HKNIC

核電知多少
Understanding Nuclear Power

核能是一種可靠的能源，不僅成本具競爭力和潔淨，而且近乎零排放。就讓我們透過這本小冊子，學習核能各方面的知識，了解它在應對氣候變化中所扮演的角色。

Nuclear energy is a reliable, cost-competitive and clean source of energy, with practically no emissions. Let's learn more about nuclear energy and its role in addressing the challenges brought about by climate change.

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1 核能與低碳未來
Nuclear Energy and a Low Carbon Future

燃燒化石燃料的後果
The Consequences of Burning Fossil Fuels

電力與我們的生活密不可分。今天，全球仍然依賴高碳排放的化石燃料作為主要的發電燃料。與此同時，各國的能源需求也不斷增加。

Electricity is inseparable from our way of life. Today, a large percentage of the world's electricity generation relies on burning carbon-emitting fossil fuels. At the same time, the world's demand for energy is increasing.

按燃料劃分的全球淨發電量—展望
World Net Electricity Generation by Fuel – Projected Outlook

資料來源：美國能源資訊局（2017）
Source: U.S. Energy Information Administration (2017)

72%
的全球排放來自與能源行業有直接關係的活動
of global emissions come from activities directly related to the energy sector

餘下28%的排放由非能源行業產生
The remaining 28% is emitted by non-energy sectors

資料來源：世界資源研究所（2012）
Source: World Resource Institute (2012)

溫室效應
二氧化碳及其他溫室氣體不斷被排放至大氣中，使地球氣溫上升，並帶來破壞性後果。

The Greenhouse Effect
The continuous release of carbon dioxide (CO_2) and other greenhouse gases into our atmosphere is gradually warming our planet and having destructive consequences.

日益頻繁的極端天氣
More frequent and severe weather events

海平面上升及海水酸化
Rising ocean levels and ocean acidification

生態系統改變及生物絕種
Changing ecosystems and species extinction

糧食及水源短缺
Food and water shortages

轉用潔淨能源刻不容緩。
The switch to clean energy is imperative.

低碳能源的選擇
Low Carbon Energy Choices

電力行業的挑戰源於能源政策「三重挑戰」的矛盾，即如何能夠在符合環保要求下，提供安全可靠的電力，同時將電價控制在合理水平。

The challenge for the electricity industry comes from the tensions that are apparent in the Energy Trilemma – how to deliver a safe and reliable supply to acceptable environmental standards whilst containing tariff at reasonable levels.

平衡能源政策目標的三重挑戰
Managing the Energy Trilemma

我們尚未找到完美的燃料，既可滿足能源需求，同時又環保，因此，多元化燃料組合是目前最理想的方案。

Until we find the perfect fuel, a diversified fuel mix is the best option for meeting our energy demands and environmental requirements.

在各種低碳能源選擇中，核電是近乎零碳排放的能源，在我們未來的燃料組合中將發揮重要作用。

Out of our low carbon energy choices, nuclear power emits virtually no CO_2 during generation and has an important role to play in our future fuel mix.

不同燃料的溫室氣體排放量△
Greenhouse Gas Emissions by Fuel△

公噸二氧化碳/百萬度
Tonnes CO_2/GWh

	風能 Wind	水能 Hydro	太陽能光伏 Solar PV	生物質能 Biomass	天然氣 Natural Gas	核能 Nuclear	燃煤 Coal	燃油 Oil
供應量 Availability	供應無限，但受地理環境限制 Unlimited supply, but with geographical constraints				足夠未來數百年使用 Adequate supply for centuries	足夠未來數百年使用 Adequate supply for centuries	足夠未來數百年使用 Adequate supply for centuries	足夠未來數十年使用 Adequate supply for decades
發電的可靠性 Reliability of Performance	不穩定 Unstable				高 High	高 High	高 High	高 High
價格* Price*	高 High				中 Medium	低 Low	低 Low	波動 Fluctuate

* 根據香港應對氣候變化策略及行動綱領公眾諮詢文件(2010年)的資料：
天然氣發電的單位成本：每度電約70-90分
燃煤發電的單位成本：每度電約40-60分
從內地輸入核電的單位價格：每度電約50分
According to Hong Kong's Climate Change Strategy and Action Agenda Consultation Document (2010):
Unit cost of natural gas-fired electricity: about 70-90 cents/kWh
Unit cost of coal-fired electricity: about 40-60 cents/kWh
Unit price of nuclear electricity imported from the Mainland: about 50 cents/kWh

資料來源：世界核能協會
Source: World Nuclear Association

△ 生命週期排放量涵蓋在發電過程中所產生的直接排放，以及其他相關過程(包括燃料開採、運送及加工)所產生的間接排放
Life cycle emissions cover the direct emissions from electricity generation and indirect emissions from other related activities such as fuel mining, transportation and processing

總結不同研究所得的平均排放強度
Average emission intensity concluded from different studies

不同研究的數值範圍
Range between studies

香港是全球其中一個人口最稠密、最具活力的城市，需要多元化的能源組合，為社會民生和經濟活動提供可靠和潔淨的電力。

Hong Kong is one of the world's most populous and dynamic cities. It needs a diversified fuel mix to support social and economic activities with reliable and clean power.

香港邁向低碳未來的能源組合
Diversified Fuel Mix for Hong Kong's Low Carbon Future

香港氣候行動藍圖2030+

香港特區政府已制定減少碳排放的新目標，力求在2030年把香港的碳強度從2005年的水平降低65%至70%。這個行動藍圖更包含香港未來的能源組合。

在可選擇的潔淨能源中，核電可靠度高，其溫室氣體排放量近乎零，因此在香港邁向低碳未來的過程中，將繼續擔當重要角色。

Hong Kong's Climate Action Plan 2030+

The HKSAR Government has set a new emissions reduction target: to reduce carbon intensity by 65% to 70% by 2030 compared with 2005 levels. The action plan outlines the future fuel mix for the city.

Out of Hong Kong's clean energy choices, nuclear power is highly reliable and practically without greenhouse gas emissions. It has a pivotal role to play in our transition to a low carbon future.

香港氣候行動藍圖2030+
Hong Kong's Climate Action Plan 2030+

2 核能是甚麼？ What is Nuclear Energy?

鈾——核燃料
Uranium – Nuclear Fuel

核能是指核裂變過程中所產生的熱能，最常用於核能發電的燃料是鈾235。

Nuclear energy refers to the heat released during the fission process. The most common type of material for nuclear power generation is uranium 235 (U235).

原子組成地球上所有物質

Atoms make up all matter on earth

鈾從哪裡來？
Where does uranium come from?

以下國家生產全球超過三分之二的鈾。

Over two-thirds of the world's uranium is produced by these countries.

