中英（广东）CCUS 中心
UK–China (Guangdong) CCUS Centre

China Resources Power
Haifeng Carbon Capture Test Platform (HCCT)

Muxin Liu

UK-China (Guangdong) CCUS Centre

University of Edinburgh Business School

China Resources Power South China Region

China Energy Engineering Corporation
Guangdong Electric Power Design Institute Co., Ltd.

UK-China (Guangdong) CCUS Centre

Project Overview

Background

On September 27th, 2013, a MOU was signed under the witness of Xiaodan Zhu, governor of Guangdong province, and Gregory Baker, director of UK Department for Energy and Climate Change.

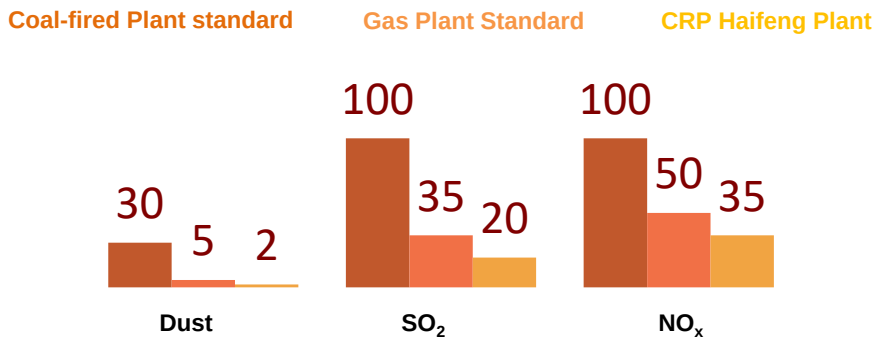
Guangdong Electric Power Design Institute Co. Ltd of China Energy Engineering Group (GEDI), Clean Fossil Energy Corporation, UK CCS Research Centre (UKCCSC) and Scottish CCS Centre (SCCS) jointly conducted research on carbon capture, utilisation and storage. On December 2013, UK-China (Guangdong) CCUS Centre was lauched.

Under the guidance and support of GDDRC, GEDI, The University of Edinburgh and CRP cosigned a cooperation agreement on the prefeasibility study of China Resources Power Haifeng Power Plant CCUS ready and CCUS demonstration project.

