厦門大學能源学院
College of Energy—Xiamen University

# 2019 International Clean Energy Science & Technology Summer School and World Forum on New Energy Science & Technology Worldwide Energy Universities Network

世界能源大学联盟

Authors: **Dr Mark S. D. Read**
*University of Birmingham*
*Director of the Sino-British Cooperative Programme*

**Prof. Jun Yao** (姚军)
*China University of Petroleum - Beijing*
*Deputy Secretary General, WEUN Secretariat*

**Summary Report**

**July 2019**

Organiser: Office of International Cooperation and Exchange
College of Mechanical and Transportation Engineering
College of Safety and Ocean Engineering

# Contents

# 1 Executive Summary

Hosted jointly between Xiamen University (XMU) and China University of Petroleum - Beijing (CUPB), the 2019 International Clean Energy Science & Technology Summer School was held successfully from $9^{th}$ to $29^{th}$ June 2019; providing excellent opportunities for students from the U.K. (Universities of Birmingham (UoB) and Leeds (UoL)), U.S. (University of Michigan (UOM)) and other Worldwide Energy Universities Network (WEUN) members (Canada, Denmark, Norway and Russia) to learn both the underpinning fundamental theory of, and current research activities in, the important topical area of Clean Energy. Students also visited nuclear facilities under various stages of construction to see the practical application of this technology (activities that the U.K. and U.S. have not witnessed for over 20 years!) thus providing the unique experience of a "living textbook" for nuclear reactors. The locations provide excellent opportunities for students to witness the growth and pace of energy development in China in addition to learning and appreciating the associated culture, especially those students for whom this is the first visit to China. All participants were immensely impressed by the latest developments in new and clean energy in China and noted the determination, effort and achievements made by the Chinese government to decrease the country's carbon emissions whilst providing for increasing energy demands.

The programme also remained extremely beneficial in promoting exchanges and learning between Chinese students (XMU and CUPB) and U.K./U.S. students. Participants broadened their horizons and learnt about cultures other than their own. This programme also promotes the international exchange of students and academic collaborations between universities, including the "2+2" undergraduate training program of XMU and UoB as well as the "111 project" of CUPB jointly held with UoB and UoL.

# 2 Introduction

## 2.1 Background to the Summer School

For the sustainable, safe and efficient development of nuclear power, it is essential to develop solutions for the management of nuclear waste and subsequent disposition in conjunction with a comprehensive nuclear fuel cycle. As the leading countries continue to develop and deploy nuclear energy, China, the U.K. *et al.* have become aware of increasingly similar interests and requirements in this subject. This led Xiamen University to host an International Symposium in 2013 (supported by the British Consulate-General in Guangzhou, China National Nuclear and Radiation Safety Center and the China Nuclear Energy Association) on "Nuclear Energy and the Fuel Cycle" and invited prominent government officials, academics and industrial experts from the U.K., U.S., Sweden, Japan and China to report on their policies and technologies relating to nuclear energy and the fuel cycle, with particular focus on nuclear wastes. As an invited guest and speaker, this symposium provided the opportunity to forge the initial research links in the area of civil nuclear technology between Xiamen University and the University of Birmingham.

Previously, in collaboration with the University of Michigan, an International Summer School has been hosted successfully by The College of Energy (formerly the "School of Energy Research" prior to 2013) at Xiamen University since 2004. Following the above International

Symposium Prof. Jun Yao invited the Universities of Birmingham and Leeds to join the International Summer School programme to further strengthen the collaborative links formed in 2013. In 2018 the scope of the programme was widened with the second half of the Summer School being hosted by the China University of Petroleum - Beijing, providing additional nuclear facilities for field trips and other energy topics. To date, over 250 international students have attended this programme, producing fruitful international collaboration between Universities and promoting positively the related network.

## 2.2 Aims and objectives

In 1988 construction started on the last Nuclear Power Plant (NPP) to be built in the U.K., Sizewell B, a Pressurised Water Reactor (PWR), started generating and supplying 1198 MW to the national grid in 1995. The last two NPPs to be built in the U.S. were the Watts Bar plant (constructed between 1973 and 1990) becoming operational in 1996 and the River Bend plant, built in 1977 and going online in 1986. Hence, in both countries, there has been no nuclear build for over 20 years which means that the majority of current faculty staff members lecturing on the topic of nuclear energy and the fuel cycle have not witnessed or seen the construction of a NPP! This Summer School provides the unique opportunity to visit sites such as the Fuqing Nuclear Power Plant (福清核电站) in Fuqing, Fujian Province, China. The station currently has four 1089 MW CPR-1000 PWRs which are an advanced PWR design developed by China from the Areva-designed PWRs at the Daya Bay Nuclear Power Plant (visited in previous years). The plant was jointly constructed and is operated by China National Nuclear Corporation (51%), China Huadian Corp. (39%) and the Fujian Investment & Development Co Ltd. (10%).

Construction of the first unit in Fuqing began on 21 November 2008 and was completed in 2014. First concrete for Unit 2 was poured on 17 June 2009 and the unit started in October 2015. Unit 3 began construction on 31 December 2010 and Unit 4 was planned to begin in 2011, but was delayed until November 2012 by China's nuclear safety review after the Japanese nuclear accident at the Fukashime Daichi NPP. Unit 3 was completed in Phase II on 24 October 2016. In November 2014 it was announced that units 5 and 6 would be of the Hualong One (updated CPR-1000) design, with unit 5 scheduled to be in operation about 2019. The first concrete was poured for Fuqing 5 on 7 May 2015. This timeline aligns conveniently with that of the Summer School and thus provides faculty staff and students with the unique opportunity to see different stages of NPP construction in one location.

The aims of the Summer School are threefold: Firstly, to provide an understanding of the associated theory and technical requirements of 'clean energy production' in conjunction with relevant historical influences through formal lectures and workshops. Secondly, to appreciate the practical application and realisation of this theory *via* field trips to relevant nuclear and energy related sites. Thirdly, to learn and experience the rich and diverse culture of the hosting country China and for students to have the opportunity to receive formal lessons on these topics.

# 3 Lectures

## 3.1 Technical Energy Topics

The Summer School schedule comprises three sections. As in previous years, the first section is arranged for UoM students as part of an accredited module. From $13^{th}$ May to $9^{th}$ June UoM students attended lectures including Physical Electronics (taught by School of Physics and Electrical Engineering, XMU) and Chinese culture. The second section ran from $10^{th}$ to $20^{th}$ June for UoB, UoL and UoM students where the programme includes lectures covering “Clean Energy Science and Engineering - I” (CESE) arranged and hosted by the College of Energy at XMU. On $20^{th}$ June, the U.K. students transferred to Beijing, the second hosting institution, CUPB. Here, students attended the Worldwide Energy Universities Network World Forum on New Energy Science and Technology Conference. In addition to attending conference presentations, the students subsequently participated in the second half of the Summer School, “Clean Energy Science and Engineering - II” hosted by the International Department of CUPB (CUPB-ID).

CESE is designed for students from a variety of science and engineering disciplines and covers the majority of aspects of clean energy science and engineering, including nuclear, solar, bioenergy, chemistry energy and energy efficiency. The lectures are delivered by faculty members from the College of Energy at XMU and U.K. and U.S. academics attending the summer school. Previously employed by National Nuclear Laboratories, two of the Western academics (Prof. Ron Fleming and Dr Mark Read) have direct experience of the nuclear industry, which greatly informs their technical lectures and provides an authoritative source of knowledge during the nuclear site visits, in addition to impromptu extra-curricula discussions.