全球鈾產量
Global Uranium Production

資料來源：世界核能協會 (2016)
Source: World Nuclear Association (2016)

鈾的核素
Nuclides of Uranium

「核素」：質子數目相同，但中子數目不一樣。

"Nuclides" – having the same number of protons and different number of neutrons.

鈾是自然界的一種元素。
Uranium is an element found in nature.

天然的鈾主要由兩個核素組成，包括約0.7%的鈾235，其餘大部分是鈾238。

Uranium found in nature consists largely of two nuclides, about 0.7% of U235 and the remaining mostly U238.

為甚麼我們不使用鈾238？

鈾238過於穩定，難以進行核裂變。

然而，我們可使用較先進的快中子反應堆將鈾238轉化為鈈239，以便進行核裂變。

Why don't we use U238?

U238 is too stable for nuclear fission.

However, it can be converted into plutonium 239 by using the more advanced fast neutron reactors and then undergoing fission.

核裂變及發電過程
Nuclear Fission and the Generation Process

鈾235原子在核裂變的過程中會釋放熱能、中子及輻射。

During the fission process, a U235 atom releases heat, neutrons and radiation.

核裂變及鏈式反應
Nuclear Fission and Chain Reaction

由一粒外來的中子引發核裂變
A single incoming neutron triggers fission

裂變時會釋放兩至三粒中子
Fission occurs and 2 to 3 neutrons are released

中子隨即撞擊鄰近的鈾235原子，並持續產生裂變，這就是鏈式反應
可透過調節中子的數目來控制鏈式反應及其產生的熱能
The neutrons split the nuclei of neighbouring U235 atoms and continue a chain reaction of splitting
The chain reaction and its heat generation can be controlled by the amount of neutrons

控制棒能有效控制及調節反應堆內核裂變的速度。
Control rods can effectively manage and control the fission rate inside the reactor.

在核能發電過程中，控制棒能穩定中子的數量，藉此控制鏈式反應，提供穩定的熱能。

During nuclear power generation, control rods help to keep the number of neutrons stable. This ensures a controlled chain reaction and a consistent supply of heat.

1. 反應堆堆芯中的鈾燃料發生核裂變並產生熱能
   Nuclear fission occurs in the uranium fuel at the reactor core producing heat
2. 蒸汽發生器中的水沸騰，變成蒸汽
   Water in the steam generators is boiled and turned into steam
3. 蒸汽推動渦輪機
   Steam turns a turbine
4. 發電機產生電力
   The generator produces electricity
5. 變壓器提升電壓
   The transformer steps up electricial voltage
6. 輸電網絡將電力傳送至用戶
   Electricity reaches users via the transmission network

核能發電過程—壓水式反應堆
Nuclear Power Generation in a Pressurised Water Reactor

核反應堆與原子彈的分別
The Difference between a Nuclear Reactor and an Atomic Bomb

核反應堆會否像原子彈般爆炸？**答案是不會的**。因為核反應堆使用的鈾成份和所釋放的能量與原子彈截然不同。

Could a nuclear reactor explode like an atomic bomb? **The answer is NO**. The energy released and composition of uranium in a reactor is very different to that of an atomic bomb.

核反應堆採用只含有2%至5%鈾235的低濃度燃料，亦設有控制系統，能控制由核裂變產生的能量。

Nuclear reactors use low enrichment fuel with 2% to 5% U235. Reactors also have control systems that properly control the power produced.

原子彈採用含有超過90%鈾235的高濃度燃料，能引發大規模的鏈式反應，一瞬間產生巨大的能量。

Atomic bombs use high enrichment fuel with over 90% of U235 to create a massive chain reaction and produce a great amount of energy at once.

反應堆不會像原子彈般爆炸。
A reactor is not capable of exploding like an atomic bomb.

試想像兩者鈾成份的差別，就如啤酒和烈酒(例如伏特加)酒精含量的分別。
Think of it like comparing the alcohol content of beer to strong liquor such as vodka.

不易燃
Not Flammable

啤酒 Beer
~5% 酒精 Alcohol

易燃
Flammable

烈酒 Strong Liquor
>40% 酒精 Alcohol

反應堆的種類
Types of Reactor

世界各地常見的核反應堆
Nuclear Reactors Used Worldwide

60%

壓水式反應堆

- 有兩個完全分隔、水壓不同的冷卻水迴路
- 二迴路及所產生的蒸汽不會帶有輻射物質

Pressurised Water Reactor (PWR)

- Consists of 2 completely separate circuits of coolant water with different pressure
- Secondary circuit and the steam released are free from radioactive products

20%

沸水式反應堆

- 只有一個迴路，水壓較低
- 堆芯周圍的水及蒸汽含有微量的輻射物質若須排出蒸汽，氣體會帶有小量輻射物質

Boiling Water Reactor (BWR)

- 1 single circuit with lower water pressure
- Water and steam around the core of the reactor contains some traces of radionuclides. Should venting occur, the steam is slightly radioactive

10%

壓力重水式反應堆

- 反應堆壓力管的設計可將個別的壓力管與冷卻系統隔離，因此反應堆運行時也可以更換燃料

Pressurised Heavy Water Reactor (PHWR or CANDU)

- The design of the pressurised tubes enables refuelling of the reactor during operation by isolating individual pressure tubes from the cooling circuit

10%

其他

氣冷式反應堆、水冷石墨反應堆和快中子反應堆

Others

Gas-cooled, light water graphite and fast neutron reactors

重水是甚麼？
What is Heavy Water?

3 輻射與日常生活 Radiation and Daily Life

輻射是甚麼？ What is Radiation?

輻射以電磁波或帶電荷的亞原子粒子形式出現，是一種可穿透空間的能量。

Radiation is energy in the form of electromagnetic waves or electrically-charged subatomic particles that can travel through space.

非電離輻射
- 微波、可見光和紫外線
- 低能量電磁波
- 一般只會使分子震動和產生加熱效應

Non-ionising Radiation
- Microwaves, visible light and ultraviolet light
- Low-energy electromagnetic waves
- Generally only manages to cause molecules to vibrate and induces heat effects

電離輻射
- 高能量電磁波和帶電荷的原子粒子
- 某些不穩定的原子，在分裂或轉變成另一種原子的過程中，會釋放能量或產生帶電荷的粒子
- 大量的電離輻射會導致物質產生化學變化，甚至損害活組織及破壞人體細胞

Ionising Radiation
- High-energy electromagnetic waves and charged atomic particles
- When splitting or transforming into other types of atoms, certain types of unstable atoms will release energy or electrically-charged particles
- Can cause chemical changes in materials, damage living tissues and destroy human cells when in high quantities

輻射單位
Radiation Units

貝可 Becquerel
量度放射性物質所釋放出的輻射量
Measures the amount of radiation emitted from a radioactive material

戈瑞 Gray
量度每單位質量的物質（例如人體組織）所吸收的輻射量
Measures the radioactive energy absorbed by a unit mass of substance (such as body tissue)

毫希沃特 Milli-Sievert
量度電離輻射對健康造成的影響
Measures the health impact of exposure to ionising radiation

電離輻射可導致化學變化或損害活組織。
Ionising radiation can cause chemical changes or damage to living tissues.

