ECONOMIC GEOGRAPHY UNDER CARBON NEUTRALITY IN THE GREATER BAY AREA

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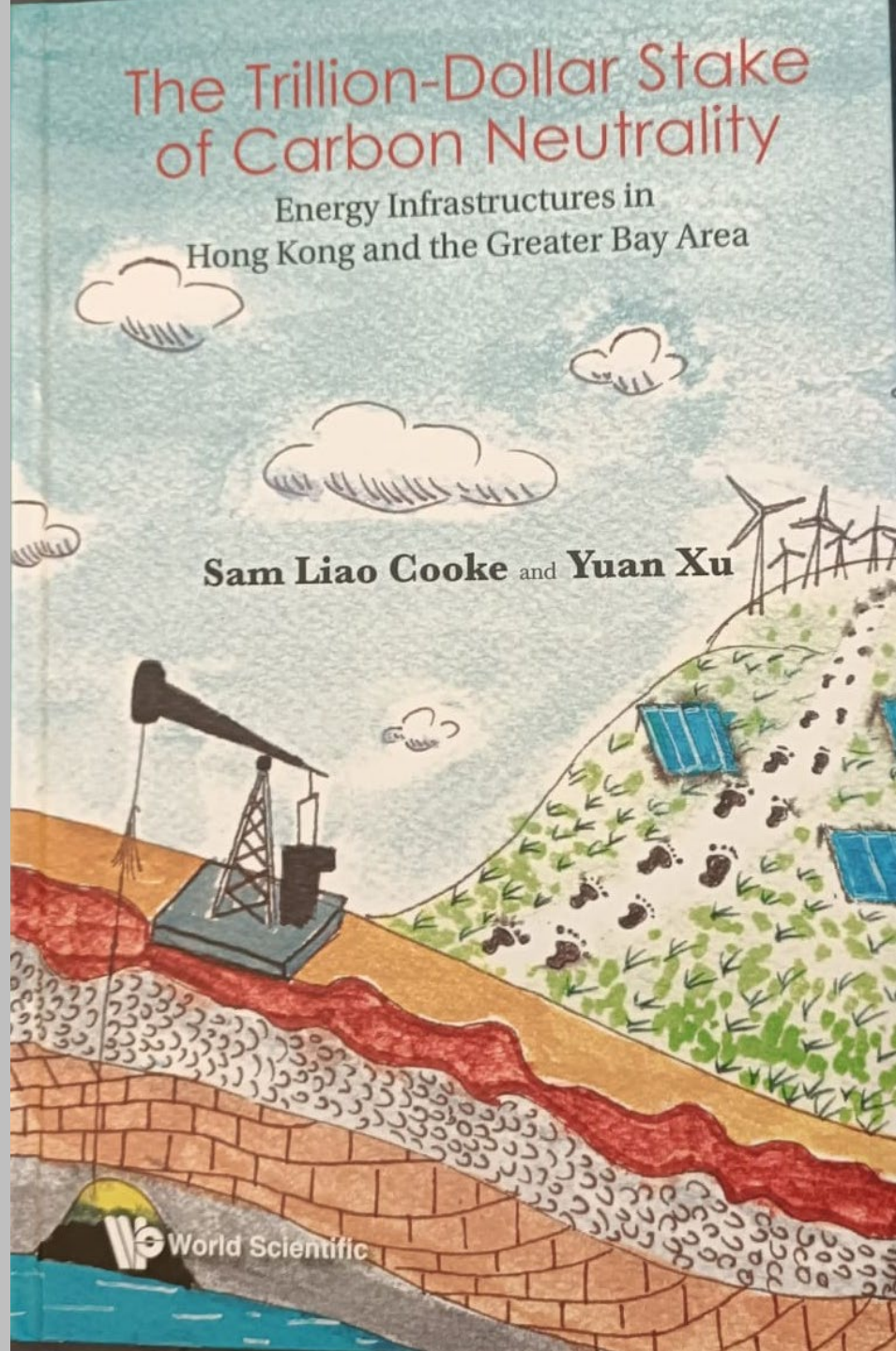


Agenda & Who I am

- Sam Cooke co-author of the book
- Former researcher (Climate & Energy) at CUHK
- Former co-founder of own startup

- Why this book
- Executive Summary
- Main findings and process
- What next

Why this book

- In the September 2020 UN conference Xi Jinping announced China's net zero 2060 target.
- We felt that with this policy announcement would lead to large amount of research into the number of projects that would be required for this transition.
- However Professor Yuan Xu and I felt that for any transition to happen we need to examine the cost of transition and for that to work decided what of the current infrastructure already in place needs to be either decommissioned or expanded.
- Hence our book looked at four key areas 1) Fossil Fuel Infrastructure in Guangdong/GBA, 2) Current Non-Fossil Fuel Infrastructure in Guangdong/GBA, 3) What is the gap, and finally 4) What are our solutions.

Executive Summary

This book introduces readers to an in-depth understanding of carbon neutrality from the perspective of energy infrastructures. The book focus on the role energy infrastructure within the GBA (including Hong Kong) which at the time of writing had a population of over 86 million and a GDP of 1.7 trillion USD.

