Evaluating Taiwan's optimal power supply mix in 2050

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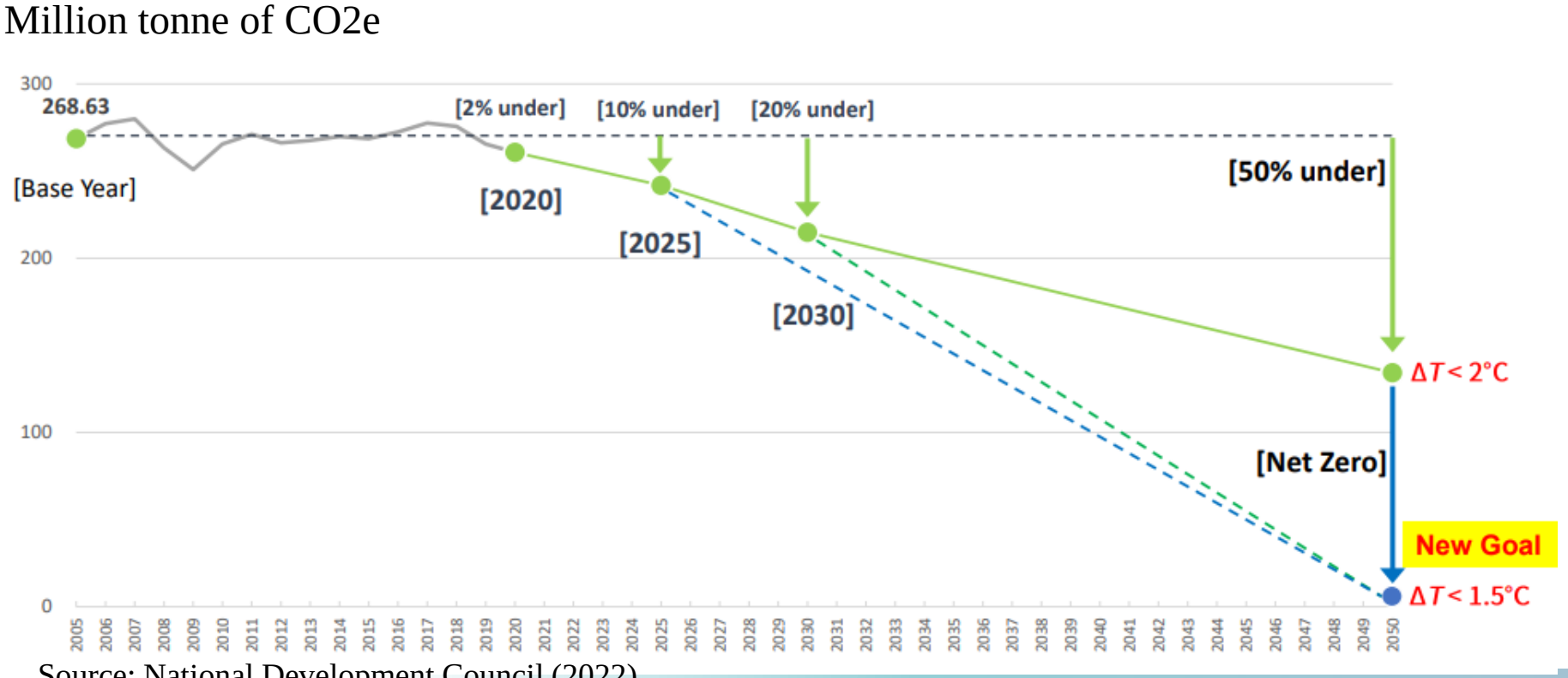
The net zero emission target of Taiwan

- In 2022, the Taiwanese government announced the net zero target for 2050

Emission target for 2050



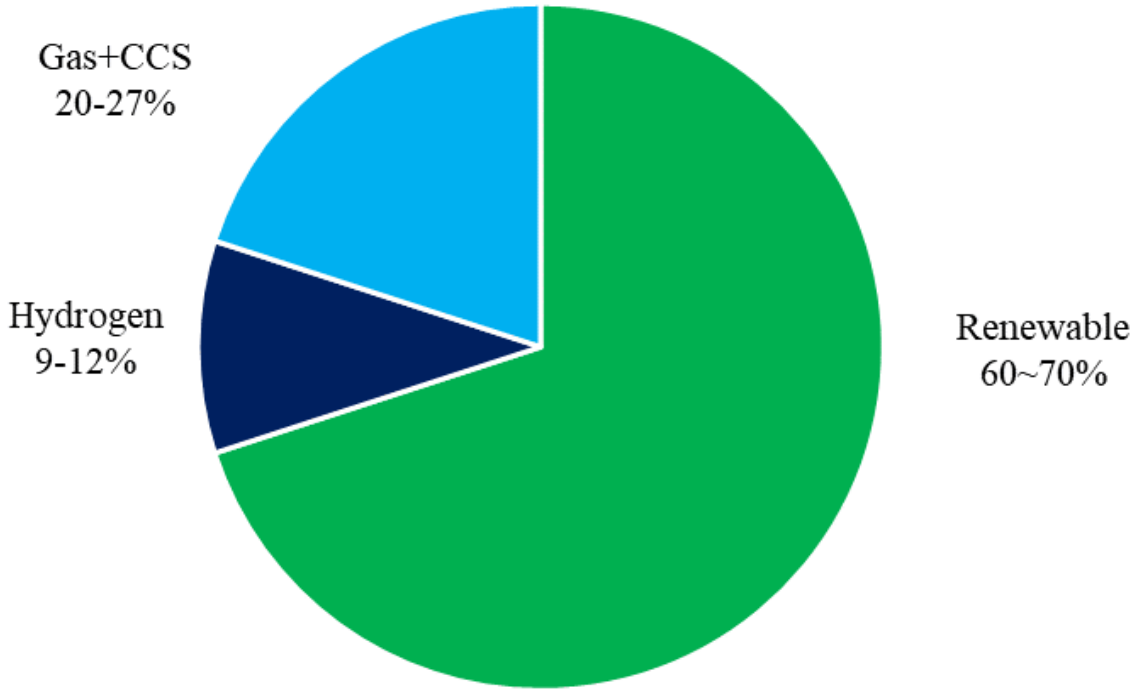
Source: National Development Council (2022)