常見的電離輻射種類
Common Types of Ionising Radiation

日常活動和輻射劑量
Daily Activities and Radiation Dosage

儘管很多人擔心受到輻射影響，事實上，輻射在我們的日常生活中無處不在。地球本身就有天然輻射，甚至我們呼吸的空氣、吃下的食物，以及身處的地方都有輻射。

While many people worry about radiation, it is in fact part of our daily lives. The earth is naturally radioactive, so is the air we breathe, the food we eat and the ground we stand on.

每公斤香蕉
Banana per kg
130Bq

我們日常接觸到的輻射中，天然輻射佔

85%

of our radiation is completely natural

前往世界核能協會的資料庫查看更多有關輻射的資料
More about radiation on World Nuclear Association's database

香港一年的本底輻射(包括宇宙射線、陸地、空氣中的氡氣等)
Background radiation per year in **Hong Kong** (including cosmic ray, radon from the ground and in the air)

輻射水平(毫希)
Level of Radiation (mSv)

0.0002 | 0.0004 | 0.08 | 0.01-0.13 | 2.4 | 3-15 | <20 | 100 | 1,000 | 10,000 | >10,000

戶外踢足球
Playing outdoor football
2 小時 hours

郊外行山
Trail walking
4 小時 hours

於四萬呎高空飛行
Flying at 40,000 feet
10 小時 hours

X光
X-ray

胸肺
Chest
0.02 毫希 mSv

牙科
Dental
0.01 毫希 mSv

乳房造影
Mammogram
0.13 毫希 mSv

電腦斷層掃描
Computed Tomography (CT) Scan

全身
Whole body
12 毫希 mSv

胸肺
Chest
15 毫希 mSv

頸部
Neck
3 毫希 mSv

核電廠工人每年所接受的人工輻射劑量限值
Annual limit of a worker in a nuclear power station

因工作需要而接觸較高輻射水平的人士，例如放射治療師或核電廠工作人員，可以透過限制受照時間來控制所吸收的輻射劑量。

For those exposed to additional radiation through work, such as radiotherapists or workers at nuclear power stations, the dose received is usually controlled by limiting the time of exposure.

對人體健康不構成顯著影響
No human health effects demonstrated

癌症病例增加
Some increase in the incidence of cancer

出現各類輻射徵狀
Various radiation sicknesses

致命
Fatal

輻射與健康
Radiation and Health

如果吸收過量的電離輻射，就會對人體造成傷害。

Ionising radiation can be harmful to the human body if an excessive dose is received.

人體如在短時間內吸收大劑量的輻射，會引致急性輻射傷害，短期徵狀包括噁心、嘔吐、極度疲倦及脫髮。

A sudden large dose of radiation to the body will cause acute radiation injuries, resulting in short-term symptoms like nausea, vomiting, extreme tiredness and hair loss.

輻射對健康的影響取決於以下因素：
Factors affecting the degree of health damage caused by radiation:

輻射污染不易傳播給其他人，更換衣物、以濕布抹拭皮膚及淋浴都是有效清除輻射污染的方法。

Radiological contamination is not readily transferable. Changing clothes, wiping the skin with a damp cloth and showering are effective means for decontamination.

輻射防護
Radiation Protection

暴露時間
暴露於輻射的時間越短，身體吸收的輻射劑量便越少。

Exposure time
The less time you are exposed to radiation, the lower the dose of radiation you will receive.

距離
距離輻射源越遠，所受的輻射影響便越小。

Distance
The further away you are from the source of radiation, the less intense its effects will be.

屏蔽
躲在厚混凝土牆後面並留在室內，能有效地阻隔輻射。

Shielding
Shielding yourself behind a thick concrete wall and staying indoors are good ways to reduce radiation penetration.

4 大亞灣核電站和核安全
Daya Bay Nuclear Power Station and Nuclear Safety

供香港使用的核電來自哪裡？
廣東大亞灣核電站生產的核電滿足香港約25%的電力需求。

Where Does Hong Kong's Nuclear Power Come From?
Nuclear power from Guangdong Daya Bay Nuclear Power Station meets roughly 25% of Hong Kong's electricity needs.

大亞灣核電站設有兩台壓水式反應堆發電機組。自1994年以來，核能為香港減少逾1億噸的二氧化碳排放。
Daya Bay Nuclear Power Station comprises two pressurised water reactor type electricity generating units. Since 1994, nuclear energy has helped Hong Kong cut carbon dioxide emissions by over 100 million tonnes.

大亞灣核電站約80%的電力*供應香港使用。
About 80% of electricity* generated by Daya Bay Nuclear Power Station is supplied to Hong Kong.

大亞灣核電站位於深圳市大鵬半島
The Daya Bay Nuclear Power Station is located in the Dapeng Peninsula in Shenzhen

* 2017年數據
As of 2017

大亞灣核電站主要發電及安全設施

Major Generation and Safety Facilities in Daya Bay Nuclear Power Station

1 核島
Nuclear Islands

核反應堆位於兩座圓柱形的安全殼廠房內
Two cylindrical containment buildings house the nuclear reactors

2 主控制室
Main Control Room

3 常規島
Conventional Islands

裝有渦輪發電機組
House the turbine-generator units

4 泵房
Pump House

5 設有乏燃料池的燃料廠房
Fuel Building with Spent Fuel Pool

儲存新燃料和乏燃料
Stores new and spent fuel

6 場內柴油發電機
Onsite Diesel Generators

提供後備電源
Serves as back-up power supply

7 相連電網
Connecting Grid

連接廣東電網及中電電網的高壓電纜，能提供後備電源
High-voltage power cables to connect with the Guangdong Grid and CLP Power Grid as back-up power supply

8 消防局
Fire Station

9 儲水庫
Water Tank

提供後備冷卻水
Stores water as back-up coolant

10 高位水箱
Elevated Water Tank

11 高容量蓄電池
High Capacity Battery Packs

核安全
Nuclear Safety

核電史上曾發生過數次嚴重核事故，因此，公眾對核安全及輻射威脅存有一定疑慮。

With a number of severe accidents occurring in the history of nuclear power, the public may have concerns over nuclear safety and the threat of radiation.

我們對核安全的疑慮
Our Concerns on Nuclear Safety

突發的嚴重天災
Unexpected and severe natural disasters

核電站的設計缺陷
Flawed reactor designs

人為錯誤
Human error

核廢料污染
Nuclear waste pollution

缺乏監管
Lack of regulation

應急準備不足
Unprepared for emergency

安全運行是所有核電站的首要目標。萬一核電站發生緊急事故，電站人員可即時啟動後備措施來維持電站的安全運行。

Safe operation is always the top priority for all nuclear power stations. In the event of an emergency, auxiliary equipment is ready to step in and maintain safe operation of the plant.