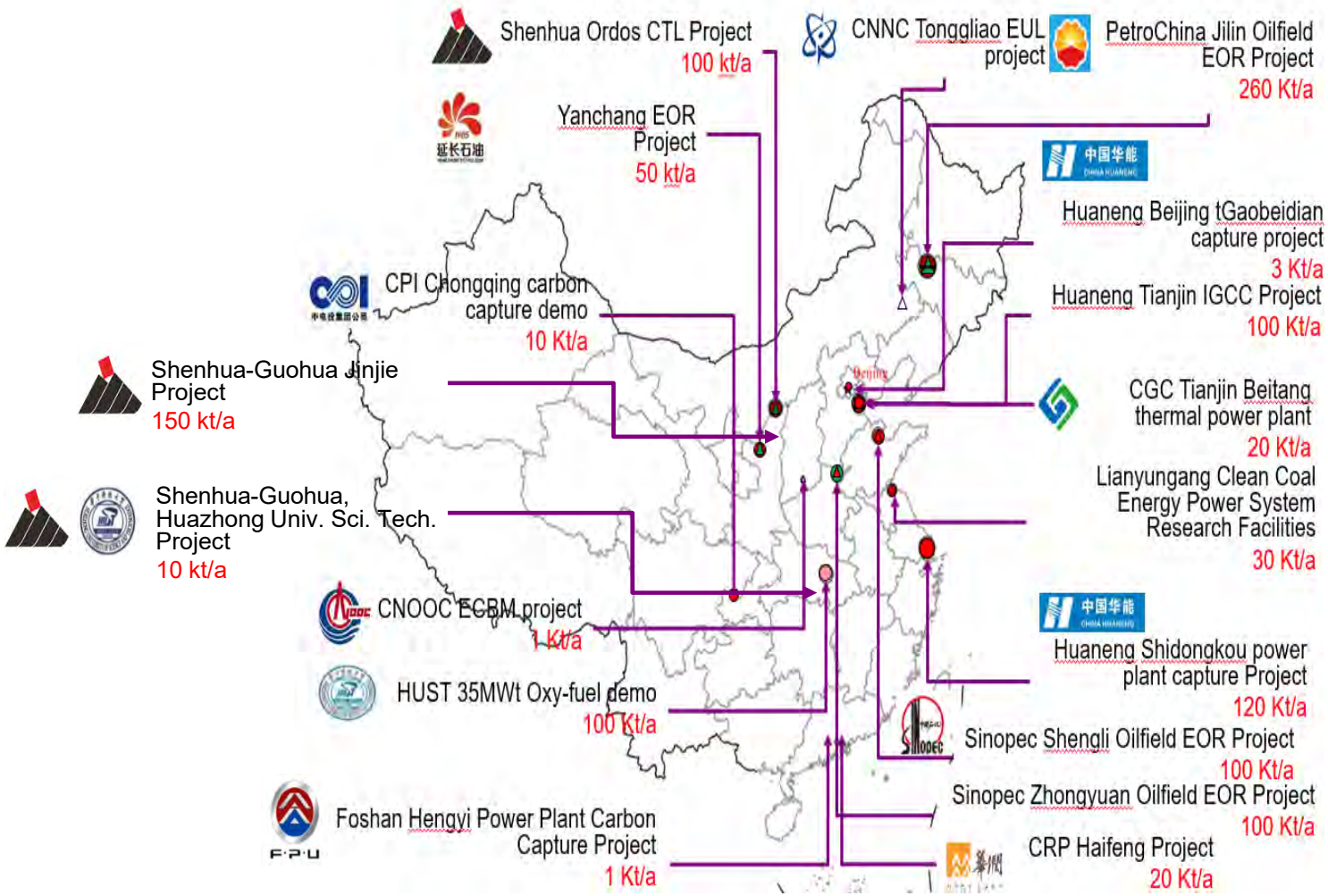
Haifeng Power Plant:

- **Units 1 &2, 2x1050MW** ultra-supercritical coal-fired power units officially began operation in 2015.
- The first million-ton Near Zero Emission Power Plant in Guangdong Province

Comparison of Power Plant Emissions



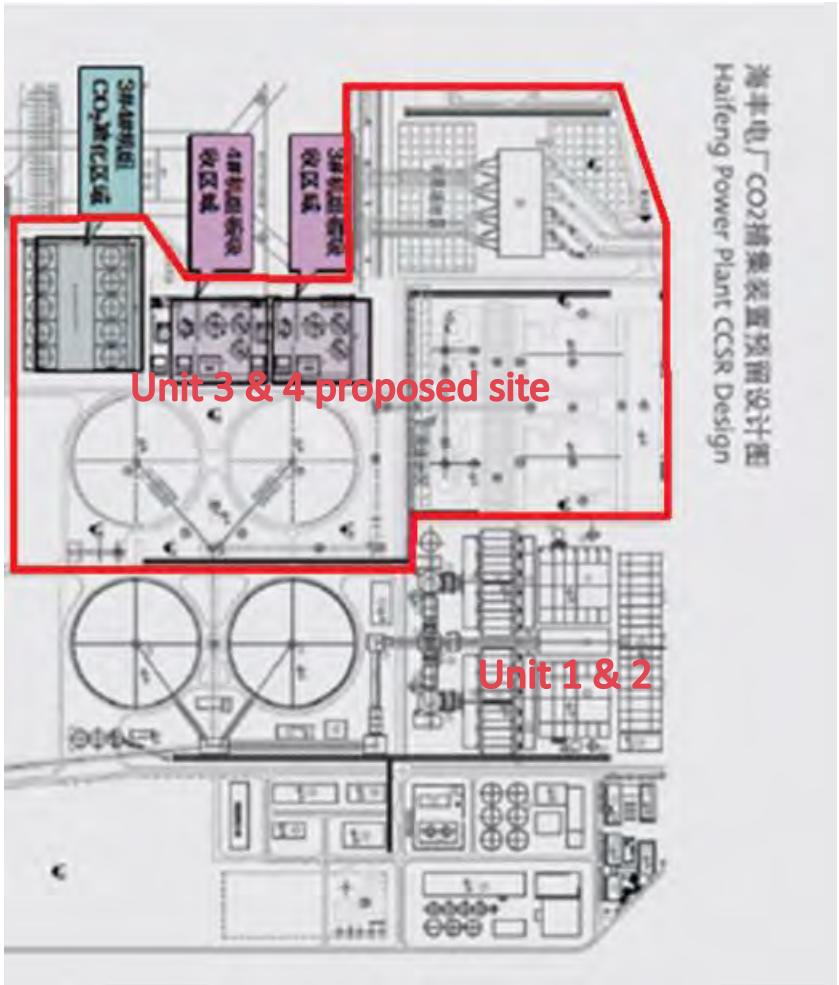
Overview of CCUS Industry Projects in China (scale > 1ktpa)