Power supply target for 2050

- **2050 power supply mix**
  - ✓ Renewables **60-70**%
  - ✓ Hydrogen: **9-12**%
  - ✓ Gas+CCUS: **20-27**%

- **Limitations:**
  - ✓ No **details** on the **renewable portfolio**
  - ✓ No reveal of **power generation costs**
  - ✓ No reveal of **power storage demand**

The 2050 official power supply target for Taiwan



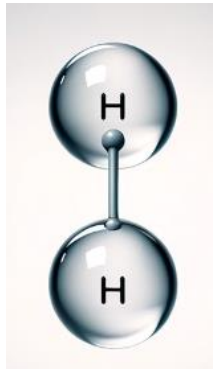
Source: National Development Council (2022)

Taiwan devotes to develop hydrogen production through pyrolysis

Natural gas:CH_4

Pyrolysis: Over 1,000°C

$2H_2$



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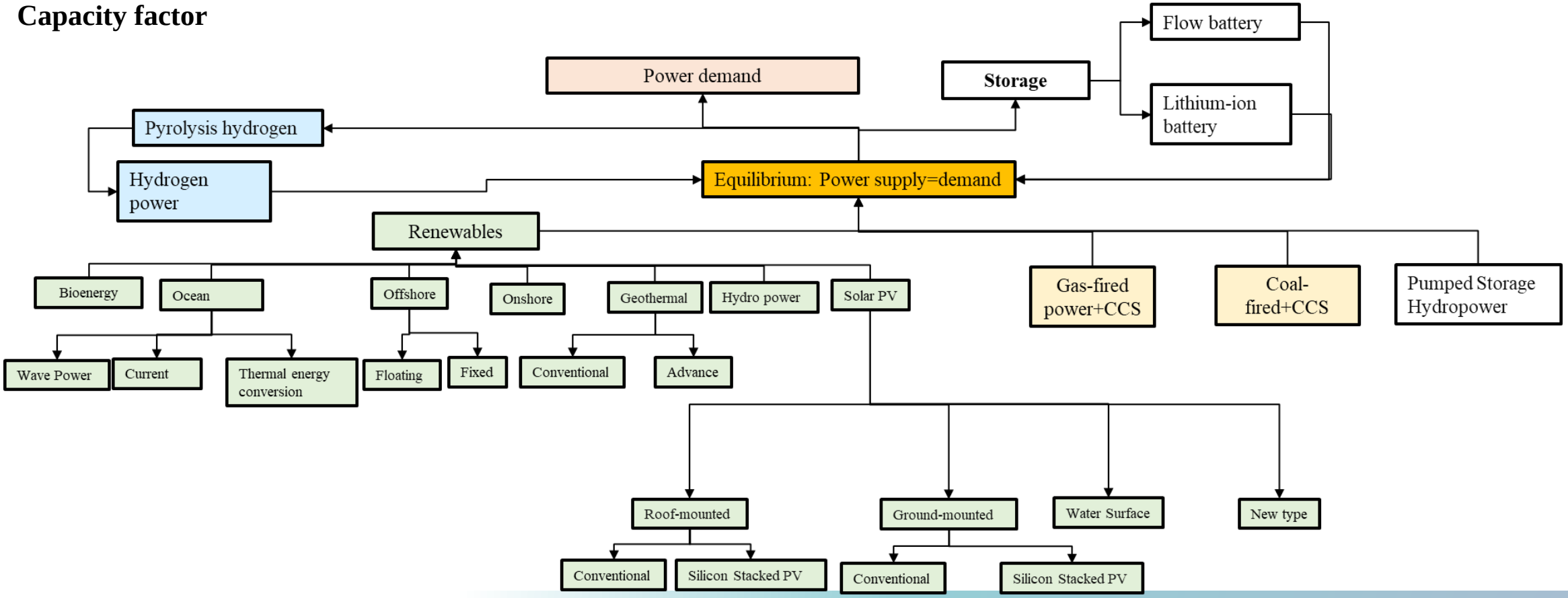
The President of Academia Sinica introduced pyrolysis hydrogen to Taiwan's former President Tsai