大亞灣核電站以縱深防禦的原則，為電站提供多重後備支援。

At Daya Bay Nuclear Power Station, defence-in-depth principles are used to ensure multiple back up support.

核電站營運的安全措施
Safe Operation at the Nuclear Power Station

審慎選址
Prudent site selection

電站設計及運行安全
Plant design and operational safety

專業及嚴格的員工培訓及考核
Professional and stringent staff training and qualifications

完善的輻射防護及監察系統
Robust radiation protection and monitoring systems

借鑑國際基準及受當地相關法例監管
International benchmarking and national governance framework

全面的緊急應變計劃
Comprehensive plans for emergency preparedness

選址
Site Selection

大亞灣核電站的選址符合國際指引的規定，並通過中國國家核安全局嚴格的安全評估。

The site of Daya Bay Nuclear Power Station was selected according to international guidelines and after a stringent safety assessment by the National Nuclear Safety Administration.

站內主要建築物、系統及設施均可抵禦修訂麥加利地震烈度表八級的地震衝擊。

Key buildings, systems and facilities of the power station are designed to withstand the impact of an earthquake at Modified Mercalli Intensity Scale Level 8.

大亞灣核電站的地理位置
Geographical Location of Daya Bay Nuclear Power Station

選址符合以下的條件：

- 地震和海嘯的風險偏低
- 冷卻水供應充裕
- 人口密度低
- 連接可靠的電網
- 與民用飛機航道、主要城市及高風險工業設施有足夠的距離
- 輸電距離較短，將功率損耗減至最低

Site Selection met the following criteria:

- Low risk of earthquakes and tsunamis
- Abundant supply of cooling water
- Low population density
- Connection to reliable power grid
- Sufficient distance from commercial flight paths, major cities and hazardous industrial installations
- Short transmission distance to minimise power loss

量度地震震級

- **修訂麥加利地震烈度表**量度地震造成的衝擊
- **黎克特制震級**量度地震震央所發出的能量

Measuring the magnitude of an earthquake

- The **Modified Mercalli Scale** measures seismic impact
- The **Richter Scale** measures the amount of energy released at the epicenter

核電站與鄰近主要城市的距離
Distance between Nuclear Power Stations and Major Cities

決定核電站與鄰近主要城市的合適距離，須考慮以下因素：

- 確保公眾安全
- 把輸電過程中的功率損耗減至最低

The optimal distance between a nuclear power station and a major city is carefully considered to:

- Ensure communal safety
- Minimise power loss during transmission

核電站設計和安全操作
Plant Design and Operational Safety

核電站從初始設計、設備安裝以至執行運行程序，均貫徹縱深防禦的安全原則。

The defence-in-depth principle is applied from the initial plant design through to the installation of all equipment and the carrying out of all operational procedures.

反應堆燃料組件
A Nuclear Reactor Fuel Assembly

大亞灣核電站每個反應堆的堆芯均裝設41,448枝燃料棒，重量約80公噸。
Each reactor core at Daya Bay Nuclear Power Station is made up of 41,448 fuel rods and has a mass of about 80 tonnes.

每座燃料組件約4米高
Each fuel assembly is about 4 metres tall

157組 燃料組件 Fuel Assemblies

其中61組燃料組件，每組裝有24枝控制棒

61 of the fuel assemblies are equipped with 24 control rods each

控制棒可捕捉游離的中子，阻止其撞擊鈾原子核，以減慢鏈式反應的速度。控制棒能於兩秒內停止反應堆內的鏈式反應

Control rods slow down the chain reaction by capturing free neutrons before they collide with uranium atoms and can stop a chain reaction within 2 seconds

三重獨立保護屏障有效防止放射性物質外洩。

The three leak-tight barriers effectively stop radioactive materials from escaping into the environment.

三重獨立保護屏障
Three Leak-tight Barriers

反應堆壓力殼 Reactor Pressure Vessel

壓力殼由200毫米厚的鋼壁製成，將含有小量放射性物質的冷卻水密封在一迴路系統內

Its 200mm-thick steel wall keeps cooling water containing a minute amount of radioactive material within the primary coolant circuit

燃料包殼 Fuel Cladding

鈾燃料被密封在反應堆燃料棒的合金包殼內。燃料包殼能完全密封核裂變所產生的放射性物質，防止洩漏

Uranium fuel is sealed inside the metal alloy cladding of the fuel rod. The cladding encloses the radioactive material produced during nuclear fission and prevents it from escaping

安全殼 Containment Building

由900毫米厚預應力鋼筋混凝土結構製成，內裝有6毫米厚鋼板，以保護反應堆壓力殼。安全殼的結構非常堅固，足以抵禦大型商用飛機的撞擊

A 900mm-thick pre-stressed concrete structure with a 6mm-thick steel interior lining houses the reactor pressure vessel. The containment building can withstand the impact of a large commercial aircraft

嚴格的人員培訓和資格考核
Stringent Training and Qualifications of Operators

大亞灣核電站高度重視安全運行，為管治組織、管理人員及所有員工建立一套安全文化。

The Daya Bay Nuclear Power Station places great emphasis on nurturing a safety culture on its governing board and amongst management and staff.

與飛機師的訓練一樣，操縱員的培訓須投放大量資源及持續不斷地進行，以維持極高的專業水平。

Training to become an operator is like training to be a pilot – a huge amount of resources and continual training is required to uphold the extraordinarily high professional standards.

如何成為反應堆操縱員
Becoming a Reactor Operator

新員工 **New Employee**

在職培訓 On-the-job Training

- 基本技術理論及安全授權培訓
- Basic training on fundamental theory and safety authorisation

- 完成逾100個相關課程
- Complete over 100 related courses

- 由國家核安全局監督的操縱員培訓及執照考試
- Training for the Reactor Operator & Licensing Examination supervised by the National Nuclear Safety Administration

- 操縱員執照考試
- Operator licensing examinations

操縱員 **Operator**

- 每兩個月進行一次演習訓練
- Drill training every two months

- 必須通過每兩年一次的執照續期考試，方可繼續留任
- Must pass license renewal examinations every 2 years to remain in their post

- 持續培訓及參加執照考試，以晉升高級職位
- Further training and licensing examinations to advance to senior posts

監管與法規
Governance and Regulations

所有核電站營運者均受當地的相關法例所規管。國際間的協作是確保全球核安全的關鍵。

All nuclear operators are regulated under their national governance frameworks. International collaboration among countries is essential to achieve global nuclear safety.

