National Education Series for Teachers:
(3) Energy Resources and Environmental Governance of Our Country

Speaker:
Dr. MAH Ngar-yin Daphne
Associate Professor, Department of Geography, Director, Asian Energy Studies Centre, The Hong Kong Baptist University

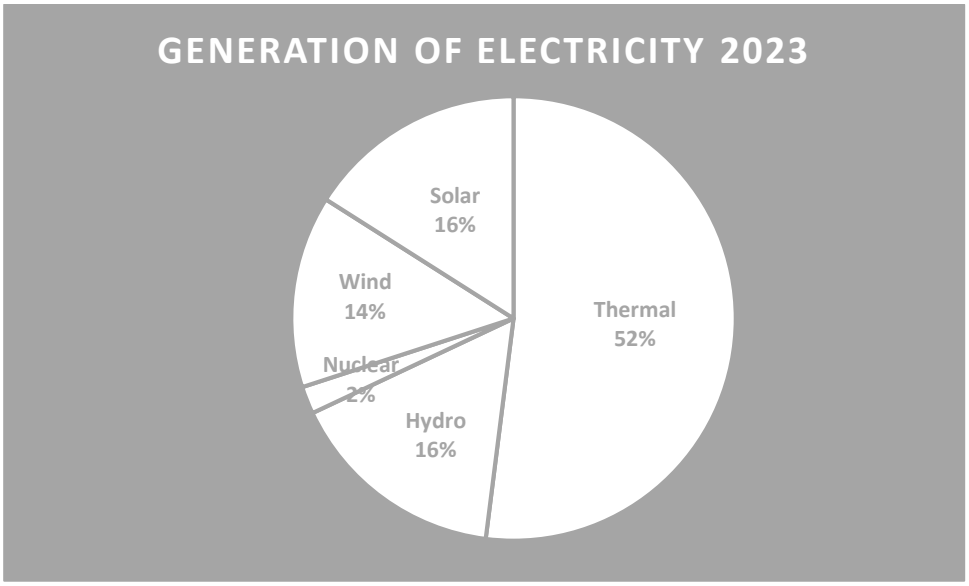
Date: 19 March 2024 (Tuesday)

I. An overview of the energy development in China

A. Overview

China is accelerating the promotion of low-carbon energy transformation

- Enhancing the stability of power supply
- "2030 Peak Carbon Emissions" and "Carbon Neutrality by 2060"
- Reducing coal-fired power generation
- Continuing the development of renewable energy
- Strengthening energy conservation"



- Coal : about 52% of its electrical power installed capacity (發電機組裝機容量).
- It is dependent on hydro for 16%
- A modest amount for wind (14%), solar (15%)
- Nuclear (2.2%)

Thermal	Hydro	Nuclear	Wind	Solar
133329	41406	5553	36564	39268

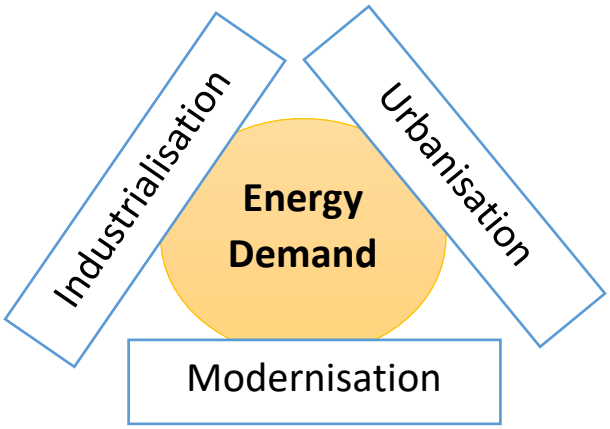
Unit: 10000kW

https://www.stats.gov.cn/sj/ndsj/2023/indexeh.htm

Energy is driving the rapid development of China's economy.

- Area: 9.6 million km2 (~US)
- Population continues to growth: 1.41 billion (2022) population (1/5 of the world's population) - the most populous country in 2022
- Economic reforms since 1978 – from a command and planned economy to a more market-based economy
- Rapid economic growth: 3 decades of double-digit growth - about 10%/yr since 1978; world's second-largest economy – GDP: US$17.96 trillion (2022)
- GPD growth: 2007-2017: 8.2% (growth rate per annum); 2018: 6.6%; 2022: 3%
- World's largest developing country: GDP per capita - US$12,720.2 (2022)
- Structure of the economy rapidly changed: industrialisation and urbanisation

Three driving forces in China's energy system



Major challenges of energy developments in China

Economic Challenges	✚	**Environmental Challenges**	✚	**Social Challenges**
• Energy security • Power shortage				