## 3.2 Chinese Culture

This programme includes a series of lectures covering Chinese culture, arranged for the international students. The subject was taught by Shaolian Liao (廖少廉), an academic from XMU who has a wealth of experience in teaching Chinese language and culture to foreign students. To improve the effectiveness of these Chinese lectures and reinforce key points, Shaolian Liao augmented topics with visits to associated places, for example, local religion culture at the Southern Putuo Temple neighbouring XMU and important tea culture at a restaurant where students were invited to drink local Oolong tea and learn the associated preparation, serving and ceremony. In addition, local student volunteers from both XMU and CUPB accompanied international students to nearby scenic tourist places, business quarter and leisure areas in their spare time as well as encouraging them to sample and enjoy local culinary delicacies providing a true local experience. Field trips to several culturally important and well known scenic sites were also arranged for all delegates and included Gulangyu, Tulou, Imperial Palace, Great Wall and Mings Tombs as discussed further below. Several evening meals attached with local culture were also prepared for international students so that they were able to fully appreciate the characteristics and charm of Chinese culture and cuisine. Further details of the CESE programme are shown in Tables 4–5 for XMU and CUPB respectively.

# 4 World Forum on New Energy Science and Technology

Following on from the 111 Opening Ceremony and establishment of the WEUN during the Signing Ceremony last September, described in further detail in Section 8.3, CUPB hosted the "2019 World Forum on New Energy Science and Technology". The forum was officially opened by Prof. Li Gensheng, Vice President of CUPB with distinguished guests including:

- Prof. Sun Xudong, Vice Principal of CUPB Karamay campus/WEUN Secretary General
- Prof. Duan Menglan, Dean of College of Safety and Ocean Engineering
- Prof. Liu Weifeng, Dean of College of Information Science and Engineering
- Prof. Yongxue Zhang, Dean of College of International Education
- Prof. Wang Wei Deputy Dean of College of Mechanical and Transportation Engineering

This conference provided an ideal opportunity for WEUN members to network, be appraised of progress from both the WEUN Secretary General (Prof. Sun Xudong) and key academics in the programme, the names of whom and schedule of which is listed in Table 1. Attendance to the conference gave the summer school students excellent experience of an academic meeting in addition to access to further talks on the latest research in a variety of energy topics. This year, the emphasis happened to be focussed on computer modelling, from "Human Machine Interface", through "simulating the corrosion chemistry of energy materials" to the crucial and underpinning role of "Supercomputing architecture and applied application". Fruitful discussions and workshops were held providing excellent opportunities for delegates to network and discuss potential collaboration.

# 5 Prof. Jun Yao - Research Group Seminar

*Extra mural* to the WEUN Forum and Summer School, but under the 111 collaborative agreement, Dr Mark Read was invited to attend and present at Prof. Jun Yao's research group meeting. One of the most relevant talks was given by PhD student Mr Liu Yufa entitled "Experimental Study: Two Phase Flow Erosion Corrosion of X80 Pipeline Steel" in which an overview of the project and summary of the most recent results were detailed. Dr Read delivered a presentation providing an overview of the computational chemistry techniques applicable to simulating corrosion and catalysis on surfaces along with industrial relevant examples (ICI Katalco, AWE *etc.*). Ensuing discussion identified areas of mutual interest and future collaboration to be pursued further and realised with Prof. Jun Yao with whom contact will be maintained *via* our 111 project and WEUN network. The possibility of Sino-British PhD student exchanges to learn new techniques and work collaboratively was also discussed eagerly.

Table 1: WEUN Clean Energy Science & Technology Forum Programme

| | |
|---|---|
| **WEUN Opening Ceremony**<br>(Chaired by: Prof. Li Yongfeng) | |
| 0900 - 0905 | Invited Guests Introduction |
| 0905 - 0910 | Welcome Address by CUPB Vice President (Prof. Li Gensheng) |
| 0910 - 0915 | Speech by the Representative of International Students |
| 0915 - 0920 | Speech by the Representative of International Lecturers<br>(Prof. Morten Lind / Technical University of Denmark) |
| 0920 - 0935 | WEUN Secretariat Working Report by WEUN Secretary General<br>(Prof. Sun Xudong) |
| 0935 - 1000 | Photo and coffee break |
| **Clean Energy Science & Technology Forum**<br>(Chaired by: Prof. Jun Yao) | |
| 1000 - 1025 | Prof. Morten Lind (Technical University of Denmark)<br>“Challenges of Supervision Human Machine Interface” |
| 1025 - 1050 | Prof. Degen Farid Estefen (Federal University of Rio de Janeiro)<br>“Technology Transition from Subsea Production Systems for Oil & Gas to Ocean Renewable Energy” |
| 1050 - 1115 | Dr Mark Read (University of Birmingham)<br>“Advanced Modelling Techniques for Simulating Materials Corrosion” |
| 1115 - 1140 | Prof. Weifeng Liu (China University of Petroleum - Beijing)<br>“Supercomputing and its Applications” |
| 1140 - 1230 | Lunch buffet (First Floor of Cuigong Hotel) |
| 1230 - 1800 | Technical workshops and discussions |
| 1800 - 2000 | Dinner (Cuigong Hotel) |

# 6 Field Trips

## 6.1 Background to China's nuclear incentive

The majority of mainland China's electricity is produced from fossil fuels, predominantly coal (73% in 2015). Two large hydro projects are recent additions: Three Gorges of 18.2 GWe and Yellow River of 15.8 GWe. Wind capacity in 2016 was 9.1% of the total installed generating capacity. Rapid growth in demand has given rise to power shortages, and the reliance on fossil fuels has led to significant air pollution. The economic loss due to pollution is estimated to be 6% of GDP by the World Bank, thus from March 2013 the new leadership has prioritised measures that address this issue.

In August 2013 the State Council reported that China should reduce its carbon emissions by 40-45% by 2020 from 2005 levels, and would aim to boost renewable energy to 15% of its total primary energy consumption by 2020. In 2012 China was the world' s largest source of carbon emission, 2626 MtC (9.64 Gt $CO_2$), and its increment that year comprised about 70% of world total increase. In March 2014 the Premier said that the government was declaring "war on pollution" and would accelerate closing coal-fired power stations.

In November 2014 the Premier announced that China intended about 20% of its primary energy consumption to be from non-fossil fuels by 2030, at which time it intended its peak of $CO_2$ emissions to occur. This 20% target is part of the 13th Five-Year Plan and was reiterated by the president at the Paris climate change conference in December 2015, along with reducing $CO_2$ emissions by 60 to 65% from 2005 levels by 2030. This means that China' s energy growth has entered a 'new normal' phase including environmental protection, and to address this, **vigorous development of nuclear power is required**. By 2030 nuclear capacity will be 120 to 150 GWe, and nuclear will provide 8% to 10% of electricity.

## 6.2 Nuclear Sites

To augment the lectures given in this programme, another important part of the international summer school is to reinforce theory with practical application and thus the visiting of Nuclear facilities in China including a nuclear power plant (NPP, Fuqing NPP), nuclear power research laboratory (Tsinghua High Temperature Gas-Cooled Reactor Experimental Reactor) and a nuclear power institute (Atomic Energy Research Institute).

