO<sub>2</sub>的销售，和上网小时数的提高，弥补了示范装置运行的部分费用。也是示范工程能长期运行的关键。

CO<sub>2</sub> sales and power generation time increasing can make up part of operation cost of demo facility, which are important for long-term operation.



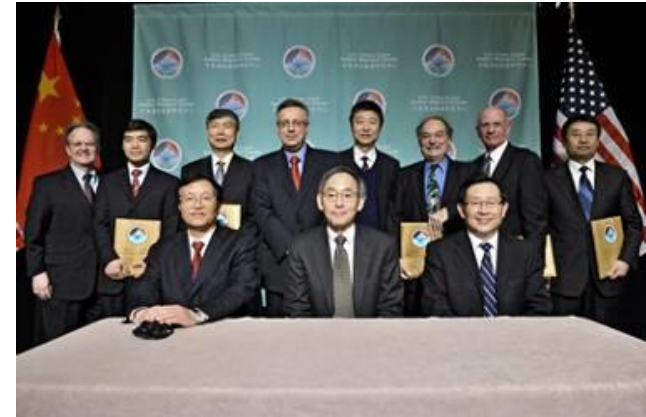
## 示范工程的经验

## Experience of Demonstration Project

- 国际合作交流，扩大了影响，促进了政府和国际资金的支持，与国际上的许多单位建立了合作关系。

International cooperation expand the influence of CERI, and promote the financial support by government and international funds.

- In Nov. 2009, President Barack Obama and President Hu Jintao announced the establishment of the Clean Energy Research Center (CERC).
- The primary purpose of the CERC is to facilitate joint research, development, and commercialization of clean energy technologies between the U.S. and China.
- CERI is key member of ACTC Advanced Coal Technology Consortium, Dr. Xu Shisen is the co-chair of CERC-ACTC.





## 示范工程的经验

# Experience of Demonstration Project

### — CERI-SaskPower

- ✓ 1,000,000t/a CO<sub>2</sub> capture technology assessment and feasibility study.
- ✓ Engineering stage technical review of BD3 unit large-scale demonstration project .

### — CERI-PowerSpan

- ✓ Technical cooperation in the project assessment and project bidding.

### — CERI-CSIRO

- ✓ Cooperation in 100kg/hCO<sub>2</sub> capture mobile platform design and test;
- ✓ large-scale CCUS research and feasibility studies.

### — CERI-WorleyParsons

- ✓ The Australia-China PCC Feasibility Study





## 示范工程的不足之处

## Shotage of Demonstration Project

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- 发挥媒体的宣传效应，通过科普等形式向社会宣传示范项目，提升公众认知、参与度和支持度。

Public propaganda on the demo project is very important to enhance public awareness, participation and support of carbon capture project.

- 在示范工程的建设中，与公众的沟通缺乏。

lack of communication with the public during the construction of demonstration projects.

- 由于市场原因，油田目前进行EOR的CO<sub>2</sub>主要来自化工厂，电力和石油行业尽管组建了CCUS联盟，还未实现CCS的完整链条示范。

Due to market conditions, CO<sub>2</sub> used for EOR now is mainly from chemical engineering industries.

The formation of CCUS alliance between power and oil industry has not implemented a complete chain of CCS demonstration



Thank you for your attention



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