B. Energy in China: Five major features & trends

- Reducing the reliance on coal, while coal continues to dominate as a fuel
  Coal - 2010:73% -> 2022: 52%
- Rapid growth in the scale of electricity sector
  - China's first power generation: launched in 1882 in Shanghai, with an installed capacity of 11.67 kW.
  - How "big" was this 1st power plant in Shanghai? For a 11.67 kW power plant to operate for one hour, it can generate 11.67 kWh of electricity which allows an IC Cooker to operate (hence to have hotpot) for 4 hours.
  - The growth rate of China's electric power in the mid-2000s - "the largest in history"
  - Installed capacity (發電裝機總容量) - 2020: 31932 -> 2022: 256794
- Rapid growth in energy consumption
- China has remained as the world's major GHG emitter
  - In 2006 - Along with economic growth, China emitted over 6.2 billion tons of CO2 and surpassed the U.S. (5.8 billion tons CO2).
    http://www.theguardian.com/environment/2007/jun/19/china.usnews China: http://www.eia.gov/countries/country-data.cfm?fips=CH#cde US: http://www.eia.gov/countries/country-data.cfm?fips=US#cde
  - CO_2 emission per capita: Chinese CO_2 emission per capita was 7.6 tons in 2019, while the average per capita carbon dioxide emissions worldwide is 4.78.
  - The electricity sector: contributed to about 50% of the total national CO_2 emission in 2020 (Wang, Lin et al. 2021, IEA 2022)
    (Source: World Bank: http://data.wohrltdtbpasn:k/./owrgw/inwd.isctaatotirs/tEaN..cAoTmM./CsOta2tEi.sPtCic/cso/u2n6t8ri7es5/31W/c-oC2N--eUmS?idsissipolanys=-gpraeprh-c)apita-worldwide-since-1990/)
- Energy resource endowment – abundant, but the geographical distribution is very uneven across China

Regional distribution of energy resources, economy and energy use in 1990 (%)

	North China	Northeast China	East China	Central China	Southwest China	Northwest China
Energy resources of which:	32.3	5.9	9.6	8.5	23.7	20.0
Coal	43.2	5.8	11.4	6.2	9.9	23.5
Hydropower	1.2	2.0	3.6	15.5	67.8	9.9
Oil & Natural gas	10.0	47.8	18.4	8.	4.7	11.1

Zhang, Z. (1998). The economics of energy policy in China : implications for global climate change / Cheltenham, UK; Northampton, MA, USA: Edward Elgar., p. 54

Xinjiang – China's major energy base

	National total
Coal reserves	40%
Oil reserves	25%
Natural gas reserves	30%
Wind energy resource	25%