The growth of nuclear power in China has been characterised by the evolution of several domestic and imported reactor designs. The mainstay of the Chinese reactor programme has been and remains the PWR. There are a number of different Chinese-developed PWR models under construction, with more advanced versions in the design stage.

Mainland China has approximately 45 nuclear power reactors in operation, a further 15 under construction and more about to be built. The government's long-term target for nuclear generated electricity, as outlined in its Energy Development Strategy Action Plan 2014-2020, is for 58 GWe capacity by 2020, with 30 GWe more under construction. The impetus for nuclear power in China is increasingly due to air pollution from coal-fired plants.

China's policy is to have a closed nuclear fuel cycle, thus nuclear fuel reprocessing is now being considered. China has become largely self-sufficient in reactor design and construction, as well as other aspects of the fuel cycle, but is making full use of western technology while adapting and improving it (*e.g.* from the CPR-1000 to the new HPR1000). Relative to the rest of the world, a major strength of China lies within the nuclear supply chain. Interestingly, China's current policy is to 'go global' with exporting nuclear technology including heavy components in the supply chain.

Indeed, China has a determined policy at NDRC level of exporting nuclear technology, based on development of the CAP1400 reactor (an enlarged version of the AP1000 PWR), and subsequently the Hualong One reactor, with Chinese intellectual property rights and backed by full fuel cycle capability. The 'go global' policy is being pursued at a high level politically, utilising China's economic and diplomatic influence. In January 2015 the cabinet announced new incentives and financing for industry exports, particularly nuclear power and railways, on the back of $103 billion outbound trade and investment in 2014. In May 2017 the Belt & Road Initiative (BRI) was formally launched, with much publicity, to boost global connectivity and trade and inviting countries to become partners in the BRI. Projects in Pakistan, Indonesia, eastern Europe and northern Africa were mentioned along with Chinese funding of $75 billion from banks, $20 billion through a new Silk Road Fund, and $12 billion as aid.

CNNC and SPIC/SNPTC are focused on the export potential of the CAP1400, and SNPTC aims at "exploration of the global market" from 2013, particularly in South America and Asia. The Hualong One reactor is also intended for export, with CGN focusing on Europe and CNNC elsewhere, particularly Pakistan and South America.

Within the U.K., following Toshiba's decision last year to withdraw from its nuclear new-build project in the UK and to wind up NuGen, China General Nuclear is ready to ramp-up its plans for a new plant at Bradwell based on its HPR1000 (Hualong One) design in order to keep the **U.K.'s nuclear power programme on track!** Thus, another pertinent and excellent reason for the U.K. students to see the current HPR1000 (Hualong One) in Fuqing undergoing commissioning.

### 6.2.1 Fuqing Nuclear Power Plant (福清核电站)

It is exceptionally rare to see six reactors under three different stages of construction, however, Fuqing provides this unique opportunity and is a "living textbook" for the entire progress of a nuclear power plant from construction through to commissioning. The six reactor types are listed in Table 2 along with the construction and operation start dates respectively.

CPR-1000

The CPR-1000 (improved Chinese PWR) is a Generation II+ PWR, based on the French 900 MW three cooling loop design (M310) imported in the 1990s, improved to have a net power output of 1000 MW (1080 MW gross) and a 60-year design life. Built and operated by the China General Nuclear Power Group (CGNPG), formerly known as China Guangdong Nuclear Power. Progressively more Chinese manufactured components were used in the units; the second unit built had 70% of its equipment manufactured in China, with a 90% Chinese content target for later builds.

Table 2: The Fuqing Nuclear Power Plant comprises 4 operational and 2 reactors under construction.

| Unit | Type | Construction start | Operation start |
|---|---|---|---|
| **Phase I** | | | |
| Fuqing 1 | CPR-1000 | 21 Nov 2008 | 22 Nov 2014 |
| Fuqing 2 | CPR-1000 | 17 June 2009 | 16 Oct 2015 |
| **Phase II** | | | |
| Fuqing 3 | CPR-1000 | 31 Dec 2010 | 24 Oct 2016 |
| Fuqing 4 | CPR-1000 | 17 Nov 2012 | 17 Sep 2017 |
| Fuqing 5 | Hualong One | 7 May 2015 | 2019 |
| Fuqing 6 | Hualong One | 22 Dec 2015 | 2020 |

Hualong One

The Hualong One, or HPR1000, is a Chinese PWR design developed by the China General Nuclear Power Group (CGNPG) and the China National Nuclear Corporation (CNNC) based on the ACPR1000 and the ACP1000 designs. Both are three-loop systems originally based on the same French design.

In December 2015 China Guangdong Nuclear Power Group (CGN) and China National Nuclear Corporation (CNNC) agreed to create Hualong International Nuclear Power Technology Co. as a joint venture to promote the Hualong One in overseas markets, which was officially launched in March 2016. On 19 January 2017 the United Kingdom Office for Nuclear Regulation (ONR) started their Generic Design Assessment process for the Hualong One, expected to be completed in 2021, in advance of possible deployment at the Bradwell nuclear power station site. On 16 November 2017 the ONR and the Environment Agency announced they are progressing to the next phase of their Generic Design Assessment of the UK HPR1000 reactor. Step 2 formally commenced on this day and is planned to take about 12 months. The targeted timescale for the UK HPR1000 GDA process is about five years from the start of Step 1.

At the time of our visit, cold hydrostatic testing had begun at unit 5 marking the first time the reactor systems are operated together with the auxiliary systems. Cold functional tests are carried out to confirm whether components and systems important to safety are properly installed and ready to operate in a cold condition. The main purpose of these tests is to verify the leak-tightness of the primary circuit and components, such as pressure vessels, pipelines and valves of both the nuclear and conventional islands, and to clean the main circulation pipes. The tests at Fuqing 5 began on 27 April. CNNC reported this was 50 days ahead of schedule and marks the transition of the unit from the installation phase to the commissioning phase. After a tour of the facilities and informative historical exhibition, CNNC gave an overview presentation on progress and future plans and very obligingly held an excellent questions and answer session enabling the students to ask technical questions to the operational staff and management. The entire day was extremely well planned, organised and ran very smoothly. Both students and staff were impressed at the scale of the NPP, the comprehensive tour and the vast amount of knowledge gained. Our hosts were most welcoming and it was encouraging for the students to see such enthusiasm, determination and concrete realisation of China's nuclear ambitions!

### 6.2.2 China Museum of Nuclear Science and Technology

The 2018 student cohort were fortunate enough to visit this excellent museum, charting China's nuclear history with a comprehensive array of models and exhibits. Further details and photographs were reported last year. Unfortunately, for operational reasons the exhibition halls were unavailable to this year's summer school students.

### 6.2.3 Institute of Nuclear and New Energy Technology - Tsinghua University

In 2018, members of the summer school visited the laboratory of high-temperature gas-cooled reactor (HTGCR) experimental reactor at Tsinghua University in Changping, Beijing. Supported by the National 863 Program, Tsinghua University began research and development of a 10 MW HTGCR experimental reactor in 1986. The 10 MW HTGCR-test Module (HTR-10) is a graphite-moderated helium gas-cooled reactor. As the first gas-cooled reactor in China, construction of HTR-10 was started in 1995 with the completion of basic design and safety review. It reached its criticality in December 2000 and was operated in full power condition in January 2003. About 100 commissioning tests have been completed, and six safety demonstration experiments have been conducted since 2003.