Purpose: Evaluate Taiwan's power supply portfolio for 2050

- **Cost minimization considering**
  - ✓ Data **8760** hours/year
  - ✓ **Installation potentials**
  - ✓ **Installation/maintenance costs**
  - ✓ **Capacity factor**

The structure for power supply model



Data sources

Category	Ministry of Economic Affairs	Taipower company	2050 Calculator	Academia Sinica
Installation/ Operation & Maintainace cost	Storage, solar PV, offshore, onshore, geothermal, ocean power, electrolytic hydrogen	Pyrolysis hydrogen	hydropower, nuclear power, Gas+CCS	Hydrogen turbin
Variable costs	bioenergy	Pyrolysis hydrogen	Gas+CCS, nuclear power, pumped storage hydropower	Black carbon values
Capacity factor	Geothermal, ocean power	Solar PV (hourly), offshore(hourly), onshore(hourly), hydropower(hourly), hydrogen turbin	Nuclear power	
Installation Potential	Storage, solar PV, offshore, onshore, geothermal, ocean power, bioenergy, hydropower, pumped	Pyrolysis hydrogen, Gas+CCS	Nuclear power, pumped storage hydropower, hydropower	

Taiwan will completely decommission nuclear power plants in 2025

- Currently, only **one nuclear** reactor remains operational—the number 2 reactor of the third nuclear power plant—scheduled for **decommissioning** in May 2025

Decommission plans of nuclear power reactors in Taiwan

Nuclear power plants	Reactor number	Installed capacity (GW)	Decommission date
First	1	0.638	December, 2018
	2	0.638	July, 2019
Second	1	0.985	July, 2021
	2	0.985	March, 2023
Third	1	0.95	July, 2024
	2	**0.95**	**May, 2025 (expected)**

Scenario

- **Two scenarios**:
  - ✓ **With/without** nuclear power in 2050

Power supply scenarios for 2050

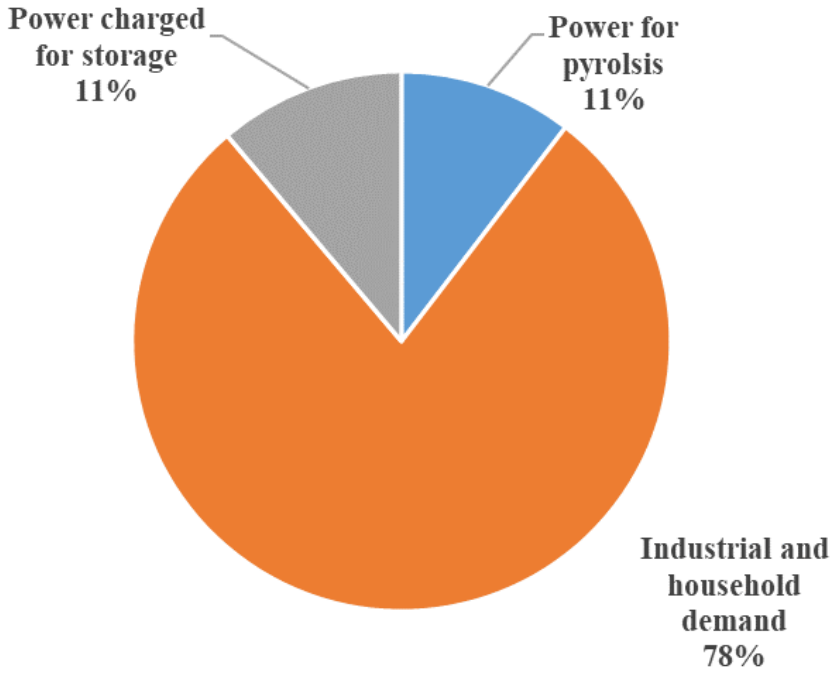
With 2nd and 3rd nuclear power plants (3.87GW)