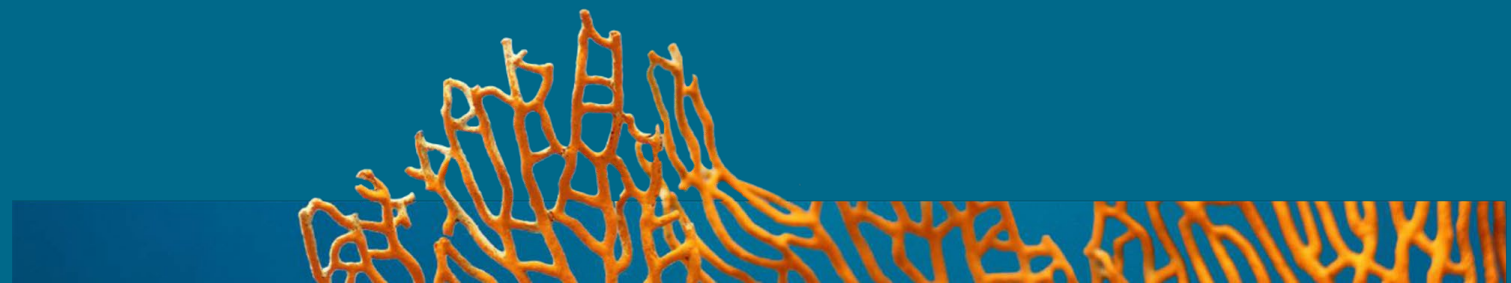
We estimated that for the GBA to reach carbon neutrality by 2060 in line with the countries carbon neutrality goals. In the book we envisioned that the cost of such a transformation for Guangdong would begin to approach 1 trillion USD or about 40-50 billion annually from 2020-2060. In the book we laid out 3 primary pathways, a renewables, a CCS and a nuclear scenario.

	Renewables	CCS	Nuclear
Dispatchability	Bad	Good	Low
Reliability and resilience	Bad	Good	Good
Emissions	Good	Medium	Good
Land and water required	Bad	Good	Good
Rebalancing economic geography	Good	Bad	Medium
Technological readiness for deployment	Bad	Bad	Medium

Main findings and process

Process Step 1

- First, we need to know how much infrastructure is currently within the region
- Data on all current energy infrastructure within Guangdong focusing on the GBA (including Hong Kong and Macau)
- Energy infrastructure included transmission lines, nuclear reactors (by unit), gas, coal, solar projects, wind projects, pipelines, hydro/ pumped hydro and other dams, oil burning plants, oil refinery and oil & gas storage facilities.
- Using project records and database find all currently in preconstruction & construction projects within the region and plot their location as well.