中國核監管架構
China Nuclear Regulatory Structure

其他國際核能組織
Other International Nuclear Associations

輻射防護及環境監察
Radiation Protection and Environmental Monitoring

大亞灣核電站多年來對環境的輻射影響微不足道，遠低於國家嚴格的限值。

根據深圳市衛生局一項為期25年的研究結果顯示，大亞灣核電站及嶺澳核電站並沒有對附近居民的健康構成任何負面影響。

The radiation impact from the Daya Bay Nuclear Power Station over the years is minute and well within the stringent national limit.

Findings of a 25-year study by the Shenzhen Municipal Health Bureau show that Daya Bay and Ling Ao Nuclear Power Stations do not have any negative health impacts on nearby residents.

年輻射劑量 Annual Radiation Dose

0.25 毫希 mSv

核電站附近居民吸收的輻射劑量限值
limit for the people in the vicinity of the nuclear power station

2.4 毫希 mSv

香港居民吸收的本底輻射
background radiation received by Hong Kong residents

大亞灣核電站10公里範圍內的環境監測站
Environmental monitoring stations within 10 km of the Daya Bay Nuclear Power Station

- 氣象站 Meteorological Station
- 液體排放監測站 Liquid Discharge Monitoring Station
- 大氣輻射監測站 Atmospheric Radioactivity Monitoring Station
- 遙控伽馬射線源監測站 Remote-control Gamma Ray Monitoring Outpost

緊急應變
Emergency Preparedness

香港特區政府制定了「大亞灣應變計劃」，說明在大亞灣發生嚴重核事故時香港須採取的應變措施。

HKSAR government has put in place a comprehensive Daya Bay Contingency Plan outlining measures to be taken in the unlikely event of a serious nuclear accident at Daya Bay.

大亞灣應變計劃
Daya Bay Contingency Plan

大亞灣應變計劃
Daya Bay Contingency Plan

- 及時向公眾發布訊息
- 對方圓20公里內的居民採取撤離、屏蔽或服用甲狀腺封閉劑等措施
- 對方圓85公里內的食物及食水進行輻射污染監測
- 監控來自內地的食水及食物
- 定期監測環境伽馬射線的輻射水平
- 對從內地進入香港的人士進行輻射測試

- Timely communication with the public
- 20 km radius – Evacuation, sheltering or the use of stable iodine
- 85 km – Food and water monitored for contamination
- Monitoring water and food from the Mainland
- Regular monitoring of ambient gamma radiation levels
- Scanning people entering Hong Kong from the Mainland for radioactivity

緊急事故的通報機制
Communication Mechanism in Emergency Situations

緊急事件

一般來說，即國際核事件分級表*中的2級或以上事件，國務院頒佈《核電廠核事故應急管理條例》，規定國務院授權的政府機構須及時向公眾發布有關事件的訊息。

非緊急事件

即國際核事件分級表中0、1級或2級（非緊急性質）的事件。在確定事件之後兩個工作天內透過運營公司的網站公布。如涉及大亞灣核電站，中電旗下的香港核電投資有限公司將於同一時間在其網站上載事件的摘要，以通知公眾。

Emergency Events

During events level 2 or above on the International Nuclear and Radiological Event Scale (INES)*, the Regulation on Emergency Management of Nuclear Accidents at Nuclear Power Plants promulgated by the State Council requires authorised government agencies to communicate with the public in a timely manner.

Non-emergency Events

INES events at level 0, 1, and 2 of a non-emergency nature must be disclosed within two working days after their confirmation via the operation company's website. If the event is related to Daya Bay Nuclear Power Station, the Hong Kong Nuclear Investment Company Limited, a subsidiary of CLP, will simultaneously publish the event on its website to inform the public.

核電站必須在任何時刻作好應急準備。

Preparedness for any accident is at the heart of the nuclear power station's operation.

* 關於國際核事件分級表的詳情，請參閱第44頁
* Please refer to P.44 for the details of the INES

5 核廢料管理 Nuclear Waste Management

核廢料的種類 Types of Nuclear Waste

相比化石燃料所產生的廢料，核廢料的體積十分細小，只要妥善管理，便不會為人類及環境帶來損害。

When compared with fossil fuel waste, the volume of nuclear waste is minimal and can be safely managed without causing harm to people or the environment.

90% 低放射性廢料 **Low-level Waste**
受輕微污染的物件，例如工具及工作服，佔整體核廢料放射量的1%
Lightly-contaminated items like tools and work clothing account for 1% of radioactivity found in nuclear waste

7% 中放射性廢料 **Intermediate-level Waste**
使用過的過濾器、反應堆內的鋼組件，以及後處理所產生的污水，佔整體核廢料放射量的4%
Used filters, steel components from within the reactor and some effluents from reprocessing account for 4% of radioactivity found in nuclear waste

3% 高放射性廢料 **High-level Waste**
乏燃料，佔整體核廢料放射量的95%
Spent fuel accounts for 95% of radioactivity found in nuclear waste

資料來源：世界核能協會
Source: World Nuclear Association

相同發電量下所產生的廢料體積
The volume of waste produced to generate the same amount of power

1 : 1000

高放射性廢料只佔核廢料總體積的3%。

High-level nuclear waste accounts for only 3% of total nuclear waste volume.

大亞灣核電站所有的核廢料處理程序，均受到國家核安全局按照國際原子能機構的指引及慣例監管。

At Daya Bay Nuclear Power Station, all nuclear waste treatment processes are regulated by the National Nuclear Safety Administration based on guidelines and practices formulated by the International Atomic Energy Agency.

公眾關注
- 高放射性廢料在運送途中很容易發生意外及受到恐怖襲擊
- 放射性物質會對運輸路線的環境造成污染

事實
自1971年以來，全球各地的核電站對高放射性廢料進行了超過20,000次安全運送（總重量逾50,000噸），期間沒有對環境或人員健康構成任何損害或影響。

Public Concerns
- High-level waste is vulnerable to accidents and terrorist attacks during transportation
- Radioactive materials will pollute the environment along its transportation route

Facts
Since 1971, there have been more than 20,000 safe shipments (over 50,000 tonnes) of high-level waste worldwide with no damage to the environment or health hazard to the personnel involved.

資料來源：世界核能協會
Source: World Nuclear Association

燃料循環管理
Fuel Cycle Management

核燃料循環的流程包括開採及處理鈾原料、使用核燃料發電，最後是乏燃料（使用過的核燃料）後處理或核廢料處置。

The nuclear fuel cycle covers the whole process of uranium mining and treatment, use of nuclear fuel for power generation, and the reprocessing of spent fuel (used nuclear fuel) or its disposal as waste.

經玻璃固化的高放射性廢料

在已發展國家中，若只使用核能發電，一個人一生產生的高放射性廢料的體積，大約等如一罐375毫升的汽水。若以人均計算，每人每年所產生的乏燃料只有30克。

Vitrified High-level Waste

Generating enough electricity for one person produces just 30 grams of spent fuel each year. In a developed country, the typical amount of vitrified high-level waste produced using nuclear electricity over the lifetime of a person has a volume equivalent to a 375ml can of soda.