Without nuclear power plants

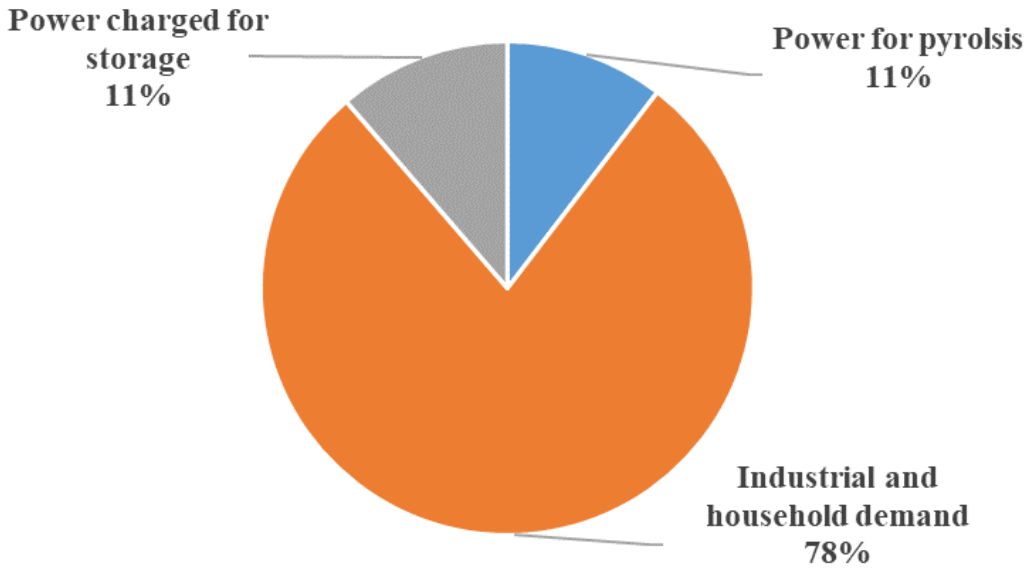
The 2050 power demand

- **The official projection for 2050 power demand: 500,300 GWh/year**
  - ✓ Use the 8,760-hour pattern of total power demand from Taipower Company, upscaling it to 500,300 GWh
  - ✓ With or without the nuclear power, the power charged for storage constitutes **11%** of total power demand while power for pyrolysis is also **11%**