C. Four energy technological developments in China

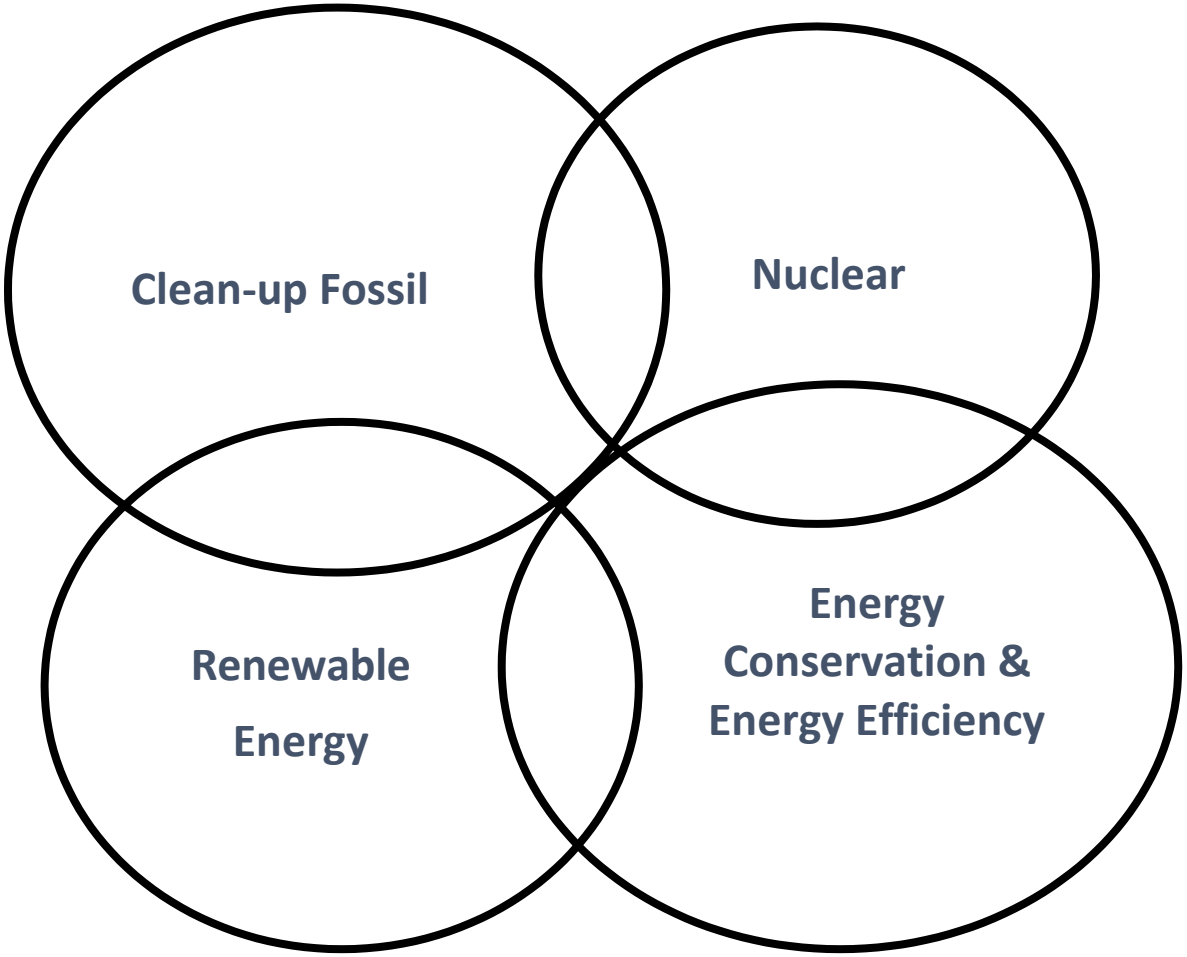
1. The Three Principles of Sustainable Energy Development:
   a) Economic sustainability: Affordability, Reliability (energy security) and Efficiency
      - Durable economic growth, financial stability, a low and stable inflation
   b) Environmental sustainability: Low Emission and the Resilience of Biophysical Systems
   c) Social sustainability: Acceptability & Accessibility

Sustainable Energy … the adequate and secure supplies of energy at affordable prices with low or even zero environmental impacts whilst there is a high public acceptability on those energy decisions that have been made.

SE Principles	Coal	Oil	Natural Gas	Nuclear	Hydro	Other RE (e.g. solar, wind)
Environment: **Low emission and resilience**	"The dirtiest fossil fuel"	High emissions; oil spills	• Lower (and yet still high) emission • Still emits NOx and particulates	• Low carbon emission in power generation • Used fuel disposal • Consumes large amount of fresh water	• Low carbon emission in power generation • Impacts on hydrology • Sediments • erosion	• Low carbon emission in power generation • Wind: siting concern (visual, noise)
***Economy*:** **Affordability, Reliability & Efficiency**	• Finite in supply • Coal mines are not always located at places of high demand (e.g. Guangdong) • rail transport	• Finite in supply • Uneven global distribution • Price fluctuation	• Finite in supply • Uneven global distribution • Price fluctuation	• Uranium: Finite in supply • High construction cost (Cost Overrun)	• No fuel required • Geographically limited	• No fuel required • many RE are not yet cost competitive • Major uptake of RE has resulted in noticeable price increases (e.g. Gr, It, Japan) • Intermittency and grid connection limitations • Geographically limited
Society: **Accessibility, Acceptability**	NIMBY problem	• Wars • NIMBY problem	• Wars • NIMBY problem	• NIMBY problem • Relocation of locals • Land to be abandoned for decades	• Relocation of locals	• Green jobs • Biofuel: food price; farmland availability

				• Unbearable risk?		

Four Major Energy Approaches



2. Energy technological option (1): Cleaning up fossil fuels and carbon markets
   a) Major technological developments of cleaning up coal in China:
      - Carbon capture, utilisation and storage (CCUS) technologies: involve capturing and compressing carbon dioxide emitted from power generation and industrial facilities,
      - storing it securely underground or moving it for use in other applications such as enhancing oil production.
      - CCUS projects are capital intensive, complexity and small scale of the industry have kept costs high.