The HTR-10 is a pebble-bed reactor HTGR utilising spherical fuel elements with ceramic coated fuel particles. The reactor core comprises of 27 000 fuel elements, each using low enriched uranium with a design mean burn up of 80 000 MWd/t, and is surrounded by graphite reflectors. The pressure of the primary helium coolant circuit is 3.0 MPa. Modelled after the German HTR-MODUL, the HTR-10 is claimed to be fundamentally safer, potentially cheaper and more efficient than other nuclear reactor designs. Outlet temperature ranges between 700 and 950 °C, greatly improving the efficiency (40 %) and enabling this type of reactor to generate hydrogen as a by-product efficiently, thus supplying inexpensive and non-polluting fuel for fuel cell powered vehicles.

HTR-10 design includes the advanced concepts of newly developed modular high temperature reactors. Featuring a compact side-by-side arrangement of the reactor core and the steam generator, spherical fuel elements (6 cm in diameter) with TRISO coated particles, continuous process of fuel loading and unloading, all-around computerized protection system and in-depth defence principles. A completely passive decay heat removal system and a surface cooling system are designed for HTR-10. Two reactor shutdown systems are located in the reactor side reflector, namely the control rod system and the small absorber ball system, enabling the automatic shutdown of the reactor under emergency conditions.

Unfortunately, for operational reasons, the 2019 cohort of students were unable to visit this site to augment their lectures. This was a shame since last year the reactor operators gave a fascinating tour of the plane and were extremely gracious of their time in answering questions and explaining the technical details.

### 6.2.4 China Institute of Atomic Energy, Beijing

The China Institute of Atomic Energy (CIAE), formerly the Institute of Atomic Energy of the Chinese Academy of Sciences, is the main research institute of the China National Nuclear

Corporation (CNNC). Founded in 1950 as the "Second Department of Modern Physics", it conducts research in the fields of nuclear physics, nuclear engineering, radiochemistry and in the development of nuclear science and technology as well as the innovative bases for the research of national nuclear defence and energy development.

The CIAE houses China's Experimental Fast Reactor (CEFR) which is China's first fast nuclear reactor. It aims to provide China with fast-reactor design, construction and operational experience, and will be a key facility for testing and researching components and materials to be used in subsequent fast reactors. The reactor achieved first criticality on $21^{st}$ July 2010 and started generating power a year later on $21^{st}$ July 2011. On October 2012 Xinhua announced that the CEFR had passed official checks. The CEFR was brought to full power at 1700 on $15^{th}$ December 2014 and operated at this level continuously for three full days.

CEFR is a 65 MW thermal, 20 MW electric, sodium-cooled, pool-type reactor with a 30-year design lifetime and a target burnup of 100 MWd/kg. The CEFR was built by Russia's OKBM Afrikantov in collaboration with OKB Gidropress, NIKIET and Kurchatov Institute.

The CEFR project was approved by the Chinese State Council in 1992, with final approval given in 1995 and is one of the major energy projects under the national high-tech research and development program of China's "National 863 Program".

In 2018, the summer school group visited the fast reactor, ion accelerator and small nuclear reactor. Due to the fast reactor working on a critical experiment, entry to the laboratory was not allowed. However, access to the impressive exhibition hall containing models of accelerators and small nuclear reactors was permitted where a comprehensive tour and description was given by technical staff. Unfortunately, for operational reasons this visit was cancelled for this cohort but the principles of the fast breeder were covered in the associated lectures.

## 6.3 Chinese Cultural Tours

To augment the formal Chinese culture workshops, several activities were arranged to facilitate further appreciation of Chinese culture by the western students. Notably, visiting the world cultural heritage centres: Tulou and Gulangyu provided the opportunity to learn about the local "South Fujian Culture". Indeed, Tulou and Gulangyu have been characterised as world cultural heritage centres. The second part of the summer school was hosted by CUPB where visits were arranged to the Imperial Palace and Great Wall and Ming's Tombs. These are highly representative of Chinese cultural history steeped in a long history containing Chinese wisdom.

### 6.3.1 Tulou

Fujian Tulou is a property of 46 buildings constructed between the $15^{th}$ and $20^{th}$ centuries over 120 km in south-west of Fujian province, inland from the Taiwan Strait. Set amongst rice, tea and tobacco fields the Tulou are earthen houses. Several storeys high, they are built along an inward-looking, circular or square floor plan as housing for up to 800 people each. They were built for defence purposes around a central open courtyard with only one entrance and windows to the outside only above the first floor. Housing a whole clan, the houses functioned as village units and were known as "a little kingdom for the family" or "bustling small city." They feature tall fortified mud walls capped by tiled roofs with wide over-hanging eaves. The most elaborate structures date back to the $17^{th}$ and $18^{th}$ centuries. The buildings were divided vertically between families with each comprising two or three rooms on each floor. In contrast with their plain exterior, the inside of the tulou were built for comfort and were often highly decorated. They were inscribed in 2008 by UNESCO as World Heritage Site, as "exceptional examples of a building tradition and function exemplifying a particular type of communal living and defensive organization, and, in terms of their harmonious relationship with their environment, an outstanding example of human settlement."

An amusing piece of historical trivia originates from the Cold War era when the U.S. first received satellite photos (initially, with poor resolution) from this area. Intelligence analysts spotted many fairly large circular structures in this region, not far from Taiwan and thought that they might be missile silos. Eventually, the structures were confirmed as houses by 'visitors' on the ground.

#### 6.3.2 Gulangyu Island

The Gulangyu, Gulang Island or Kulangsu is a pedestrian-only island off the coast of Xiamen, Fujian Province in southeastern China. A UNESCO World Cultural Heritage Site, the island is about $2\,km^2$ in area, and is reached by a 8 min ferry ride from Xiamen centre. Although only about 20 000 people live on the island, Gulangyu is a major domestic tourist destination, attracting more than 10 million visitors per year, and making it one of China's most visited tourist attractions. Gulangyu not only bans cars, but also bicycles. The only vehicles permitted are small electric buggies and electric government service vehicles.

For a time, Gulangyu had the peculiarity of having constituted the only international settlement on Chinese soil apart from the more celebrated International Settlement at Shanghai. Soon after Xiamen became a treaty port resulting from China's loss in the First Opium War and the Treaty of Nanking in 1842, foreign residents on the island established an informal organisation that became formally organized several decades later when its Land Regulations were approved by the government of China in May 1902. Eventually 13 countries, including Great Britain, France, The Netherlands and Japan, were to enjoy extraterritorial privileges there and take part in the Kulangsu Municipal Council that administered the settlement. As with the Shanghai International Settlement, the British played a predominant role in the administration and Sikh policemen from British India were charged with the policing of the Settlement. The consulates, churches, hospitals, schools, police stations, *etc.* built by those foreign communities explain the predominantly Victorian-era style architecture that can still be seen throughout Gulangyu. Japanese occupation of the island began in 1942, and lasted until the end of World War II. The Hokkien dialect is spoken on the island, as it is in Xiamen.