後處理
Reprocessing

後處理廠及核廢料儲存庫與核電站一樣，均受所屬國家特定的安全法規監管，其設計、建造、營運及退役必須符合有關規例及要求。

Like nuclear power stations, reprocessing plants and nuclear waste repositories are subject to safety regulations specific to each country. They are designed, built, operated and decommissioned in compliance with the relevant regulations and requirements.

後處理設施與市中心的距離
The Distance between Reprocessing Facilities and Town Centres

約有 About

17%

的法國核能發電量，是經後處理的乏燃料所產生。

of France's total nuclear power output is produced from reprocessed fuel.

乏燃料的後處理是世界核工業的重要一環，亦已被納入中國的國策中。

Reprocessing nuclear spent fuel is an essential part of the nuclear industry worldwide and has been adopted as a national policy in China.

約96%的乏燃料（包含鈾和鈈）經提取後可重新用來發電。

About 96% of spent fuel (containing uranium and plutonium) can be extracted and reused for energy generation.

圖片來源：塞拉菲後處理廠
Source: Sellafield Ltd

臨時儲存和永久儲存
Interim and Permanent Storage

核廢料經仔細的表徵鑒定及調整後，會被密封包裝並運送至儲存設施。核廢料的儲存過程及質素均有妥善記錄。

After careful characterisation and conditioning, nuclear waste is packaged and transported to disposal facilities. The disposal and quality of nuclear waste are carefully documented.

資料來源：世界核能協會
Source: World Nuclear Association

水可用來冷卻高溫的乏燃料及屏蔽其放射性。反應堆內的乏燃料會在水中被移送至乏燃料儲存水池。約8至10年後，便可轉為以乾式儲存方法存放。兩類貯存方式皆是世界認可的成熟技術。

Water can cool hot spent fuel and shield its radioactivity. Spent fuel in a reactor is removed underwater and transferred to a spent fuel pool. After 8 to 10 years it can be transferred to dry cask storage. Both storage methods are well established in the world.

乏燃料儲存水池由堅固的鋼筋及混凝土結構加上鋼製襯裡組成。

The **spent fuel pool** is a robust construction made of thick reinforced concrete with steel liners.

圖片來源：美國核能管理委員會
Source: Nuclear Regulatory Commission

乾式儲存是將乏燃料儲存在由混凝土及鋼筋製成的通風儲存模組內。

Dry cask storage is spent fuel inside a ventilated storage module made of concrete and steel.

地下深層儲存庫

1. 在後處理過程中抽取高放性核廢料，以玻璃固定，並包裝在金屬儲存罐中
2. 將金屬罐放置在地下深處的儲存庫
3. 將混凝土灌入儲存庫，使之與環境隔離

Underground Geological Repository

1. High-level waste is extracted from spent fuel by reprocessing. It is then immobilised in glass and packed in metal canisters
2. Canisters are loaded in a deep underground repository
3. The repository is filled with concrete to isolate it from the environment

公眾關注
- 核廢料對環境的破壞將連延數十萬年
- 地下埋置的核廢料可能會污染地下水達數百年

事實
- 核廢料的放射性會自然衰減，且輻射壽命有限
- 只要妥善處理核廢料，便不會傷害人類及環境

Public Concerns
- The environmental impact of nuclear waste will remain hazardous for hundreds of thousands of years
- Underground disposal could poison ground water for centuries

Facts
- The radioactivity of nuclear waste naturally decays and has a finite radiotoxic lifetime
- Properly disposed of nuclear waste will not harm people or the environment.

資料來源：世界核能協會
Source: World Nuclear Association

廢料會被密封於儲存罐內
Waste is packed in sealed drums

中及低放射性廢料 Intermediate- and Low-level Waste → 臨時儲存 Interim Storage → 永久儲存 Permanent Storage

廢料儲存庫
Storage for intermediate and low-level waste

退役
Decommissioning

核電站的設計壽命一般為40年。若審慎營運和妥善維修，現代化壓水式反應堆的壽命可延長至約60年。

Nuclear power stations are designed to have a typical working life of 40 years. Given prudent operation and maintenance, the lifespan of modern pressurised water reactors can be extended to around 60 years.

在運行年期終結時，核電站營運者須安排電站退役，包括關閉及拆除廠房設施，並在清除輻射污染後，才會將廠址轉作其他用途。整個退役程序需時數十年。

At the end of their useful lives, nuclear power stations have to be decommissioned and demolished. Their sites must then be decontaminated before being released for general use. Full decommissioning normally takes several decades.

位於美國的希平港核電站，已於1985年拆卸
Shippingport Atomic Power Station in the US, demolished in 1985

圖片來源：原子能委員會，Addison Wesley出版公司
Source: Atomic Energy Commission, Addison Wesley Publishing Company

英國Chapelcross核電站的冷卻水水塔於2007年拆卸
Demolition of the cooling towers at the Chapelcross Nuclear Power Station in the UK in 2007

圖片來源：Magnox有限公司
Source: Magnox Limited

6 嚴重核事故 Severe Nuclear Accidents

國際核事件分級表 INES

國際原子能機構於1990年制定國際核事件分級表，以協助公眾了解有關核事件的安全影響。

The International Atomic Energy Agency (IAEA) set up the International Nuclear and Radiological Event Scale (INES) in 1990 to facilitate communication to the public on the safety impact of nuclear events.

0 低於本表級別，對安全無重要影響 **Below Scale, No Safety Significance**

★ 事故 Accident ★ 事件 Incident

每宗核電站運行事件必須經過核實、匯報、分析及糾正，以防止同類事件再次發生。

All Licensing Operational Events (LOEs) must be verified, reported, analysed and rectified to prevent any recurrence in the future.

零級的核電站運行事件並無安全影響，也不會對外界環境及公眾安全構成影響。核電站通常以此作為內部參考及經驗反饋。

Level 0 LOEs carry no nuclear safety significance and they have no impact on the external environment or public safety. Nuclear power stations will use them for internal reference and improvement.

核電站內發生的事件一旦在國際核事件分級表上被評級，就會被視為「核電站運行事件」。

按照一般國際慣例，如採用壓水式反應堆的核電站出現嚴重事故，只有方圓5公里範圍內的居民才須疏散，10公里範圍內的居民則須採取屏蔽措施。

Any event that happens in a nuclear power station that qualifies for the INES scale is considered as a LOE.

According to general international practice, in the event of a serious accident in a pressurised water reactor nuclear power station, only those within 5 km of the power station need to be evacuated, while sheltering is required within the 10km zone.