        https://www.pngwing.com/en/free-png-pszcq
   b) China's national emission trading scheme (started in 16 Jul 2021)
      - When: China's national ETS began operating in July 2021
      - Objective: contribute to the effective reduction of carbon emissions.
      - Market scale: the world's largest in terms of covered emissions, estimated to cover more than 4 billion tonnes CO_2 and accounting for over 40% of the country's carbon emissions.
      - The China national ETS regulates more than 2,000 companies from the power sector with annual emissions of more than 26,000 tonnes CO_2, including combined heat and power, as well as captive power plants in other sectors.
      - It is an intensity-based system, with allowances freely allocated using benchmarks and based on actual production levels.
   c) How does Emission Trading work:

Cap	✚	Allocation	✚	Trade	=	Target

      - Cap: e.g. A region/ a country/ a city – cap the total emission levels
      - Allocate: Emission quotes (e.g. a permit to emit one tonne of CO_2) are allocated to power plants, factors or other polluting sources
      - Trade: companies can choose:
        - ➢ Companies can buy and sell emission permits at carbon exchanges (e.g. Chicago Carbon Exchange, European Climate Exchange, Beijing Environmental Exchange)
        - ➢ CO_2 has a price tag: the price of tradable permits change according to market supply and demand, similar to stock exchange
        - ➢ Companies can choose:
          - o They can clean up emission in its own power plant (e.g. through installing flue-gas-desulphurisation units) to meet the "allowable" emission levels
          - o Some may do better than require – have spare emission permits – can sell
          - o Some may find it too costly to cut emissions in its own factor – can buy from the market
   d) China's National Emission Trading Scheme
      - As of 29 December 2023:
        - ➢ Cumulative transaction volume: 442 million tonnes CO_2,
        - ➢ Cumulative transaction value: 24.919 bn CNY (≈ 27.7 bn HKD)
        - ➢ Daily composite price closed between 41.46-81.67 CNY (≈ 46 – 90 HKD) per tonne.

          https://m.bjx.com.cn/mnews/20240103/1353882.shtml
   e) Useful references:
      - (IEA, 2020) https://www.iea.org/reports/chinas-emissions-trading-Scheme

- Zhang, Z. (2015). Carbon emissions trading in China: the evolution from pilots to a nationwide scheme. Climate Policy, 15(sup1), S104-S126. doi:10.1080/14693062.2015.1096231

3. Energy technological option (2): Nuclear Power
   a) Current status:

   Number of nuclear reactors (核反應堆):

   - 53 operating (2022)
   - 18 under construction (2022)
   - 2 under construction in Guangdong – Yangjiang and Taishan (2019)
   - Nuclear share: 2.2% of China's total power generation installed capacity – as of 2022 (Source: China Statistical Yearbook 2023)

   b) Post-Fukushima Nuclear Policy in China
   - Nuclear expansion plan is picking up its pace again
   - But, with more restrictions:
     - Locations: Only coastal projects, but not inland projects, can be approved
     - Technological requirements: only those projects with state-of- the-art technology can be approved: the third generation

4. Energy technological option (3): Renewable Energy
   a) Hydropower, wind power and solar power
   b) Achievement 1: a global leader in RE installation
   https://www.ren21.net/wp-content/uploads/2019/05/GSR2022_Full_Report.pdf
   c) Achievement 2: Global Leader in manufacturing markets of RE technologies
   - China is the home of major renewable energy industries, including global leaders of solar and wind turbine manufacturers
   - Many of the global top 10 solar PV and wind turbine

LONGi Solar (隆基綠能)	TrinaSolar (天合光能)	Goldwind
Ranked 1st solar module manufacturer globally in 2021	Ranked 2nd solar module manufacturer globally in 2021	Ranked 4th wind turbine manufacturer globally in 2022

Sources:

- Solar: https://www.blackridgeresearch.com/blog/top-solar-pv-module-panel-manufacturers-companies-suppliers-producers
- Wind: https://www.blackridgeresearch.com/blog/top-wind-turbine-manufacturers-makers-companies-suppliers

- Green economy – creation of green jobs

Year	Newly installed turbine capacity (gigawatts)	Share of turbines domestically produced (percent)	Turbine capacity domestically produced* (gigawatts)	Investment in turbine production (billion yuan)	Direct employment (jobs created)
2006	1.3	45	0.6	3.8	3660
2007	3.3	58	1.9	12.4	12010
2008	6.2	76	4.7	18.6	18050
2009	13.8	80	11.0	44.2	42850
2010	16.0	80	12.8	51.2	49670
Total (2006-10)					126240

*Because some of China's annual added turbine capacity is imported equipment, the table breaks out the portion of capacity produced only by domestic manufacturers.

d) Achievement 3: Marked cost reduction in RE technologies in China
   - Cost reduction of solar power in China (~90% cost reduction from 2010 to 2018.
   - Hydropower
     - China has abundant hydropower resources (542 GW) – the richest in the world
     - Global leader in hydropower