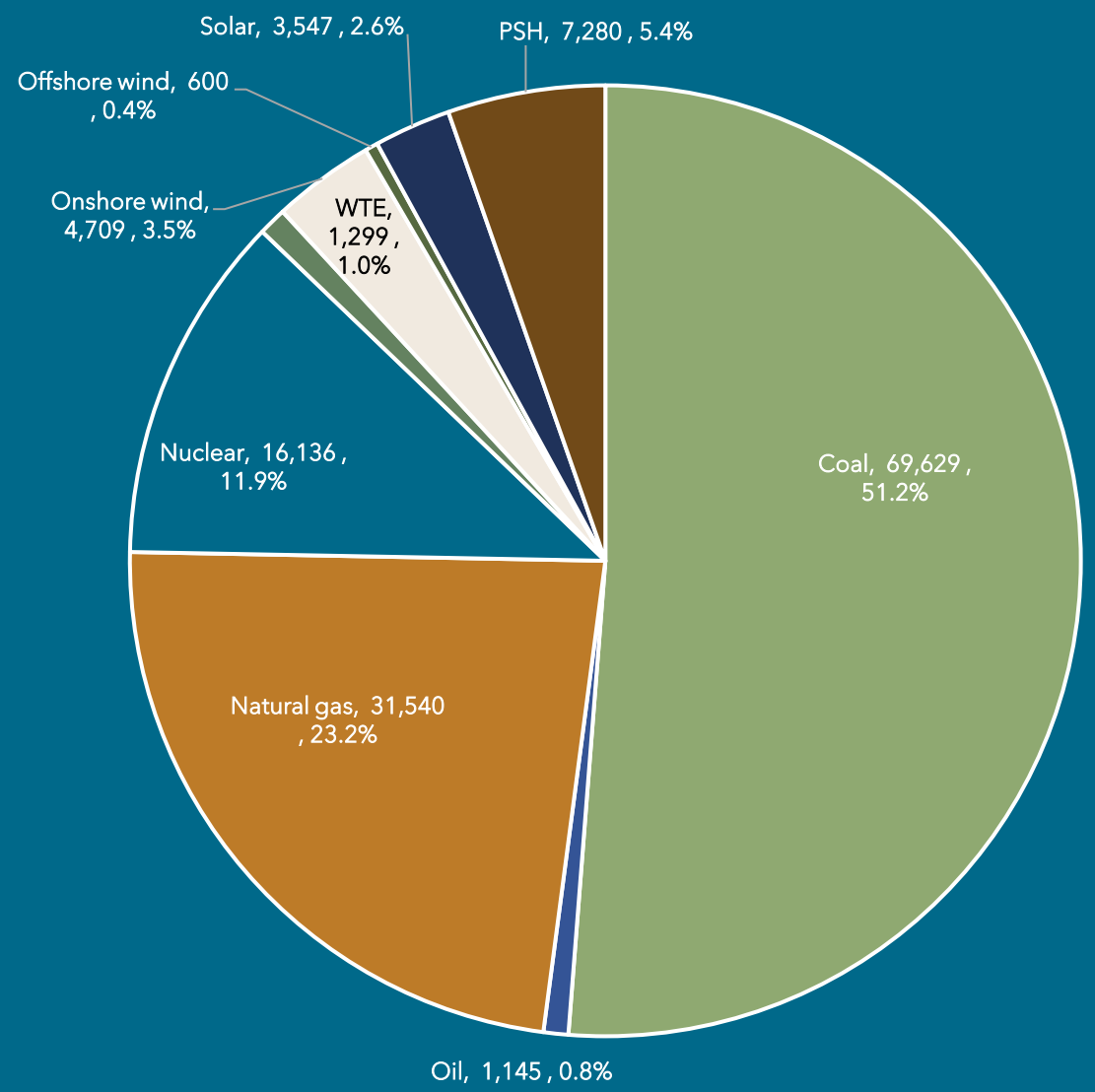


Current Energy Infrastructure

In 2020 Fossil Fuel infrastructure made up about 75% of Guangdong's energy production capacity.

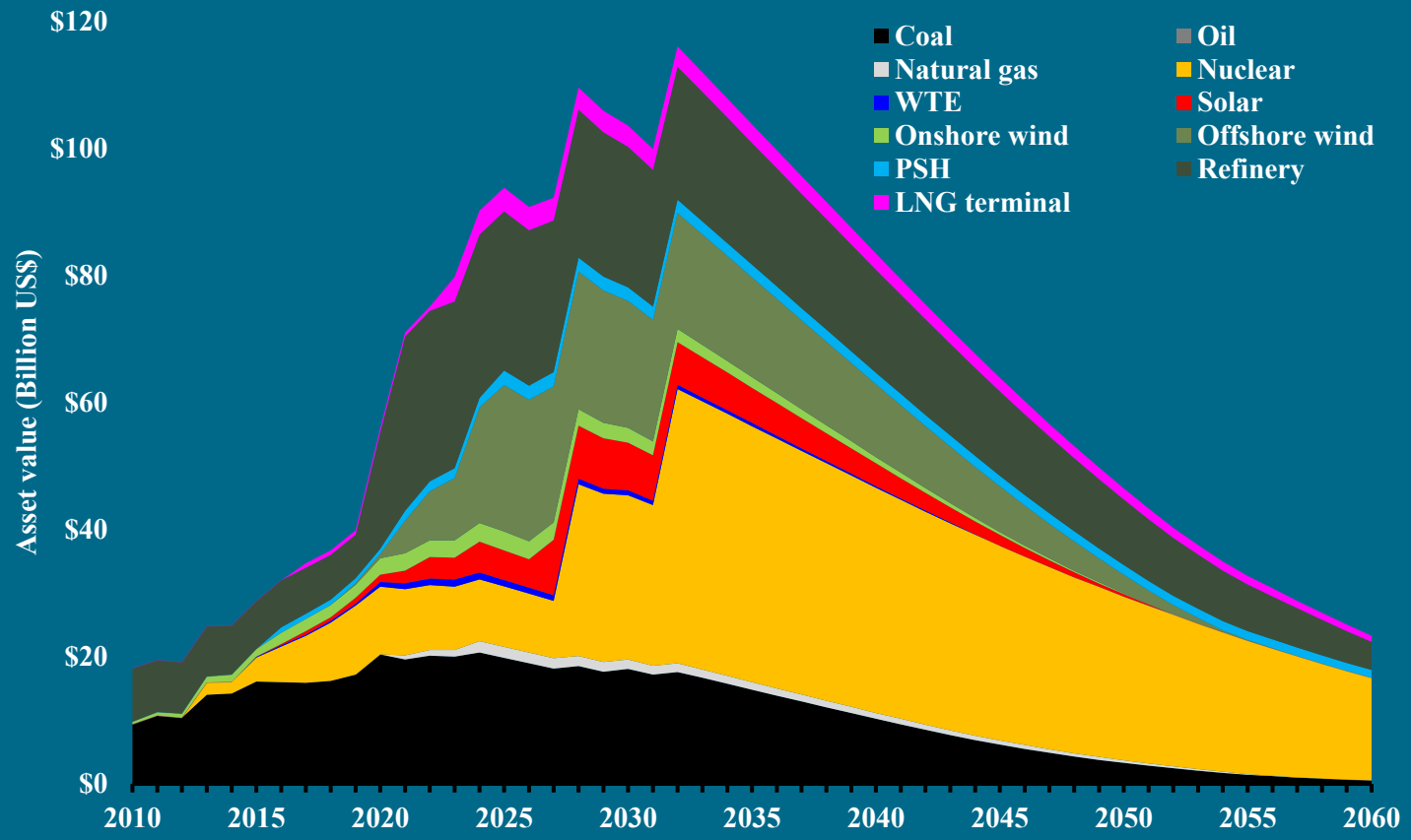
In 2023 asset value in the GBA if including storage facilities, oil refineries and LNG terminals was 47.2 billion USD, while in the rest of Guangdong it was a further 21.3 billion. (Total 68.5 billion USD)

With deprecation value was the future value in 2060 was estimated at 0.5 billion USD in the GBA and 0.7 billion in Non-GBA (1.2 billion total)



Process Step 2

- Once the location of all currently operating and in construction projects have been plotted literature review of infrastructure valuation and deprecation value is conducted.
- Expected lifetime value of remaining power infrastructure within the region including residual value and standard asset cost.