With nuclear power

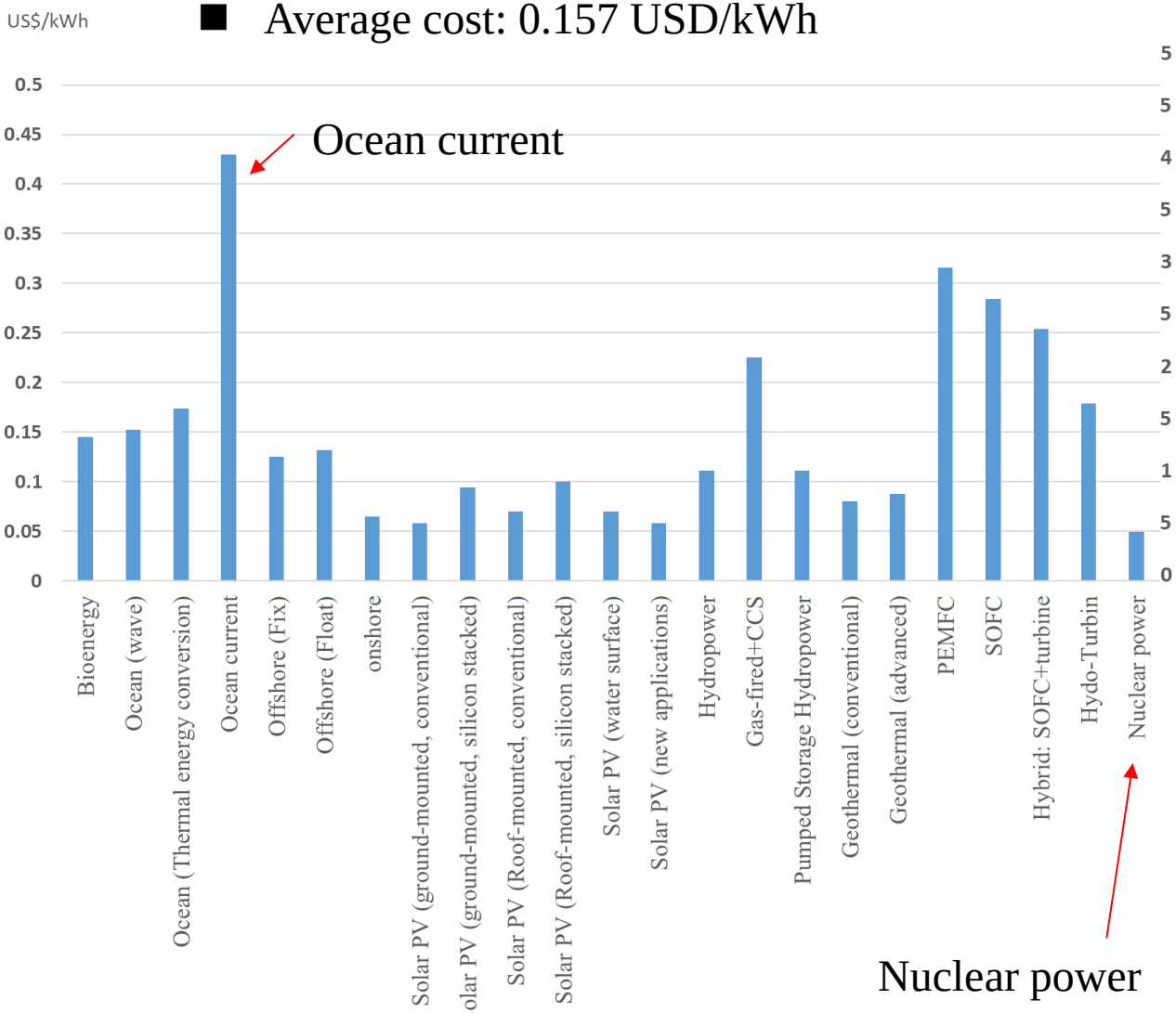


Without nuclear power

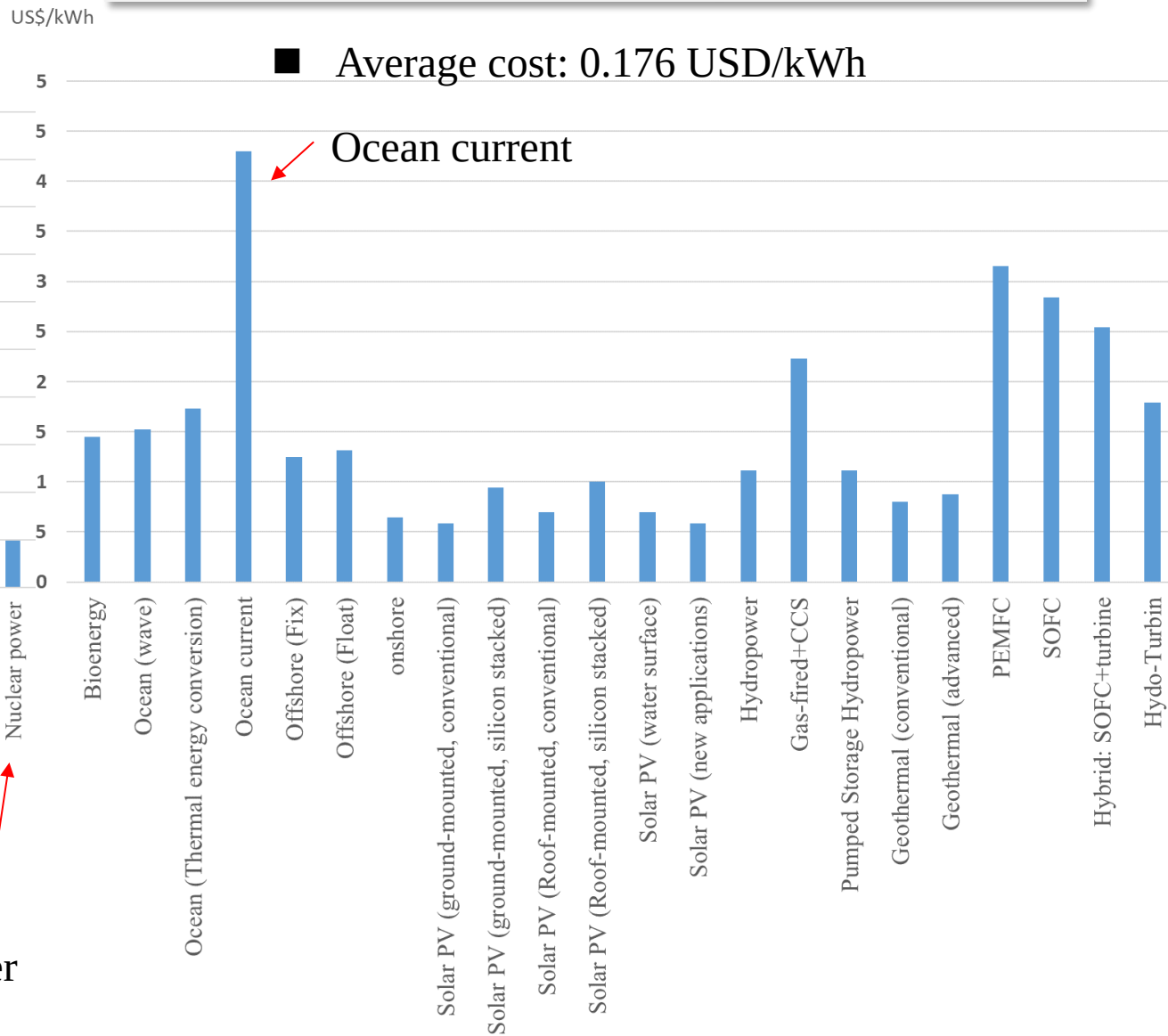


Power generation costs in 2050, by technology

With nuclear power

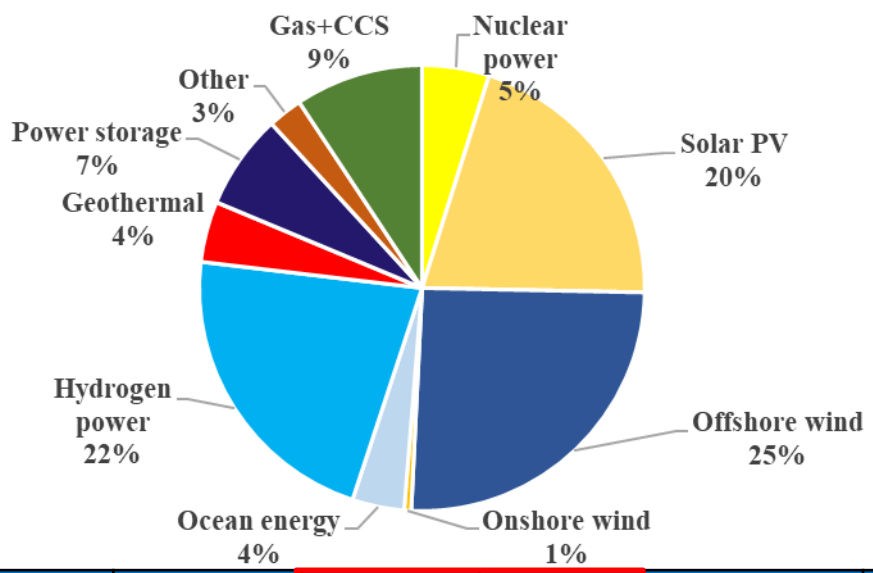


Without nuclear power



Power generation in 2050

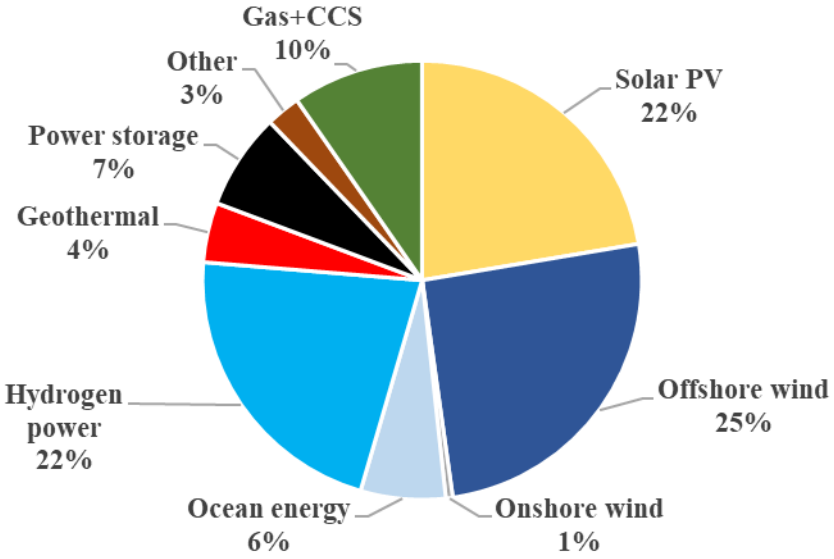
With nuclear power



	Renewable	Gas+CCS	Hydrogen	Pump storage hydropower	Nuclear power