#### 6.3.3 The Great Wall

The Great Wall of China is the collective name of a series of fortification systems generally built across the historical northern borders of China to protect and consolidate territories of Chinese states and empires against various nomadic groups. Several walls were being built from as early as the 7th century BC by ancient Chinese states; selective stretches were later joined together by Qin Shi Huang (220–206 BC), the first Emperor of China. Little of the Qin wall remains. Later on, many successive dynasties have built and maintained multiple stretches of border walls. The most currently well-known of the walls were built by the Ming dynasty (1368-1644).

Apart from defence, other purposes of the Great Wall have included border controls, allowing the imposition of duties on goods transported along the Silk Road, regulation or encouragement of trade and the control of immigration and emigration. Furthermore, the defensive characteristics of the Great Wall were enhanced by the construction of watch towers, troop barracks, garrison stations, signalling capabilities through the means of smoke or fire, and the fact that the path of the Great Wall also served as a transportation corridor.

#### 6.3.4 Forbidden City, Emperor's Palace

The Forbidden City palace complex in central Beijing houses the Palace Museum, and was the former Chinese imperial palace from the Ming dynasty to the end of the Qing dynasty (1420 to 1912). The Forbidden City served as the home of emperors and their households as well as the ceremonial and political centre of Chinese government for almost 500 years.

Constructed from 1406 to 1420, the complex consists of 980 buildings and covers 72 hectares. The palace exemplifies traditional Chinese palatial architecture and has influenced cultural and architectural developments in East Asia and elsewhere. The Forbidden City was declared a World Heritage Site in 1987 and is listed by UNESCO as the largest collection of preserved ancient wooden structures in the world.

#### 6.3.5 Ming's Tombs

The Ming Xiaoling is the mausoleum of the Hongwu Emperor, the founder of the Ming dynasty. It lies at the southern foot of Purple Mountain, located east of the historical centre of Nanjing. Legend says that in order to prevent robbery of the tomb, 13 identical processions of funeral troops started from 13 city gates to obscure the real burying site.

The construction of the mausoleum began during the Hongwu Emperor's life in 1381 and ended in 1405, during the reign of his son the Yongle Emperor, with a huge expenditure of resources involving 100,000 labourers. The original wall of the mausoleum was more than 22.5 km long. The mausoleum was built under heavy guard of 5000 troops.

## 7 Acknowledgements

The authors would like to thank and acknowledge all those who were instrumental in helping to make the 2019 Clean Energy Science and Technology Summer School and WEUN Forum so successful. To the host institutions, XMU and CUPB, the "111 project" for supporting the provision of transport and accommodation costs for the member International Foreign Experts. All faculties and students at CUPB, XMU, UoB, UoL and UoM for their engagement which contributed to the programme's success and their academic lecturers who delivered the technical classes. Huge appreciation to the local Chinese student volunteers for tirelessly ensuring that international students had such an excellent experience of China, from acting as guides to translating! Finally, a enormous debt of gratitude is owed to Prof. Jun Yao for his tireless energy and good humour whilst arranging the programme, liaising with local and overseas institutions and being such an excellent host. He also arranged such interesting cultural activities and visits to provide the students with a rich and diverse experience of China.

# 8 Appendices

## 8.1 WEUN/CESE Delegates

Table 3: WEUN Clean Energy Science & Technology Delegates

| Forename | Surname | Country | Institution |
|---|---|---|---|
| Segen Farid | Estefen | Brazil | Federal University of Rio de Janeiro |
| Morten | Lind | Denmark | Technical University of Denmark |
| Mark | Read | U.K. | University of Birmingham |
| Mary Ann | Lundteige | Norway | Norwegian University of Science and Technology |
| Yiliu | Liu | China | Norwegian University of Science and Technology |
| Jing | Wu | China | Technical University of Denmark |
| Sua | Lee | Canada | University of Alberta |
| Adam | Birchall | U.K. | University of Birmingham |
| Robert | Heymer | U.K. | University of Birmingham |
| Billy | Plant | U.K. | University of Birmingham |
| Jack | Trainor | U.K. | University of Birmingham |
| Alexandre | Souchet | France | University of Birmingham |
| Shah | Iqra | U.K. | University of Leeds |
| Dominic | Raborokgwe | Botswana | University of Leeds |
| Mohammed | Ali | U.K. | University of Leeds |
| Abhay | Sharma | U.K. | University of Leeds |
| Serish | Hussain | U.K. | University of Leeds |
| Milyausha | Sufiyanova | Russia | Gubkin Russian State University |
| Marta | Corella | Spain | Technical University of Denmark |
| Johan | Hjorth | Norway | Norwegian University of Science and Technology |
| Eduado | Marendaz | Brazil | Federal University of Rio de Janeiro |
| Xiaolin | Wang | China | CUP-Beijing |
| Liang | Ma | China | CUP-China East |
| Jiaseng | Yan | China | China University of Mining and Technology |
| Li | Li | China | Xiamen University |

## 8.2 CESE Programme Schedule

Table 4: Summer School Course Schedule <Energy Sci. & Eng.> for WEUN Students

| City | Date 日期 | Time 时间 | Location 地点 | Topic 主题 | Lecturer 教师 |
|---|---|---|---|---|---|
| 厦门 Xiamen | 20190610 周一 Mon | 9:00-12:00 | Jime 集美二 204 | Nuclear Engineering R&D, New Systems and Fuel Cycles | Ning LI 李宁 |
| | 20190611 周二 Tue | 9:00-12:00 | Jime 集美二 204 | Safety barrier engineering and management | Yiliu Liu |
| | 20190612 周三 Wed | 9:00-12:00 | Jime 集美二 204 | Computer Modelling of Nuclear Materials | Mark Read |
| | 20190613 周四 Thu | 9:00-12:00 | Jime 集美二 204 | Introduction to Nuclear Power, Challenges to Nuclear Engineering Materials | Lumin WANG 王鲁闽 |
| | 20190614 周五 Fri | 9:00-12:00 | Lianxing 联兴 202 | Modelling of Complex Systems | Morten Lind |
| | 20190615 周六 Sat | 7:00-19:00 | 土楼参观 Visit Tulou | | Jun YAO 姚军 |
| | 20190616 周日 Sun | 16:00-20:00 | 鼓浪屿参观 Visit Gulangyu | | Jun YAO 姚军 |
| | 20190617 周一 Mon | 9:00-12:00 | Lianxing 联兴 202 | Nuclear Energy Safety | Ron Fleming |
| | 2019061 8 周二 Tue | 7:00-19:00 | Fuqing 福清 | NPP Tour : Fuqing Nuclear Power Plant | Jianxiang ZHENG 郑剑香 |
| | 20190619 周三 Wed | 9:30-12:30 | College of Energy 能源学院 | Dean’s Welcome, Student Presentation, Lab Tour | Qixun GU O 郭奇勋 |
| | | 14:00-17:00 | College of Energy 能源学院 | Party, Dewang Library Tour | Qixun GUO 郭奇勋 |
| 北京 Beijing | 20190620 周四 Thu | 8:00-13:00 | 厦门-北京（Xiamen-Beijing） | | Jun YAO 姚军 |
| | | 14:00-18:00 | 十三陵参观 Visit the Ming Tombs | | Jun YAO 姚军 |