Source: *UK-China (Guangdong) CCUS Centre*, *Institute of Rock and Soil Mechanics , Chinese Academy of Sciences*，*2017*

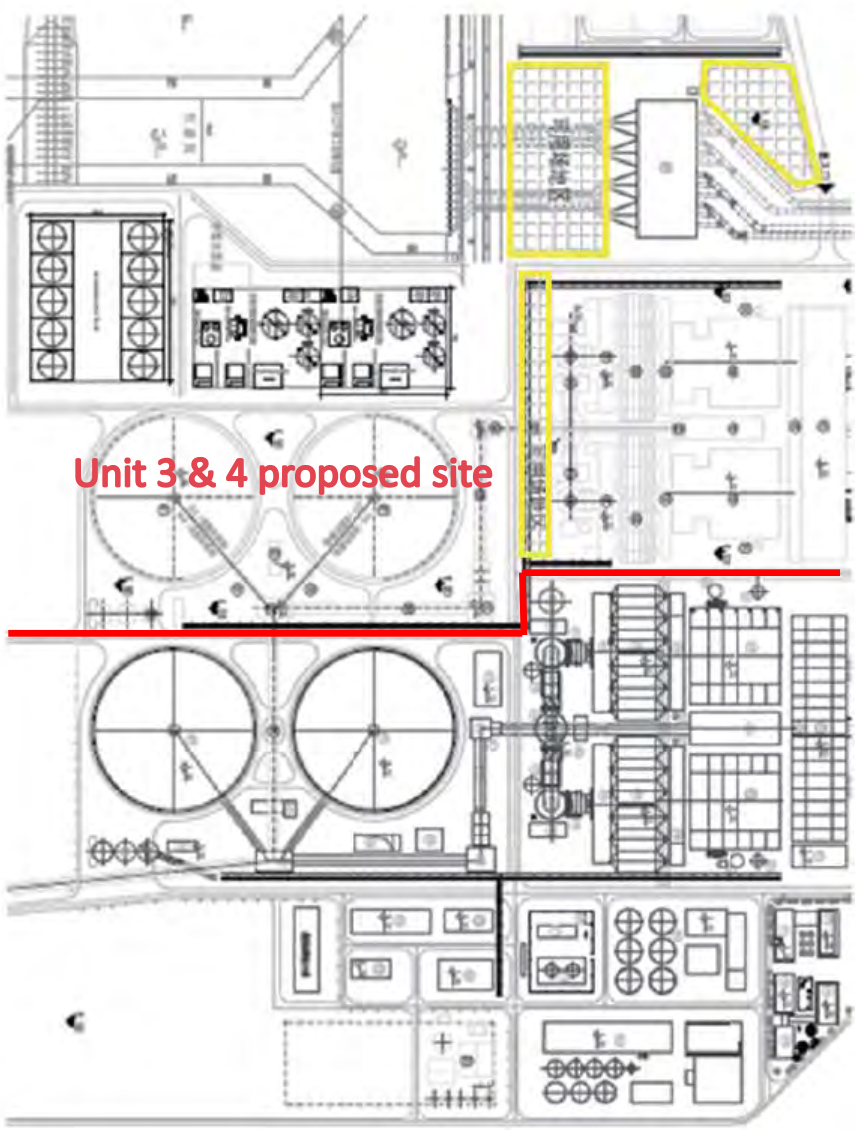
Project Overview

Demonstration Project Compatible with Multiple Carbon Capture Technologies



- CRP Haifeng Carbon Capture Test Platform (HCCT) is the Phase I of CCUS Demo Project, based on the unit 1 and unit 2.
- In Phase II, a large-scale CCUS demonstration project will be designed and constructed based on unit 3 and unit 4 of the plant, with capability of 1 million tons captured per annum.

Unit 3 & 4 CCS Readiness



The condensing type turbine design for CRP Haifeng Units 3 and 4 is characterized byfour cylinders and four exhausts, single shaft, and single reheat.

- Rated power: 1000MW
- Rotating speed: 3000 r/min
- Guaranteed heat rate: 7416 kJ/kW.h(tentative)

CCS Readiness parameters:

- Carbon capture technology : **30% MEA solution**
- The total area of one single set of CO2 capture equipment is 7000 m2**,** two units need 14000 m2. The pressurization areas need 12000 m2. The total reserved space is **26000 m2**.
- For a single boiler/turbine unit with the capacity of 1000MW, the boiler maximum continuous rating (BMCR) flue gas volume is 3,252,839Nm3 / h (dry).
- CO2 concentration is **13.3%** with **826.6t/h** of CO2 entering the capture system.
- The designed capture rate is designed at **90%**, and the total amount of CO2captured will be **743.9t/h** for the design coal.
- The CCS system is designed to be utilised **5500h** annually,

Steam extraction:

- CRP plants retrofitted with post combustion based capture systems will extract up to **50% of the steam** from the IP/LP (intermediate pressure/low pressure) cross-over pipe for **amine solvent regeneration.** As the steam supply flow from the IP/LP crossover pipe will be reduced when the load is low, during the turbine selection stage the **available steam supply and the requirements of carbon capture system** should be considered in detail to meet the steam requirement at varying loads.

Electricity Supplies

The carbon capture system will require a significant expansion of the auxiliary power system of the CRP Haifeng Power Station Units 3 and 4. The expansion project needs to consider the following factors:

- Adding and making space for 10kV and 380V auxiliary transformers
- Adding a DC power system to provide control and protection power for the new auxiliary transformers and switchgear. Also adding an AC UPS system for a CO2 Capture-Ready control system.
- Adding control and protection and power switch equipment for the new auxiliary transformers and switchgear.

Cooling water system

Units 3 and 4 of Haifeng power plant will be equipped with a once through **sea water cooling system**. The cooling water is taken from the harbour basin to the west of the plant, and discharged after heat exchange to the sea area to the northeast of the plant. **Temperature change is between 5℃ to 8 ℃ depending on season.**

- Provisions in the water steam cycle enabling bypass of the required number of condensate feed water heaters.

Capital cost estimation

It is estimated that there would be **a 27% increase** in the capital cost in CRP Haifeng Units 3 and 4 if CCS is retrofitted, including the cost of the CCS plant and modifications to the existing system.

ITEM	UNIT	Conventional PF power plants	Capture- adopt PF power plants (extract almost 50% steam)
Static Capital Cost	Yuan	Basic standard	+27%
Unit Cost	Yuan/kW	3689	4658

Operating cost estimation

According to the engineer's input and relevant research, the operating costs of carbon capture for CRP Haifeng Unit 3 and 4 is approximately **275 Yuan/tCO2 (31 £/tCO2)**, which includes manpower, management and maintenance costs, house power and chemicals consumption, and water processing fees, etc.

Opportunity cost estimation

The opportunity cost of CCS plant refers **to the lost sales revenue of the electricity**, which could otherwise be produced using **the steam consumed by the CCS plant**. Assuming 50% steam consumption from the LP, the output of Haifeng Units 3 and 4 would slide from 2000MW to 1559.2MW. Though partially offset by the increased working hours, lost electricity sales would still amount to **894.87 million Yuan (100 million £)** annually. Thus, the opportunity cost of CO2 capture is estimated at **95.67 Yuan/tCO2 (10.7£/tCO2)**.