核事故
Nuclear Accidents

核電站若管理不善，會造成嚴重的後果。切爾諾貝爾核電站事故及近年發生的福島核電站事故受到廣泛關注，亦促使各國加強合作，提高核電安全。

There can be serious and unwanted consequences if a nuclear power plant is not properly managed. Nuclear accidents such as Chernobyl and the more recent Fukushima triggered widespread concern and brought about international cooperation to improve nuclear safety.

切爾諾貝爾核電站事故

日期：1986年4月26日
地點：前蘇聯烏克蘭蘇維埃社會主義共和國普裡皮亞季
國際核事件分級：7級

Chernobyl Nuclear Power Plant Accident

Date: 26 April, 1986
Location: Pripyat, Ukrainian SSR in the Former USSR
INES: Level 7

事故 The Accident

1

為了進行測試，4號機組若干安全設備被關掉
Certain safety systems were deliberately disabled for testing purposes at Unit 4

2

反應堆在低功率及不穩定的情況下，運行了數小時
The reactor was operating in an unstable condition at low power for several hours

3

4號機組發生蒸汽爆炸，反應堆損毀，引發火警
A steam explosion within Unit 4 damaged the reactor, causing a fire

4

大量輻射外洩，波及電廠數百公里外的地區
A large amount of radioactivity was released, affecting up to several hundred kilometres away from the plant

傷亡 Casualties

31 名工人 WORKERS
直接因事故死亡
died as a direct result of the accident

>130 宗 CASES
輻射傷害個案
of radiation injuries

336,000 人 PEOPLE
被撤離
were evacuated

20,000 宗 CASES
甲狀腺癌個案（截至2016年）
of thyroid cancer as of 2016

7,000,000 人 PEOPLE
因撤離、復康或在受污染的土地上居住而承受心理影響
psychologically effected due to evacuation, the recovery process or living on contaminated land

圖片來源：世界核能協會
Sources: World Nuclear Association

成因

- 核電站設計沒有足夠的安全功能或保護
- 操作人員不了解測試的風險，反覆違反程序，以及沒做好應急準備
- 營運者缺乏安全文化或對安全的承擔
- 沒有執行安全監管

教訓及改善

- 世界核營運者協會成立，促進業界就核安全和管理模式分享經驗，以提高核行業的安全營運水平
- 國際原子能機構及經濟合作與發展組織的核能機構制定了「國際核事件分級表」，以加強在核事故時對外的溝通

Causes

- The plant design did not have enough safety features or protection
- The operator did not understand the risk of the test, repeatedly violated procedures and did not prepare for accidents
- The organisation did not have a culture or commitment for safety
- Safety regulations were not enforced

Lessons Learnt and Enhancement

- Establishment of the World Association of Nuclear Operators (WANO) to enhance the exchange of best practices and safer operation among members of the nuclear industry
- Set up of the INES by International Atomic Energy Agency (IAEA) and Nuclear Energy Agency (NEA) of Organisation for Economic Co-operation and Development (OECD) to enhance external communications during nuclear accidents

福島第一核電廠事故

日期：2011年3月11日
地點：日本福島
國際核事件分級：7級

Fukushima Daiichi Nuclear Power Plant Accident

Date: 11 March, 2011
Location: Fukushima, Japan
INES: Level 7

事故 The Accident

1

極其罕見的黎克特制9級地震引發高達15米的大海嘯，導致核電站6台發電機組中的其中4台內外供電全部中斷

An extremely rare Richter Scale 9 earthquake triggered a massive 15-metre tsunami which disabled both internal and external electric power for 4 out of 6 generating units

2

冷卻功能失效令1至3號機組的反應堆堆芯溶解，導致氫氣爆炸，4號機組其後亦發生同類爆炸

Loss of cooling caused a meltdown of the reactor cores at Units 1-3, and hydrogen explosion. Unit 4 suffered from the same explosion later

3

輻射洩漏至大氣和海洋

Radioactivity was subsequently dispersed into the atmosphere and the sea

傷亡 Casualties

2 名工人 WORKERS

死於海嘯
drowned by the tsunami

>170 名工人 WORKERS

暴露於超過100毫希的輻射劑量，但沒有錄得與輻射相關的死亡及疾病個案
exposed to radiation above 100mSv but no radiation-related death or sickness

約AROUND 86,000 人 PEOPLE

疏散，範圍遠至核電站方圓50公里。另外約74,000人自願撤離
in up to 50km of the nuclear power plant were evacuated, and another 74,000 left voluntarily

>1,000 人死亡 DEATHS

主要與撤離過程所帶來的壓力、恐慌及缺乏醫療照顧有關
mainly due to stress, trauma and lack of medical attention caused by evacuation

成因

- 核電站沒有足夠的安全設施來抵禦嚴重天災
- 營運商沒有做好應付嚴重事故的準備
- 即使已知有嚴重天災的風險，電力公司亦沒有積極改善安全設備

教訓及改善

- 調查報告指出這是「人為」的災難而非天災，亦與反應堆設計無關
- 世界各地廣泛關注核電站的安全和其抵禦極端天災及多重事故的能力
- 各國政府對所有運行中的核電設施進行安全檢查
- 國際上出現不同的討論平台，研究和商討如何加強核安全及提升核電站的應變能力
- 日本核能監管機構和法規全面改革

Causes

- The plant did not have enough safety protection against extreme natural hazards
- The operator was not well prepared for severe accidents
- The organisation did not carry out safety improvements even when extreme natural hazards became known

Lessons Learnt and Enhancement

- The investigation report concluded that the disaster was "manmade" instead of "natural", and not related to the reactor design
- The international community expressed widespread concern about the readiness of nuclear power stations to withstand extreme natural disasters and multiple events
- Safety checks were conducted for all existing nuclear facilities worldwide
- Various national and international platforms were established to review and discuss ways to strengthen nuclear safety and enhance the capabilities of nuclear power stations to handle emergencies
- Overhaul of the nuclear regulator and regulations in Japan

大亞灣核電站在福島事故後的安全檢查

事故發生後，中國政府要求全國核設施進行安全檢查，結果顯示大亞灣核電站符合國家安全標準及最新的國際作業模式。大亞灣與時並進，推行了多項改進措施，以進一步提升核安全：

- 提升核電站抗震及防洪能力
- 增加後備供電及冷卻水供應
- 改進安全分析，特別是地震及海嘯帶來的影響
- 完善應急準備及協調工作
- 加強公眾溝通

Post-Fukushima Safety Review at Daya Bay

A safety review was carried out at all nuclear facilities nationwide after the accident. The review confirmed that Daya Bay meets national safety standards and the latest global practices. To match world upgrades, a number of enhancements were implemented at Daya Bay to further strengthen nuclear safety:

- Plant improvements against earthquake and flooding
- Addition of backup power and cooling water supplies
- Refinement of safety analysis especially regarding earthquake and tsunami impact
- Enhancement of emergency preparedness and coordination
- Enhancement of public communication