Table 5: Summer School Course Schedule <Energy Sci. & Eng.> for WEUN Students

| City | Date 日期 | Time 时间 | Location 地点 | Topic 主题 | Lecturer 教师 |
|---|---|---|---|---|---|
| 北京 Beijing | 20190621 周五 Fri | 9:00-12:00 | Worldwide Energy Universities Network Summer School Opening Ceremony and World Forum on New Energy Science and Technology（世界能源大学联盟暑期学校开幕仪式暨世界新能源科学与技术发展论坛） | | 石大国际处 International Department of CUPB(CUPB-ID) |
| | | 14:00-17:00 | Lecture 1: Technology Transition from Subsea Production Systems for Oil & Gas to Ocean Renewable Energy, Segen Farid, Estefen<br>Lecture 2: Challenges of Supervision Human Machine Interface, Morten Lind<br>Lecture 3: Advanced Modelling Techniques for Simulating Materials Corrosion, Mark Read<br>Lecture 4: Supercomputing and its Applications, Weifeng Liu | | |
| | 20190622 周六 Sat | 9:00-15:00 | 长城参观 Visit Great wall | | CUPB-ID |
| | 20190623 周日 Sun | 9:00-15:00 | 颐和园参观 Visit the Summer Palace | | CUPB-ID |
| | 20190624 周一 Mon | 9:00-12:00 | 四教 108 教室 | Lecture 6: Safety Issues in Engineering SYstems | Morten Lind/Jing Wu |
| | | 14:00-17:00 | 参观清华大学核研院 Visit Nuclear Research Institute @ QingHua Univ. | | CUPB-ID |
| | 20190625 周二 Tue | 9:00-12:00 | 四教 108 教室 | Lecture 7: From Subsea Production Systems for Oil & Gas to Ocean Renewable Energy | Segen Farid, Estefen |
| | | 14:00-17:00 | Activities with CUPB students | | CUPB-ID |
| | 20190626 周三 Wed | 9:00-12:00 | 四教 108 教室 | Lecture 8: Advanced Modelling Techniques for Energy Materials | Mark Read |
| | | 14:00-17:00 | 参观原子能研究院 Visit Atomic Energy Research Institute | | CUPB-ID |
| | 20190627 周五 Thu | 9:00-12:00 | 四教 108 教室 | Lecture 9: Water Injection Performance Monitoring and Operation | Jing Wu |
| | | 12:00-18:00 | 参观故宫 Visit National Key Laboratories | | CUPB-ID |
| | 20190628 周六 Fri | 9:00-12:00 | 结束 End - Summer School Closing Ceremony | | CUPB-ID |
| | | 14:00-18:00 | 参观故宫 Visit the Imperial Palace | | CUPB-ID |

## 8.3 111 project and WEUN overview

Following a successful Higher Education Discipline Innovation Project (111) bid, funded and launched by the Ministry of Education and the State Administration of Foreign Experts Affairs, China, Dr Mark S. D. Read was appointed as a Foreign Expert in collaboration with Xiamen University and the China University of Petroleum-Beijing. The opening ceremony of the 111 project named "Offshore Oil and Gas Production Safety" was held at CUPB on $20^{th}$ June 2018. The guests included Mr Fanping Yi, Deputy Director of the Department of Education, Culture and Health Experts of the State Administration of Foreign Affairs; Mr Fei Peng, General Manager of China National Petroleum Group Offshore Engineering Company; Mr Fan Yang, Deputy General Manager of Science and Technology Development Department of CNOOC; Prof. Laibing Zhang, President of CUPB; Prof. Gengsheng Li, Vice President of CUPB; six Academicians of the Chinese Academy of Engineering and nine international experts coming from University of Birmingham, University of Leeds, University College London, Imperial College of London, Federal University of Rio de Janeiro (Brazil), University of Alberta (Canada), University of Curtin (Australia). In addition, some local experts came from Qinghua University, China Mining University and University of Science and Technology of Beijing together with faculties and students from China University of Petroleum. Over 150 delegates attended this ceremony hosted by Prof. Zhenlin Li, the Dean of School of Mechanical and Storage Engineering.

This 111 project was proposed in order to establish an intelligence base for offshore oil and gas production safety engineering at CUPB, and introduce 21 top-grade international scientists, three originating from UoB (University of Birmingham) and four coming from UoL (University of Leeds), who currently collaborate with CUPB directly in addition to having many years prior experience. All come from well-known universities in the world such as UoL, UoB, Technical University of Denmark, the Norwegian University Science & Technology, Imperial college of London, University College London, University of Alberta *etc.* This project plans to establish 1-2 Sino-foreign joint research centres or laboratories, invite 20-25 international professors to CUPB to deliver lectures as well as collaborate in joint research proposals. Consequently, this work proposed will make great contribution to speeding up the construction of offshore oil and gas production safety engineering, to the sustainable development and utilization of ocean resources and ensuring the energy supply and energy safety.

The Worldwide Energy Universities Network (WEUN) is an organisation of research universities brought together by a shared strategic interest in research, innovation, education and internationalisation within the field of energy.

**Purpose**

The primary purpose of WEUN is to create a global platform for communication and collaboration among and between the WEUN member universities in research, innovation and education in the field of energy.

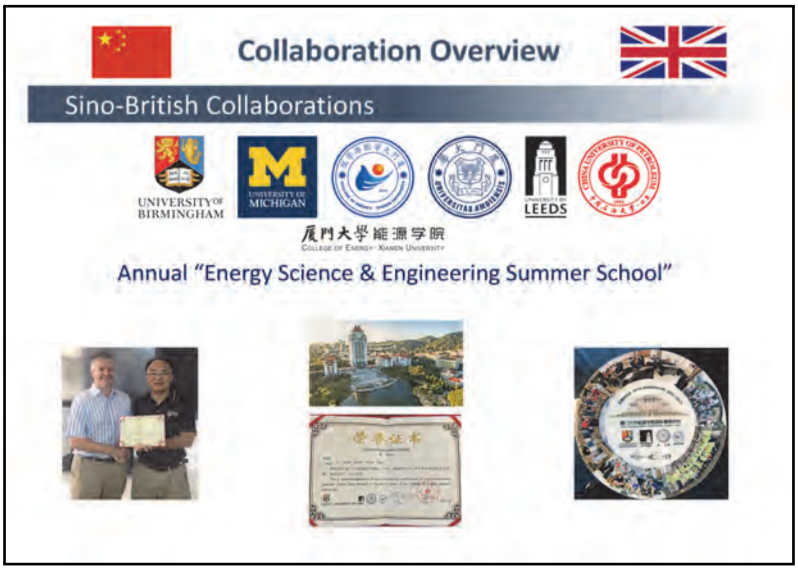
**Mission**

- To build a platform for the exchange of educational information, best practices and academic resources on energy-related issues.
- To leverage access to expertise and facilities and collaborate on basic and applied research in the field of energy and to set up joint labs or centres as interests grow.
- To coordinate energy related international cooperation in joint degree education, student and faculty exchange, summer courses or schools and training programmes.
- To promote and advertise member universities within the countries of other member universities to improve their visibility and recognition and enhance their prestige in those countries.
- To organise academic conferences or seminars to address challenges facing the energy world and energy education.