Project Overview

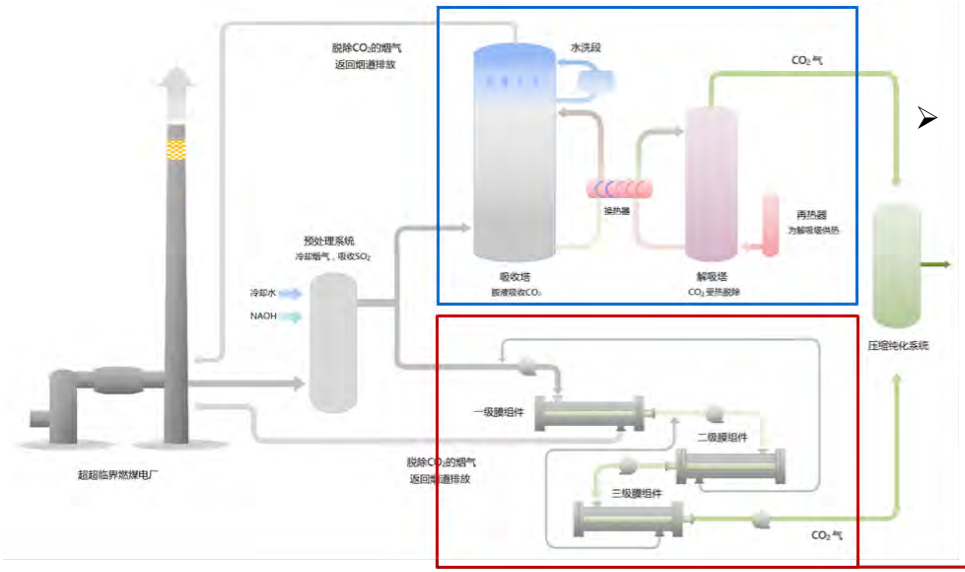
Demonstration Project Compatible with Multiple Carbon Capture Technologies

•HCCT project aims to test multi carbon capture technologies in **parallel using real flue gas from the power plant**, and to **provide an open access facility for piloting, scale-up and verification and optimization of different CO_2 capture technologies**.

•The preliminary technology screening of HCCT started from 2014 and 5 out of 14 technologies were shortlisted into the technical test pool, including physical adsorption, chemical absorption and membrane separation process. At the second round of screening, **amine-based absorption** and **membrane separation technologies** are finally selected as first batch to be tested.

•CO2 capture capability of: **20,000 t/a.**

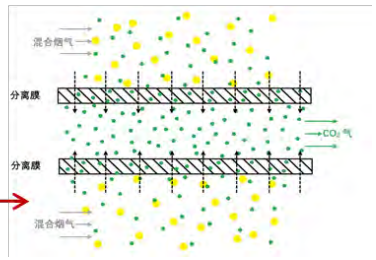
•Total investment: **£ 11.3 million**



➢ The main purpose of HCCT project is not to maximize profits as a commercial goal, but to **carry out carbon capture testing and demonstration work**, seek the **best scheme to reduce the cost and technical risk** of carbon capture projects, and promote the commercialization process of CCS.

➢ Provide data and project experience for CCUS commercialization and CCUS industry standards.

• Produce liquid CO_2 in **food grade** or **industrial grade**



• The project is the largest membrane CO_2 capture device in China and **the first three-stage membrane separation** carbon capture technology in the world.