今天的切爾諾貝爾與福島
Chernobyl and Fukushima Today

切爾諾貝爾

圖片來源：切爾諾貝爾核電站
Sources: SSE Chernobyl NPP

- 毀壞的反應堆仍然在屏蔽中
- 受影響地區的進出管制已逐漸解除，而自2010年起的重置計劃則仍在白俄羅斯進行
- 由於當地人迹罕至，野生動物的數量大增

Chernobyl

- A confinement continues to shield the ruined reactor
- Restrictions in affected regions have been gradually lifted and resettlement projects in Belarus have been on-going since 2010
- In the absence of human activities, the area sees an increase in wild life population

資料來源：世界核能協會(2016)，國家地理雜誌(2016)
Sources: World Nuclear Association (2016), National Geographic (2016)

透過世界核能協會的短片了解詳情
Find out more in the video by the World Nuclear Association

福島

- 輻射水平逐漸下降，福島附近地區的進出管制及當地生產食品的出口限制逐漸解除
- 受災民眾因輻射增加患癌的風險，以終身計算，罹患癌症的風險比正常情況高出約1%
- 撤離民眾的生活條件改善及心理壓力紓緩後，健康狀況逐步改善

Fukushima

- Radioactivity gradually decreases, allowing the restrictions on certain regions and local food to be gradually lifted
- Cancer risk due to radiation within the affected population has an additional lifetime risk of around 1%
- Gradual health improvement of the evacuees following an improvement of living conditions and reduced psychological stresses

資料來源：世界衛生組織(2013)，輻射防護及核安全研究所(2017)
Sources: World Health Organization (2013), Institute for Radiological Protection and Nuclear Safety (2017)

7 世界核能發展
Global Nuclear Development

於2017年，全球共有超過440座核反應堆，遍佈30個國家。
As of 2017, there are over 440 nuclear reactors spread across 30 countries.

歐美的核能發展相對成熟。而不少發展中國家正積極落實採用核能，以解決能源及環境問題。

Nuclear power is widely used in the US and in Europe. Many developing countries are actively implementing nuclear programmes to address energy and environmental issues.

擁有最多核反應堆的國家
Countries with the Highest Number of Nuclear Reactors

使用核電比例最高的國家
Countries with the Highest Proportion of Electricity Generated by Nuclear Power

查看更多核能發展數據
More information on global nuclear development

資料來源：世界核能協會
Source: World Nuclear Association

中國核能發展
Nuclear Development in China

為響應《巴黎協定》及「十三五」規劃更嚴格的減排要求，中國正興建更多核反應堆，為國家提供高效、可靠和潔淨的能源。

In response to the Paris Agreement and stricter emissions control under the 13th Five-Year Plan, China is building more nuclear reactors to provide efficient, reliable and clean energy for the country.

因為燃煤發電廠造成的空氣污染愈來愈嚴重，中國正逐步提高核電在能源組合中的比重。

Air pollution from coal-fired plants is one of the main drivers behind nuclear power's increasing role in China's energy mix.

根據「十三五」規劃，中國在2020年的核電裝機容量將達到5,800萬千瓦。

According to the 13th Five-Year Plan, China's installed nuclear capacity will reach 58 million kilowatts by 2020.

位於廣東省的核電站
Nuclear Power Stations in Guangdong Province

資料來源：國家核安全局(2018)
Source: National Nuclear Safety Administration (2018)

核電在中國內地的燃料組合中，將擔當重要的角色。
Nuclear power is going to play an important role in Mainland China's fuel mix.

中國內地年發電量展望
Projections of Annual Electricity Generation in Mainland China

資料來源：美國能源資訊局(2017)
Source: U.S. Energy Information Administration (2017)

未來核技術
Future Nuclear Technology

核能未來發展，主要朝向更有效地利用資源，進一步提升核裂變反應堆技術的安全水平和經濟效益的方向邁進，同時把握核聚變技術的發展潛力。

The future development of nuclear energy includes better utilisation of resources, further improvement of safety and economy of fission reactors, and tapping into the potential yet challenging prospect offered by nuclear fusion.

第一代 Gen I

1950至60年代
- 早期的原型反應堆

1950 – 60s
- Early prototype reactors

第二代 Gen II

1960年代中期
- 現今運行的核電站中，約九成採用第二代技術
- 具備小量非能動(不需要外求動力)的安全設計，即採用重力、自然對流或高壓的原理來運作
- 包括沸水式反應堆及壓水式反應堆

Mid 1960s
- Includes about 90% of nuclear power plants operating today
- Incorporates some passive (without requiring external power source) safety features, meaning to rely on gravity, natural convection or high pressure
- Includes Boiling Water Reactors, and Pressurised Water Reactors

第三代 Gen III

1990年代中期
- 先進的反應堆，具備更多非能動安全系統，能夠在沒有人為干預或電力驅動的情況下運作
- 提高了反應堆的安全性
- 包括歐洲壓水式反應堆、西屋AP1000及華龍一號

Mid 1990s
- Advanced reactors with more passive safety systems that can operate without human intervention or electrical power
- Enhanced reactor safety
- Includes European Pressurised Water Reactor (EPR), the Westinghouse Advanced Passive 1000 (AP1000) and Hualong One

第四代 Gen IV

2010年代
- 正處於概念設計階段
- 更有效運用燃料資源、減少核廢料數量，並縮短將放射性降至安全水平所需的時間

2010s
- Currently in a conceptual design phase
- Designed to better utilise fuel resources, reduce waste volume and shorten the time taken for its radioactivity to fall to a safe level

未來的技術 Future Technology

高溫氣冷式反應堆 High-temperature Gas-cooled Reactor
- 具失效安全功能，使反應堆能夠透過非能動的方式進行降溫
- 發電效能提高
- Fail-safe feature enables reactors to cool down by passive means
- Higher generation efficiency

快中子反應堆 Fast Neutron Reactor
- 採用高濃度的鈾235和鈈239
- 相同燃料數量，但發電量能提高60倍
- Uses highly-enriched uranium 235 and plutonium 239
- Can generate 60 times more energy with the same amount of fuel

聚變反應堆 Fusion Reactor
- 通過聚合不同形態的氫氣(即氘和氚)來發電
- 最終產物是無放射性的氦，即不會產生高放射性廢料
- Generates energy by fusing different forms of hydrogen (i.e. deuterium and tritium)
- The end product is radiation-free helium, which means no high-level radioactive waste is generated

參考資料
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www.clpgroup.com/nuclearenergy

大亞灣核電站及嶺澳核電站圖片來源：
Source of the photos of Daya Bay and Ling Ao Nuclear Power Stations:
大亞灣核電運營管理有限責任公司
Daya Bay Nuclear Power Operations & Management Co., Ltd.

國旗圖片來源：
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