Power generation (GWh)	361,290	59,378	139,284	3,191	31,070
Power generation share	60.8%	10.0%	23.4%	0.5%	5.2%

Unit cost of hydrogen is relative cheaper

Without nuclear power



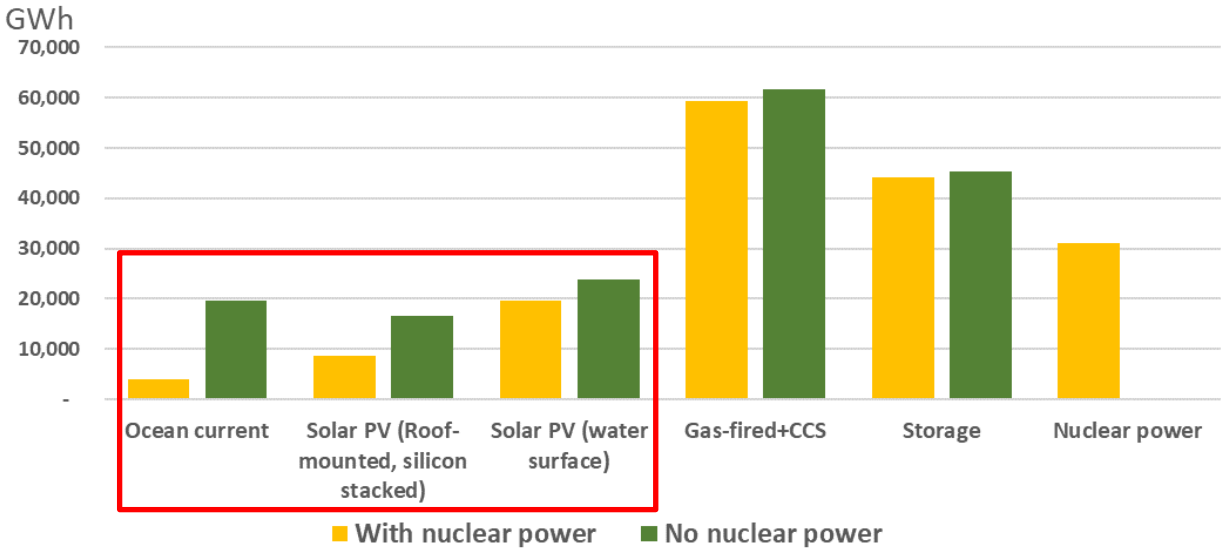
	Renewable	Gas+CCS	Hydrogen	Pump storage hydropower
Power generation (GWh)	389,617	61,806	139,284	3,191
Power generation share	65.6%	10.4%	23.5%	0.5%