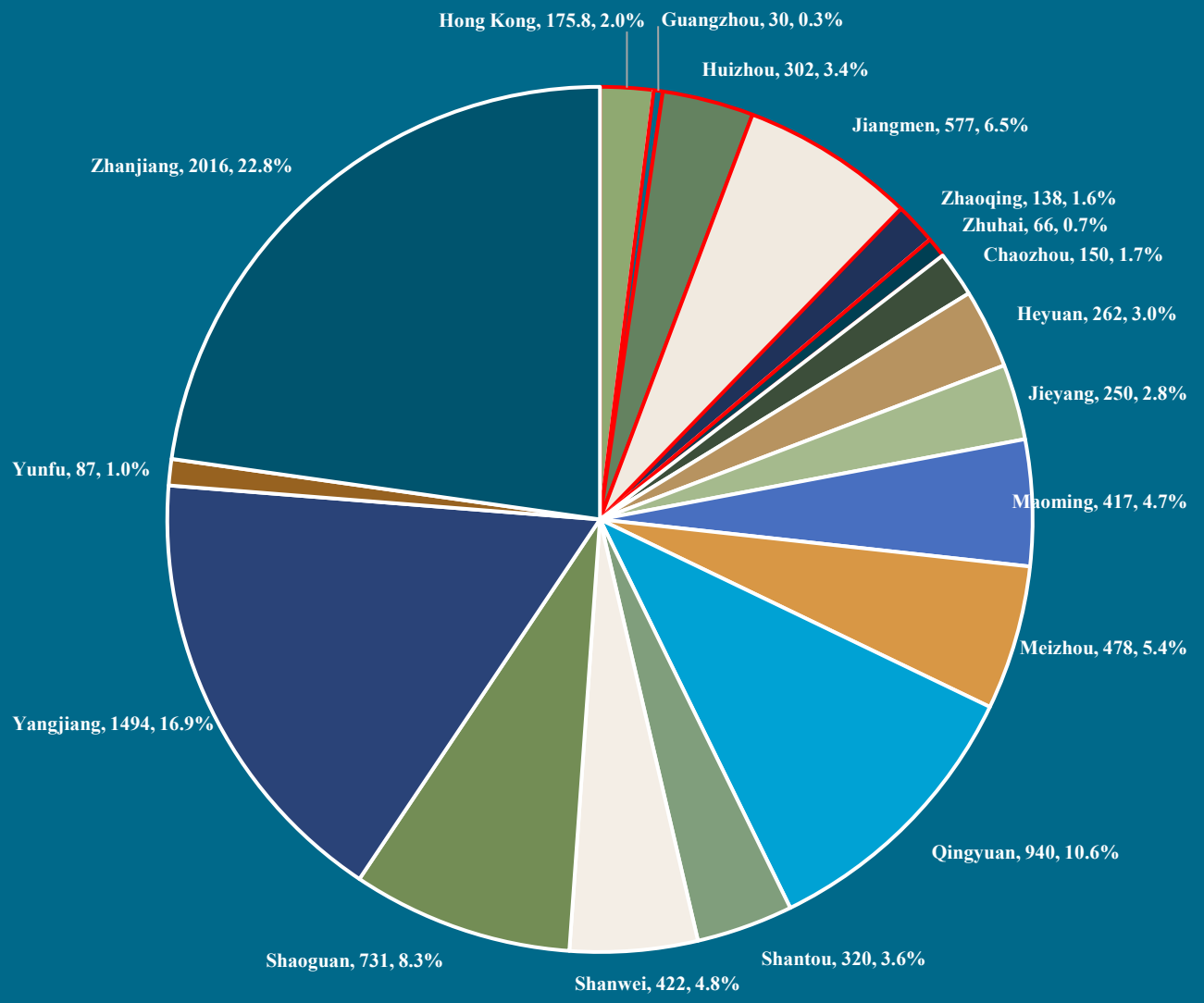


Non-Fossil Fuel Infrastructure

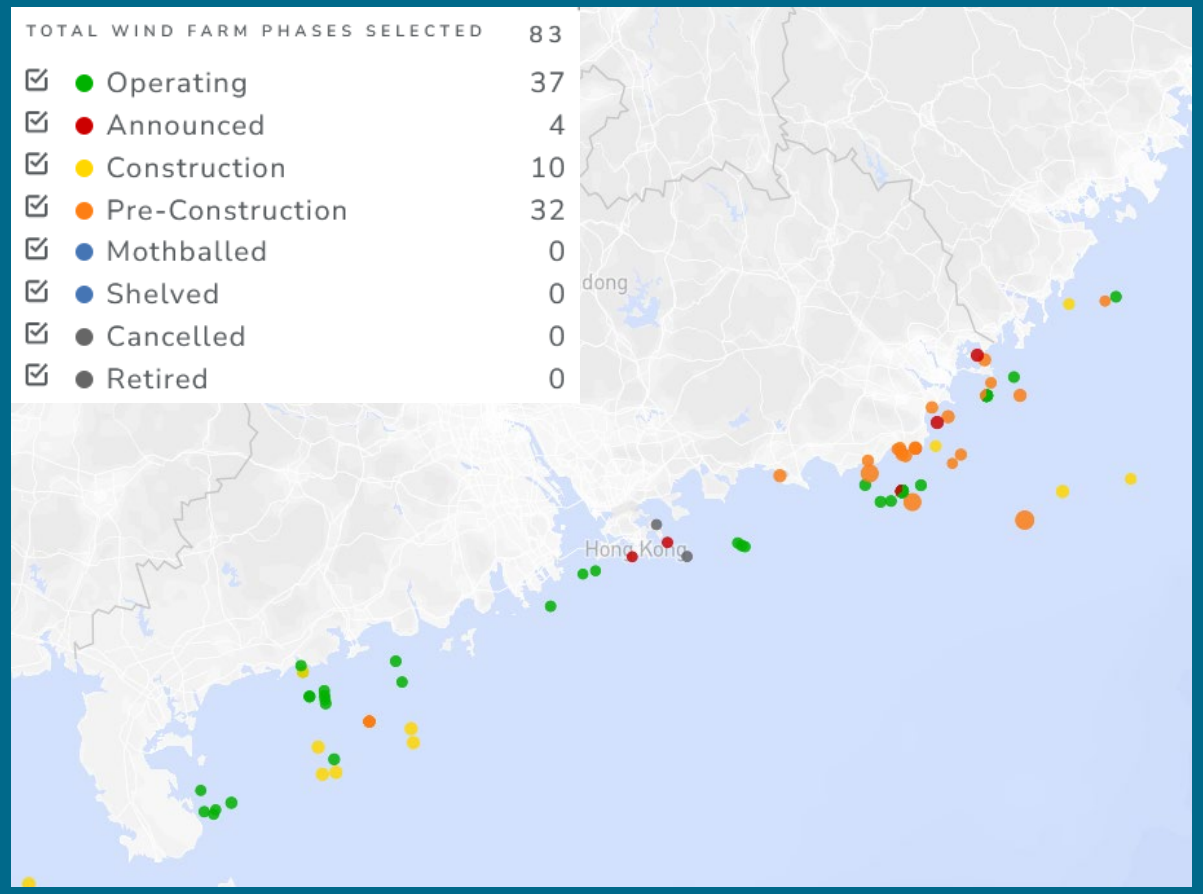
When we were writing we expected renewable capacity to grow from 8.8 GW of wind and solar in 2020 to 47GW by 2025 and 59 GW in 2030. With significant focus on non-GBA areas of Guangdong with between 85% of the provinces renewable capacity being located outside the GBA. Guangdong will also continue to import large amounts of hydro energy from Yunnan especially in the wet seasons

In addition Guangdong is currently operating just over 16 GW in Nuclear capacity with a further 7.3 GW under construction.