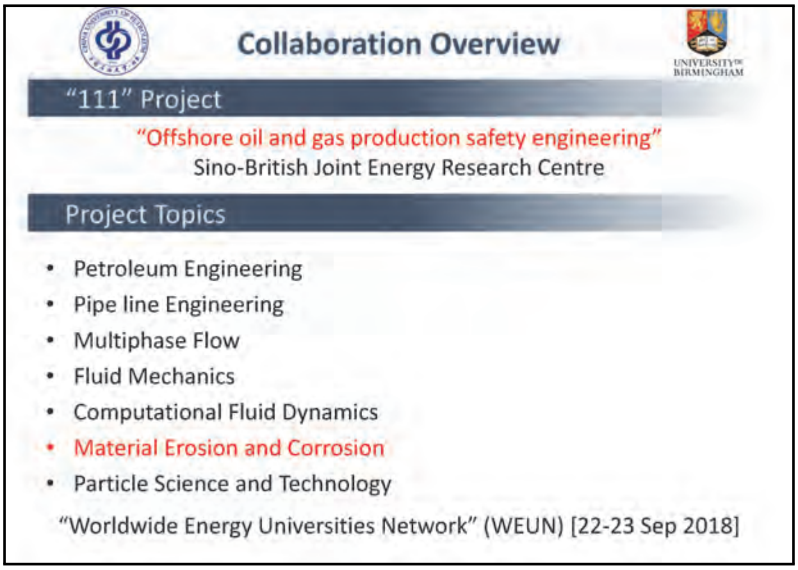
WEUN was established at a conference on the 22nd Sep. 2018 in Beijing initiated by its founder CUPB, through the representatives of the first cohort of 28 founding member universities. Dr Mark S. D. Read (Director of the Sino-British Cooperative Programme), Prof. Martin Freer (HoS Physics & Astronomy) and Dr Bing Liu (Director of International Relations) participated in the opening of the Worldwide Energy Universities Network in Beijing with 27 other universities from across the globe. The signing ceremony was broadcast on China Central Television.

### 8.3.1 111 Project Background Presentation


(a)

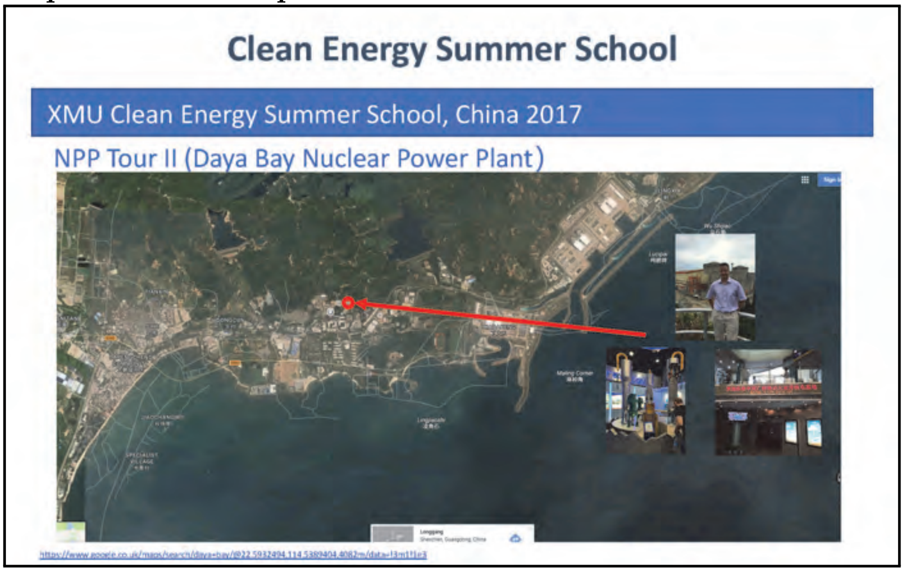



(b)



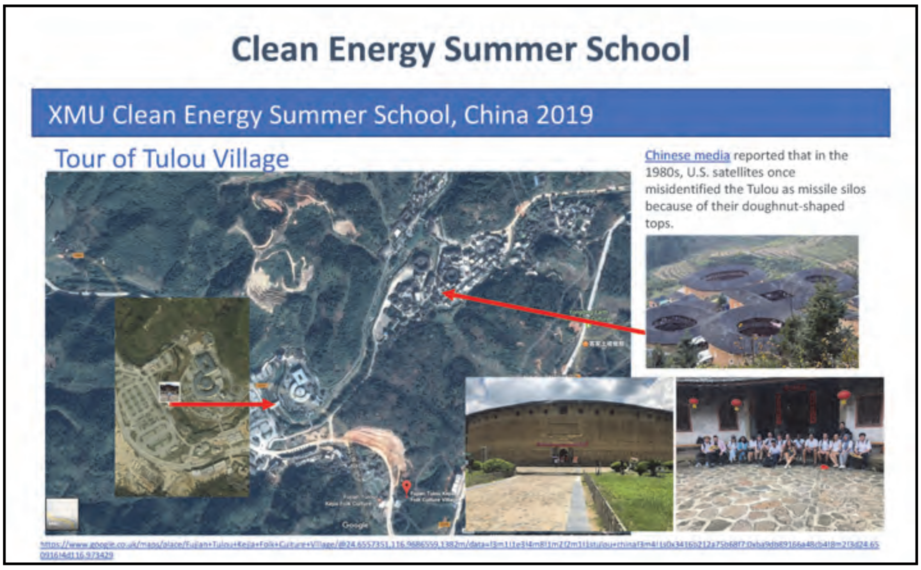

(c)

### 8.3.2 Field Trip Location Maps

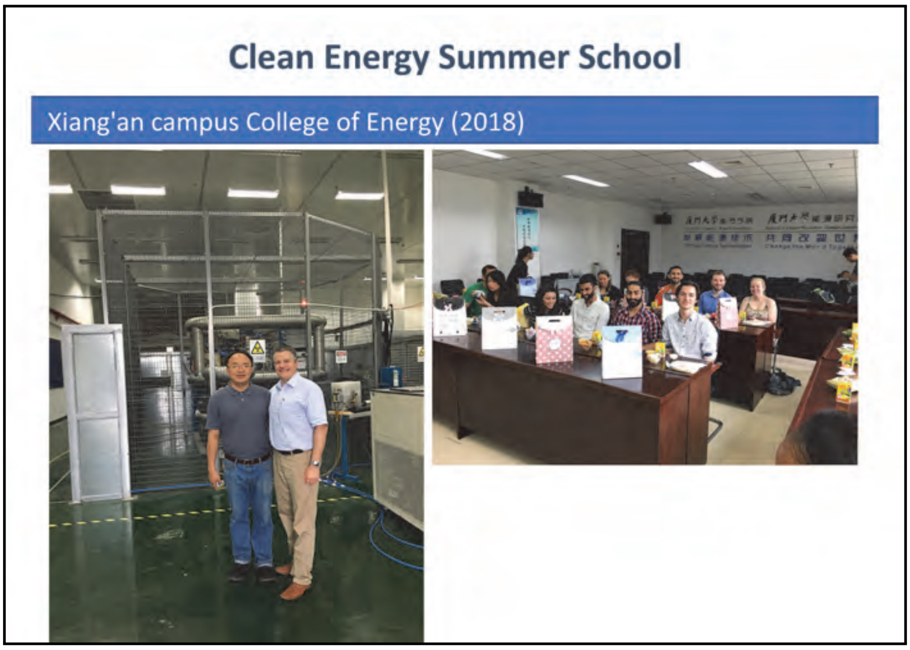



(a)