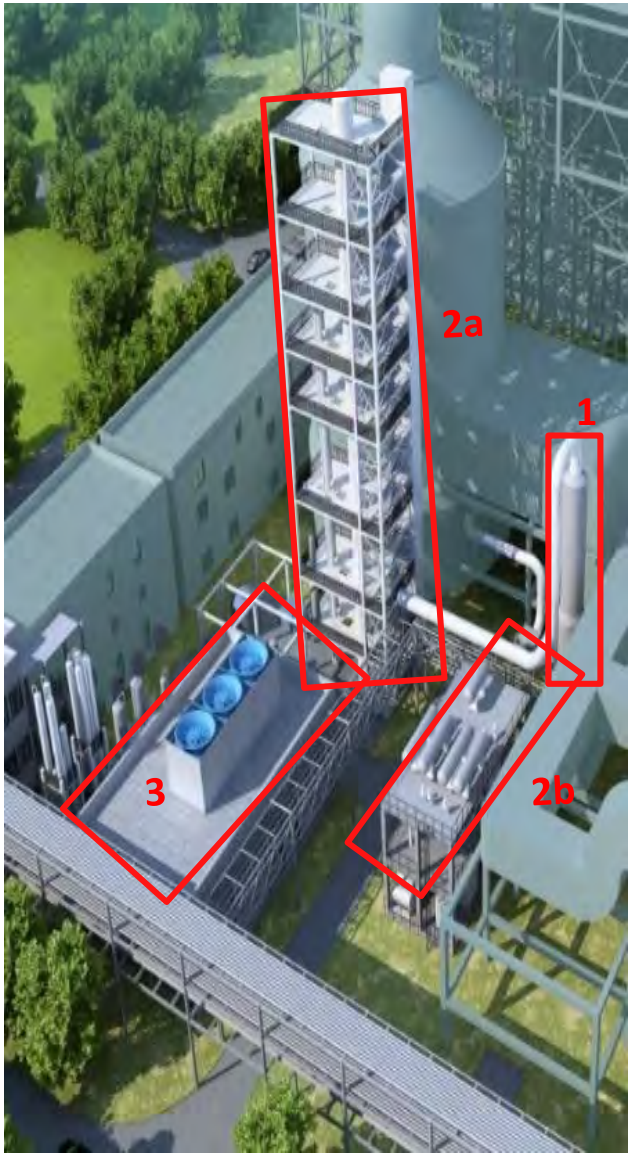
Project Overview

Demonstration Project Compatible with Multiple Carbon Capture Technologies

- The HCCT **reserves the test interface and space** for other innovative carbon capture technologies, e.g. physical adsorption CO_2 capture technology

3. Compression Purification Unit

After further compression, cooling, dehydration and removal of impurities, liquefied commercial CO_2 is stored in the corresponding industrial-grade or food-grade CO_2 storage tank according to its purity.



- **Building area (m2)**
  Pretreament: 74.4
  Membrane: 105
  Amine: 228
  Compression: 426
  Control room: 134
  Tank: 315
  Exhibition: 384
  Total: 1,666.4
- **Reserved space: 400 m2**

1. Pre-treatment Unit

Flow gas volume:

20,000 Nm3/h

(amine-10,000; mambrane-5,000 reserved 5,000.)

CO2: **12.4%**

2. Carbon Capture Unit

a) Amine-based capture device: obtain **98 %** CO2

b) Membrane capture device: obtain **95%** CO_2

HCCT Project Milestones

- **2013.12** Signed cooperation agreements with the University of Edinburgh and Guangdong Electric Power Design Institute (GEDI) for CCUS demonstration project research.
- **2016.08** UK-China (Guangdong) CCUS Centre completed Feasibility Study, commissioned by China Resources Power (CRP).
- **2017.03** The China Resources Power Holdings completed the investment decision.
- **2017.09** CCUS Centre and GEDI signed the EPC contract for the CRP HCCT project
- **2017.12.08** The project was listed as Guangdong CCUS Demonstration Project by Guangdong DRC
- **2018.01.15** Construction of the demonstration project
- **2018.12.23** Membrane capture unit started commissioning and produced the first ton of CO_2
- **2019.03.30** Amine-based capture unit started commissioning.
- **2019.05.15** **Overall project completion and put into operation.**

Jan 2018, Project start-up


Sep 2018, absorber and stripper installation


Nov 2018, membrane device installation


Nov 2018, steel structure of the amine device 90% completed; compression and purification device installed


Dec 2018, membrane device test run

Exhibition hall


CCUS laboratory.

HCCT Project Milestones