Chart; Wind and Solar capacity GW in Guangdong in 2020



Process Step 3

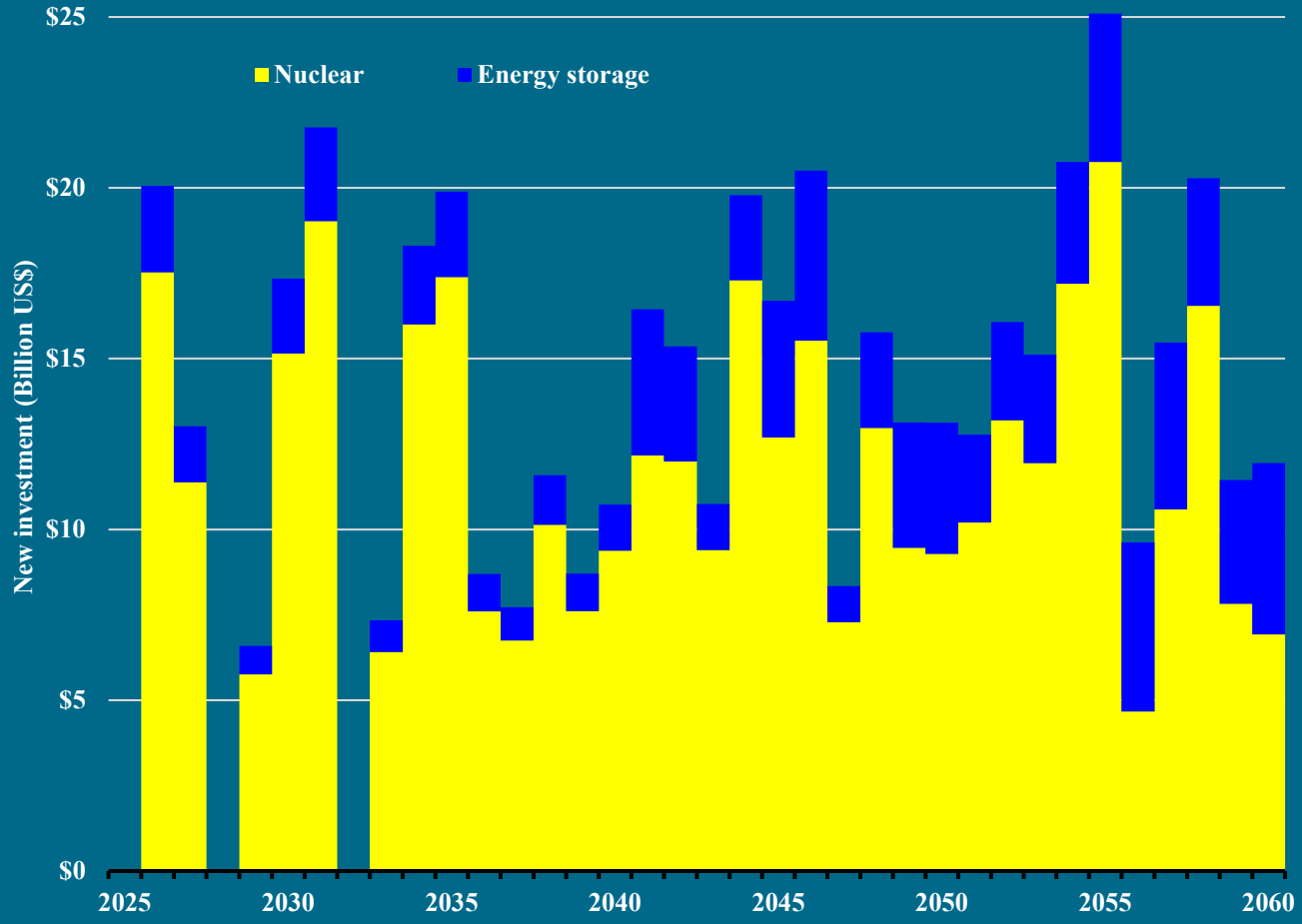


Cite: Global Wind Power Tracker, Global Energy Monitor, February 2025 release."

- For each Scenario the expected lifetime value of the assets is plotted and the location of each asset following both current buildouts, expected land value, and resource quantity. For example, in the renewable scenario lower land price in non-GBA Guangdong means a greater renewable buildout compared to the GBA. Similarly offshore wind is expected to increase due to more stable wind offshore. While in the Nuclear Scenario coasty regions will likely see more buildout due to ease of uranium transport and of cooling water. An example of plotting asset location is given. In this example data is taken from the Global Energy Montor

Process Step 4

- Next step is to figure out the underlining annual investment required to reach the stated carbon goals. An example from the Nuclear scenario with the required annual investments.



Results

How are we going to get there

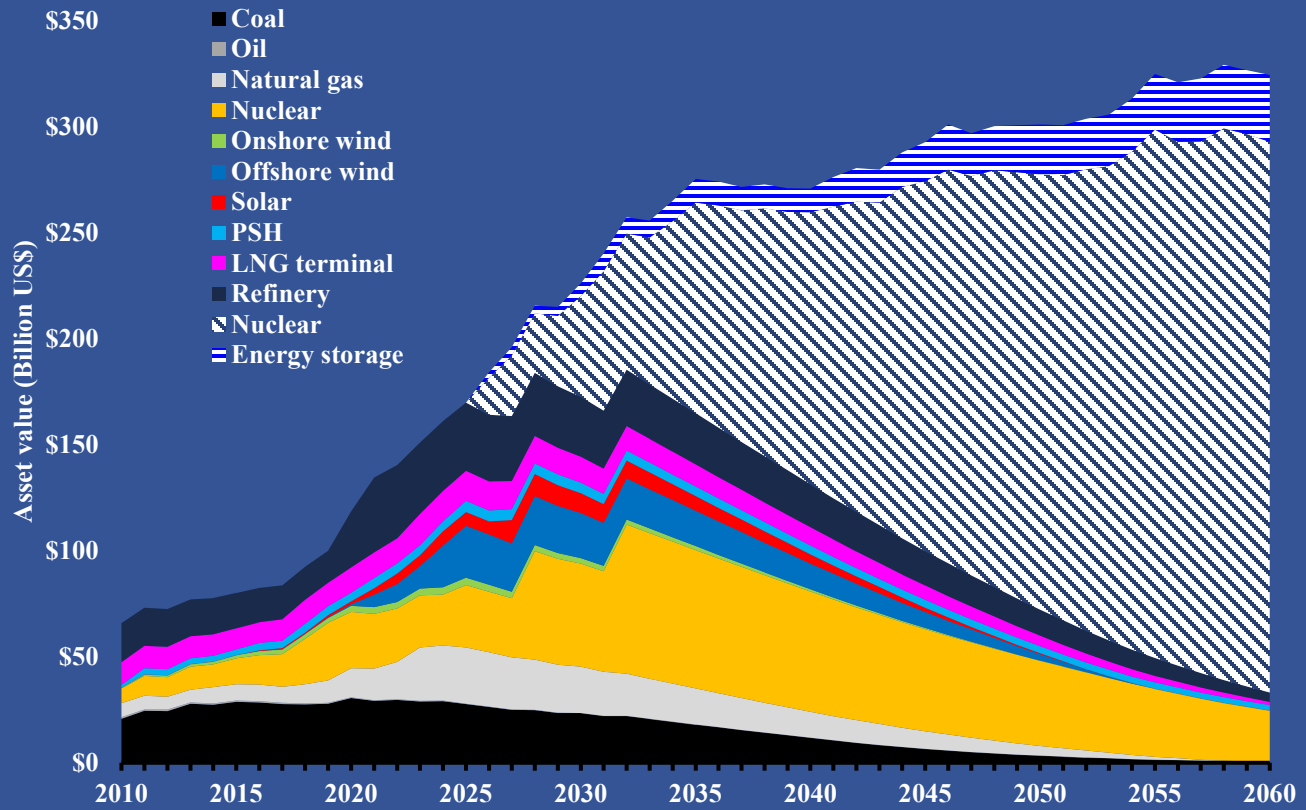
Results Summary

Under our Scenario Analysis we conducted semi-extreme ways which showcase each scenarios major pro's and con's it is likely that Guangdong will go down a middle road with a mix of increased investments in CCS, Nuclear and Renewables. Keep in mind the investment amounts do not include associated increase in transmission lines sub-stations.