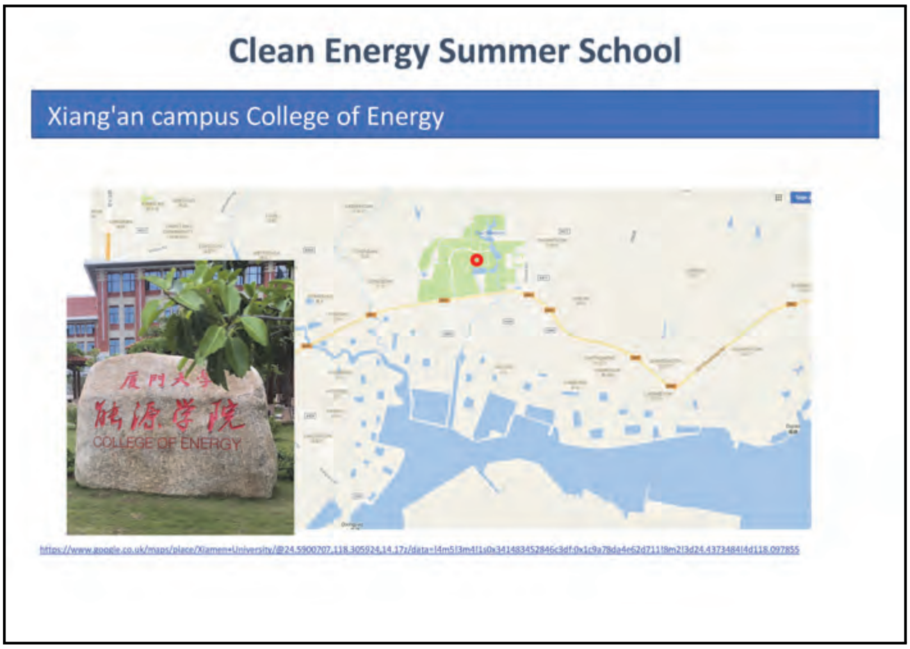

(b)




(c)


Clean Energy Summer School
Xiang'an campus College of Energy (2018)

(d)


Clean Energy Summer School
Xiang'an campus College of Energy
厦门大学
能源学院
COLLEGE OF ENERGY

(e)

## 8.4 Photographs

### 8.4.1 Tulou visit - 15/06/19


(a)


(b)


(c)


(d)


(e)


(f)

### 8.4.2 Gulangyu visit - 16/06/19


(a)

(b)

(c)

(d)

(e)

(f)

### 8.4.3 Fuqing Nuclear Power Plant visit - 18/06/19

(a)

(b)


(c)

(d)

(e)

(f)

### 8.4.4 Xiamen University

(a)

(b)

(c)

(d)

(e)


(f)

(c) and (d) Farewell Banquet - Xiamen University

### 8.4.5 CUPB, WEUN Beijing

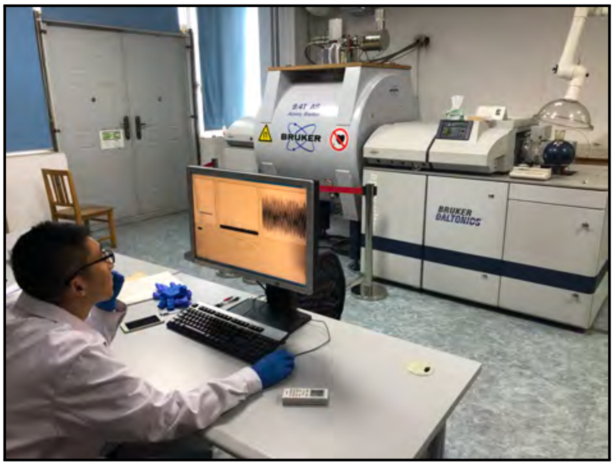
(a)


(b)


(c)

(d)

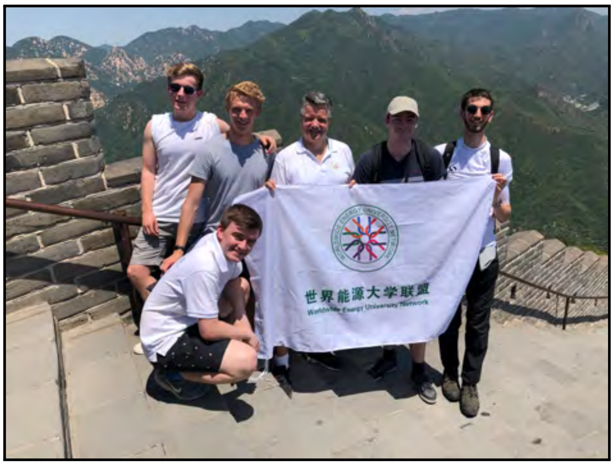

(e)




(f)

### 8.4.6 Beijing Cultural Activities

(a)




(b)

(c)

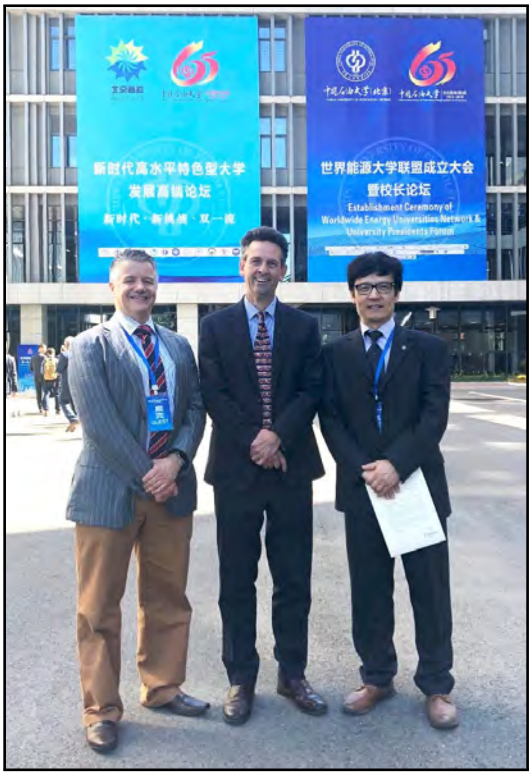
(d)

(e)


(f)

### 8.4.7 WEUN Opening Ceremony - 22/09/18


(a)




(b)

证 书

CREDENTIAL

中国石油大学（北京）
高等学校学科创新引智基地
聘书

兹聘 Mark Stuart David READ 先生为我校"高等学校学科创新引智基地"《海洋油气生产安全工程》外籍专家，聘期至 2018 年 1 月至 2023 年 12 月止。

此 聘

（校章） 校长： （签字）

China University of Petroleum-Beijing
Overseas Expertise Introduction Center for Discipline Innovation
Certificate of Appointment

China University of Petroleum-Beijing is pleased to announce the appointment of Mr. Mark Stuart David READ as a foreign expert in the Overseas Expertise Introduction Center for Discipline Innovation *Safety Engineering of Offshore Oil and Gas Production* .

Term of Appointment from Jan.2018 to Dec. 2023.

President:

(a)

(c)

Certificate awarded to Dr Mark S. D. Read by CUP President, Prof. Zhang Laibin; (b) Dr Mark S. D. Read (Director of the Sino-British Cooperative Programme), Prof. Martin Freer (HoS Physics & Astronomy) and Dr Bing Liu (Director of International Relations)