Unit cost of hydrogen is relative cheaper

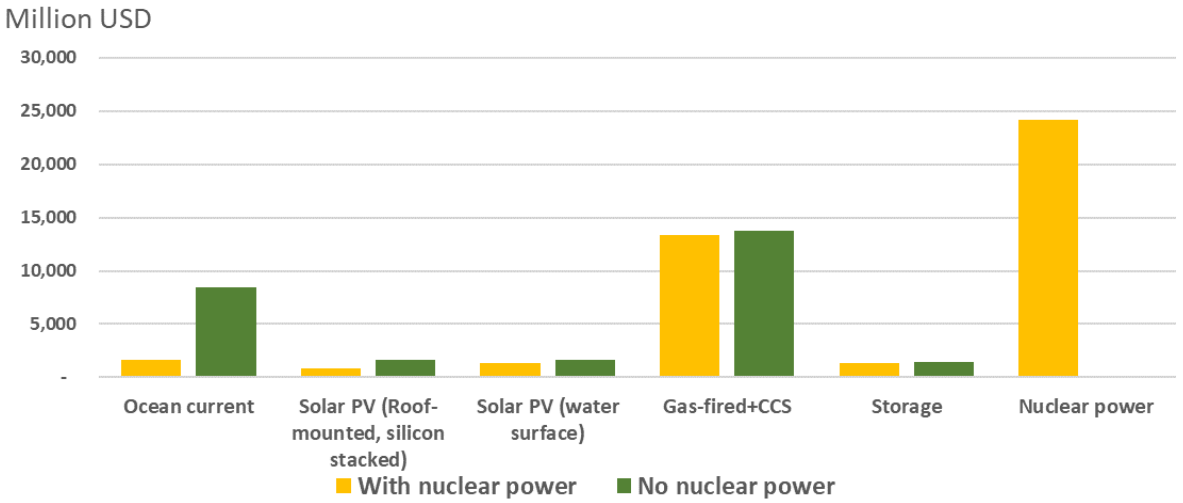
The nuclear power plants reduce the installed capacity of renewables

- The **nuclear power** has **cost advantage**: reduce ocean current, which is relatively expensive, by a large extent
- The power generation of **solar PV** is also reduced, which cannot generate power at night
- The power generation of **Gas+ CCS** remains **high**

Power generated/stored in 2050



Total costs for each technology in 2050



Power supply mix for 2050

- Natural gas+CCS has low capacity factor: shutdown in during some daytime, replaced by solar PV

With nuclear power

	Bioenergy	Solar PV	wave power	Thermal energy conversion	Ocean current power	Offshore	Onshore	Hydropower	Gas+ CCS	Pumped Hydropower	Geothermal	Hydrogen	Nuclear	Storage
Installed capacity (GW)	1.8	68.9	4.6	0.8	1.2	41.2	1.1	2.1	19.5	2.6	4.0	19.9	3.9	34.0
Power generation (GWh)	7,273	130,524	14,538	5,676	3,879	162,513	3,237	5,500	59,378	3,191	28,149	139,284	31,070	
Capacity factor	0.45	0.22	0.36	0.80	0.36	0.45	0.34	0.30	**0.35**	0.14	0.80	0.80	0.92	

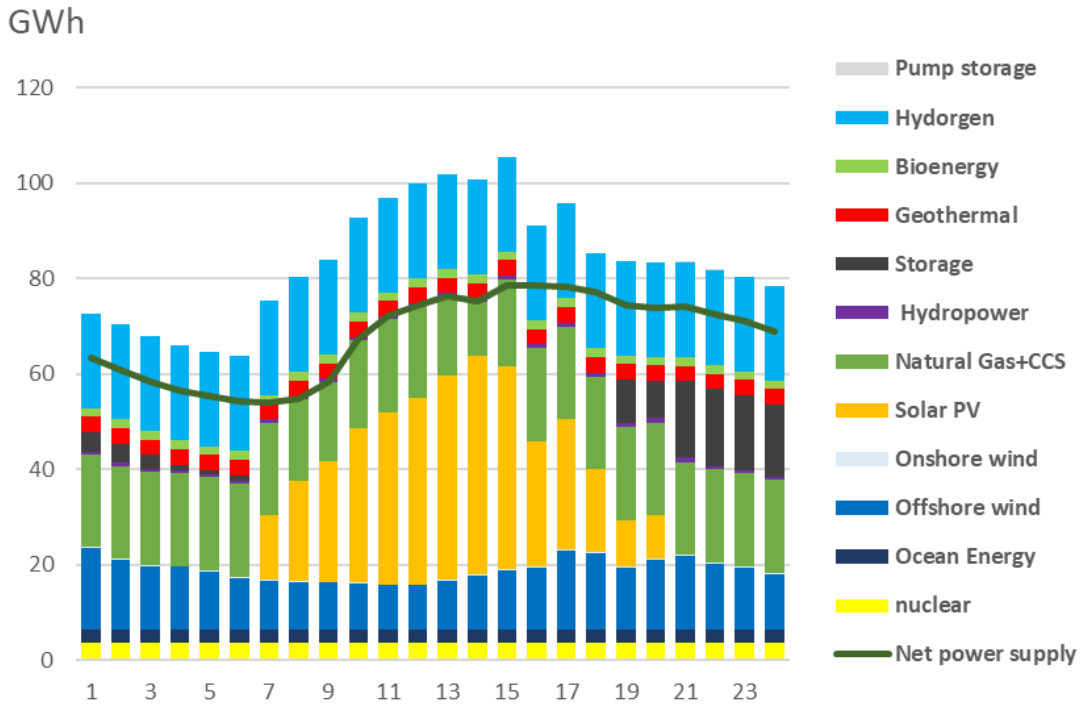
Without nuclear power

	Bioenergy	Solar PV	wave power	Thermal energy conversion	Ocean current power	Offshore	Onshore	Hydropower	Gas+ CCS	Pumped Hydropower	Geothermal	Hydrogen	Storage
Installed capacity (GW)	1.8	75.0	4.6	0.8	6.3	41.2	1.1	2.1	19.5	2.6	4.0	19.9	36.0
Power generation (GWh)	7,385	142,878	14,538	5,676	19,742	162,513	3,237	5,500	61,806	3,191	28,149	139,284	
Capacity factor	0.46	0.22	0.36	0.80	0.36	0.45	0.34	0.30	**0.36**	0.14	0.80	0.80	