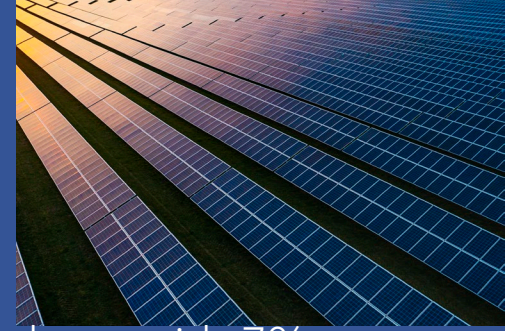
- Nuclear Scenario
  - By 2060 Guangdong holds 155.2 GW of Nuclear and 46.6 GW of battery storage BESS
  - 480.2 billion in new investment, 388.1 billion for new Nuclear.
- Renewables
  - By 2060, 19.5 GW of onshore wind, 306.2 GW of offshore wind, 178.4 GW of solar, and 75.6 GW of battery storage.
  - Total investment is 611.5 billion with the most 380 billion going to offshore wind.
- CCS Scenario
  - In 2060 69.3GW of coal power plants and 345.4 GW of natural gas.
  - 572.4 billion in investment (2026-2060), mostly to natural gas fired CCS (462 billion).

Nuclear Scenario

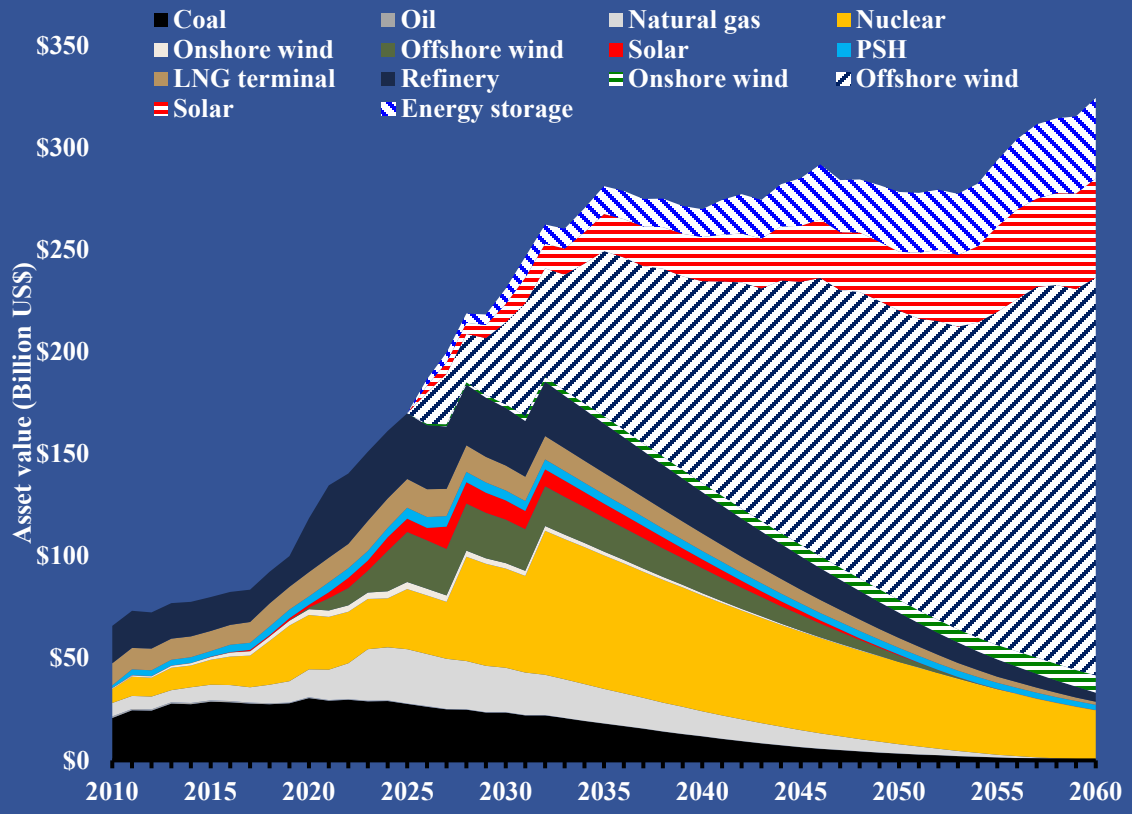
- New nuclear buildout (155.2 GW) will require some kind of battery buildout (46.6 GW), with a 4 hour duration, also some pumped hydro storage will be used.
- Total of 250.2 GW of total buildout, with 75.2% of total electricity from Nuclear.
- Infrastructure almost even between the GBA and non-GBA areas.
- 480.2 billion in investment with 388.1 billion for nuclear power plants. An average of 13.7 billion annually (11.1 billion for nuclear & 2.6 billion for storage).