The Three Gorges Dam
- Significance: the biggest infrastructural project in China after the Great Wall was built 2,500 years ago
- Construction: started in 1994
- Scale: the dam - 185 m high; the reservoir - 600 km long covering approximately 1,100 – 1,500 km^2.
- Purposes:
  - Flood control: China was devastated by the worst flooding in 44 years in 1998. (33 million people affected)
  - Improve river transport: Increase ship size from 2,000 tonnes to 10,000 tonnes
  - Generate electricity from hydropower plant

Environmental impacts of the Three Gorges Dam

1st order	Hydrology e.g. decrease velocity	Water quality e.g. temperature, suspended sediment, dissolved oxygen	Sediment e.g. decrease sediment supply	Geology e.g. waves
2nd order	Climate e.g. increase evaporation, distribution of precipitation	Habitat e.g. floodplain, connectivity, habitat complexity	Channel Change e.g. landslide, flooding	Resources lost e.g. food resources, clean water
3rd order	Aquatic fauna e.g. rare species decline, endemic species decline, biodiversity			

Tullos, D. (2009). Assessing the influence of environmental impact assessments on science and policy: An analysis of the Three Gorges Project. Journal of Environmental Management, 90, S208- S223.

- Wind power
  - 1986: China's first wind farm built in Shandong
  - Impressive growth since 2005
  - Annual growth rate – 100% (2005- 2009)
  - slowed down to 15-25% from 2010- 2013
  - China's installed capacity of wind turbines went from 0.743GW in 2004, to 25.81GW in 2009, and to 209GW in 2019 (CWEA, 2014; China Statistical Yearbook 2020)

A wind farm in Xinjiang Hami (one of the wind farms in the wind power base in Xinjiang (新疆哈密風電基地二期三塘湖 第一風電場 A 區 200 MW 項目)

- Installed capacity: 200 MW
- Land occupied: 51 km^2 (greater than the total area of Kowloon, i.e. 46.94 km^2)

  - Using larger wind turbines
    - the averaged size of the wind turbines installed in Chinese wind farms increased from 618.32 kW per unit in 2000 to ~1700 kW per unit in 2013.
    - 2013: the mainstream products of Chinese wind turbines were 1.5 MW and 2 MW turbines
    - by end 2013, 65.4% and 16.6% of installed turbine capacities are 1.5 MW & 2 MW respectively
    - 2017: 5 MW
    - The growth in turbine size serves as an important indicator for China's progress in wind technology manufacture capability.
  - Domesticalisation of wind turbine industry (風機國產化)
    - China's wind turbine technology has originated from developed nations, mostly from Europe.
    - Only approximately 11% of the wind turbines installations added in 2003 supplied by Chinese manufacturers
    - but 88% in 2013; … 90% in 2018
    - Critical to cost reduction
      https://www.weforum.org/agenda/2017/08/how-china-is-leading-the-renewable-energy-revolution

- Going offshore
  - Offshore wind – a largely untapped resources in China
  - 1st offshore wind farm in China: Shanghai - 34 turbines x 3MW (2010)
  - More offshore wind farms – e.g. in Jiangsu
  - however, offshore wind is more than twice as expensive to develop than China's still abundant onshore resources

- Solar power
  - Solar resources is abundant – >2/3 of China receives more than 2200h of sunshine (Zhang et al., 2013)
  - PV manufacturing industry:
    - In 2007, China overtook Japan and as the largest PV manufacturer by country (Zhang et al., 2014) – in 2012, China's annual production was ~27,000 MW vs. Japan's ~5800 MW and Germany's ~800 MW (Yu et al., 2014).
    - 5 out of the global top 10 solar PV cell manufacturers by capacity were Chinese companies in 2016 (REN21, 2016)

5. Energy technological option (4): Energy efficiency (and smart grid technologies)

What SG (smart grid) is…
Internet ----- Smart phone ------ Smart grids!

- SG: "The Internet of Energy"
  - to modernise our existing electric grid systems through IT
  - an enabling and transformational technology for realising sustainable energy transitions
  - SG has an important role to play in both the demand-side (e.g. energy saving) and supply-side of energy management (e.g. RE)
- Smart meters 智能電錶 (smart grids 智能電網) and empowerment of electricity end-users
  - The 13th FYP for Energy Development proposed to accelerate the development of smart energy by implementing intelligent transformation of energy supply and consumption
  - Measures include promotion of energy monitoring, energy metering, efficient dispatch and intelligent energy management systems