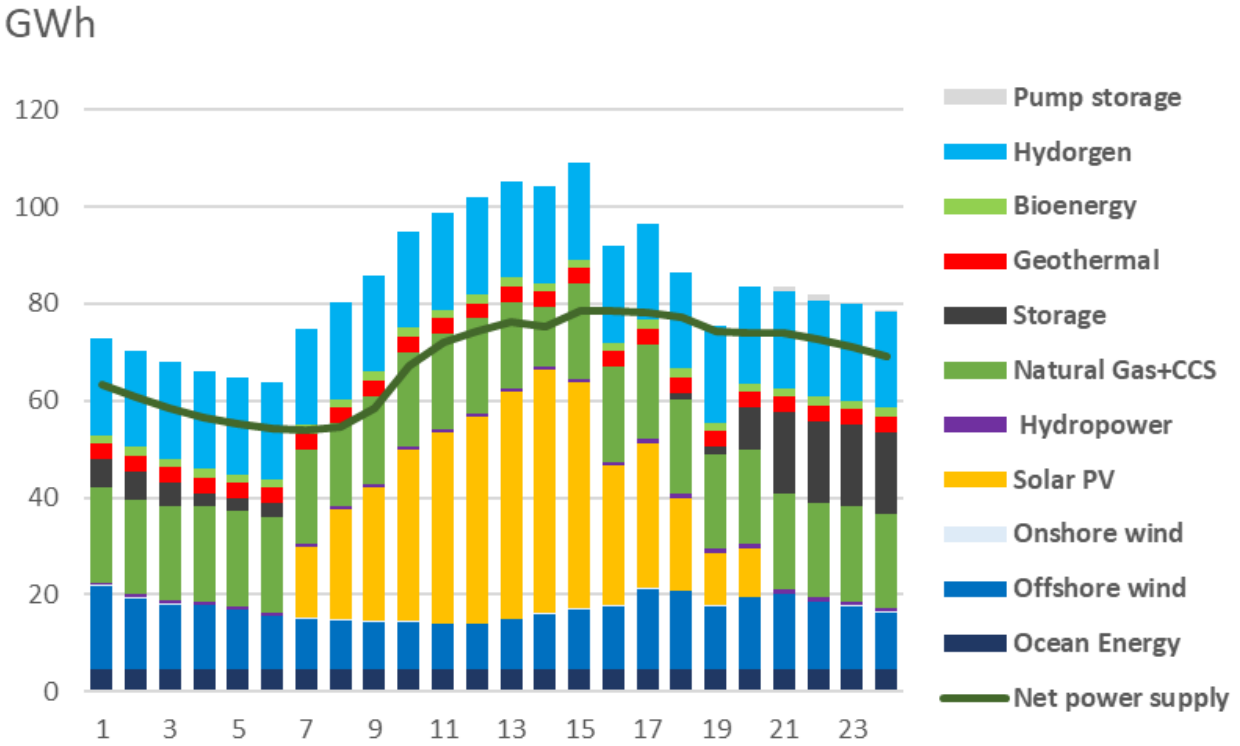
Power supply on 27th July, 2050

- This day has the **highest peak load** of a year
- Solar PV cannot supply electricity at night: We need **power storage**
- Net power supply= Total power supply- storage- electricity demand for pyrolysis
  - We need **extra power** for **power storage** and **pyrolysis** during the day time
  - Even at night, we still need more power for pyrolysis

With nuclear power



Without nuclear power



Comparison of hydrogen power in two scenarios

- The hydrogen power is **an important base load** for Taiwan: Almost the same with/without nuclear power
- Taiwan's current **supply capacity** for natural gas: 16.5 million tone/year➔ far **lower** than the **natural gas demand** 41.36-41.70 million tone/year in 2050
- Where to sell black carbon?

Comparison of hydrogen in two scenarios

	Power generated by H_2	Power demand for pyrolysis	Demand for natural gas (million tone)	H_2 demand	Black carbon
With nuclear power	139,284 GWh	66,507 GWh	**Total demand: 41.36** ✓ Pyrolysis for H2: 33.03 ✓ Gas+CCS: 8.34	6.65 million tone	19.97 million tone
Without nuclear	139,284 GWh	66,504 GWh	**Total demand:41.70** ✓ Pyrolysis for H2: 33.03 ✓ Gas+CCS: 8.67	6.65 million tone	19.97 million tone

Conclusions

- The renewable power needs reliable **base load** to support **stable power system**: Such as Gas+CCS, hydrogen power, and nuclear power
- With **nuclear power**, we can reduce the average **power generation cost** by a 12.5% (0.176 USD/kWh to 0.157 USD/kWh)
- Challenges to pyrolysis hydrogen:
  - ✓ Source of **natural gas supply?**
  - ✓ How to deal with **black carbon?**

Thank you for your attentions