Renewables Scenario



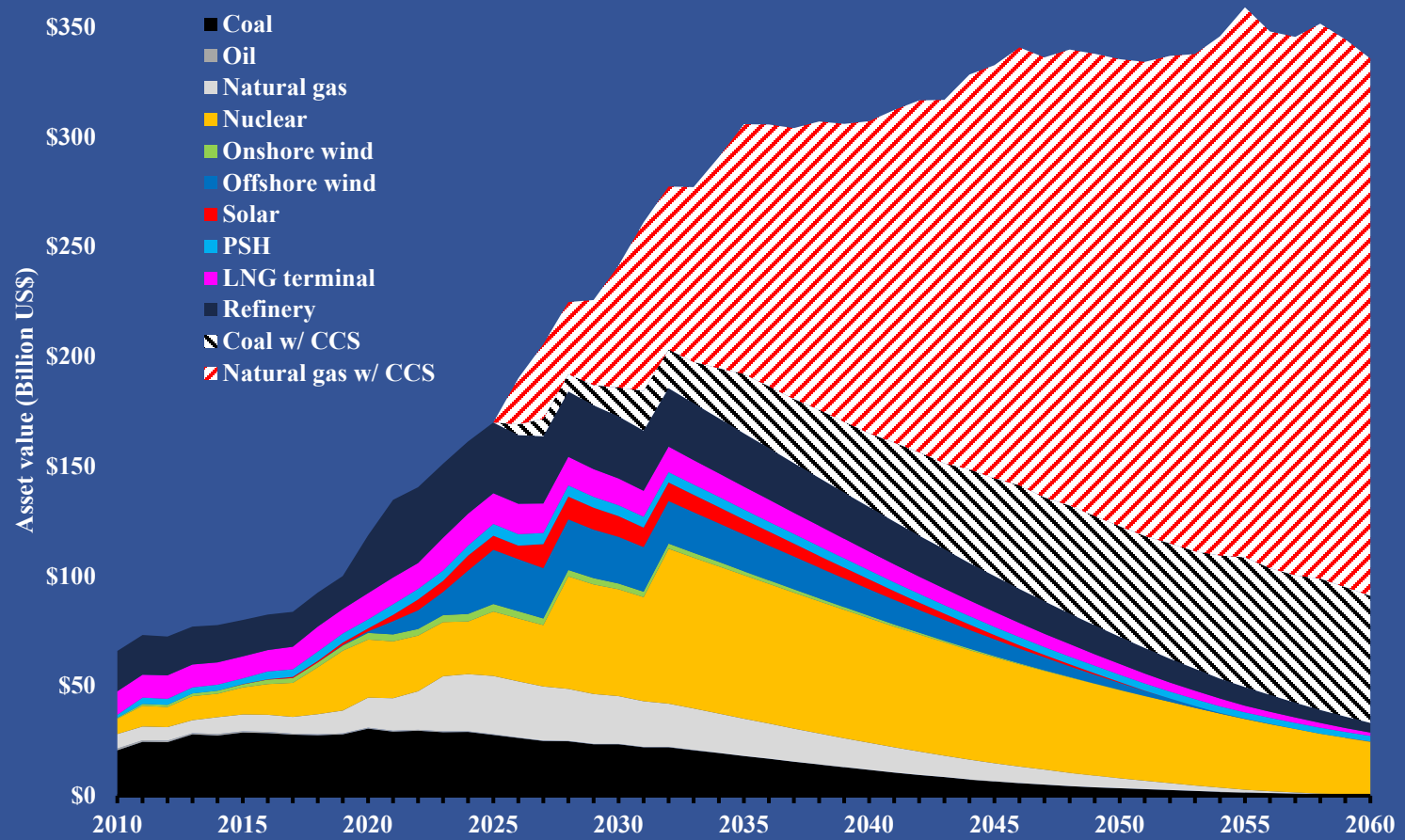
Total change in energy makeup with fossil fuels only making up 2% of electricity generation along with 7% nuclear to allow for baseload.
Due to low dispatchability and dependence on weather conditions the renewable scenario requires the most capacity with about 580 GW of new buildouts required compared to 414.7 GW in the CCS scenario and 201.8 GW in the Nuclear scenario



Type	Amount added (GW)	Asset investment billion USD
Solar	178.4	100.5
Offshore Wind	306.2	380.1
Onshore Wind	19.5	16.6
BESS + PHS	75.6	114.3

CCS Scenario

- In the CCS Scenario, 69.3 GW of coal and 345.4 GW of natural gas will have CCS, with these fossil fuel plants making up 90.8% of expected electricity production, with the remainder using nuclear power.
- Investment between 2026-2060 will be 572.4 billion including 109.4 billion for coal CCS and 462.9 billion for gas fired CCS.



Conclusions and Implications

It is likely that we will see a combination of all three scenarios, with an increase in Nuclear buildout's increasing emphasis on Carbon Capture technology not only for energy but also in industry such as in steel and cement industry.

Primary issues around maintaining flexibility and possible buildout times are important considerations which will likely help lead to a blended energy mix.

When accounting for price increase, transmission lines and other unforeseen circumstances it is feasible that energy transformation of the GBA & Guangdong will approach if not exceed 1 trillion USD.

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