China's Spent Fuel Management and Fuel Cycle Scenarios

Yun Zhou

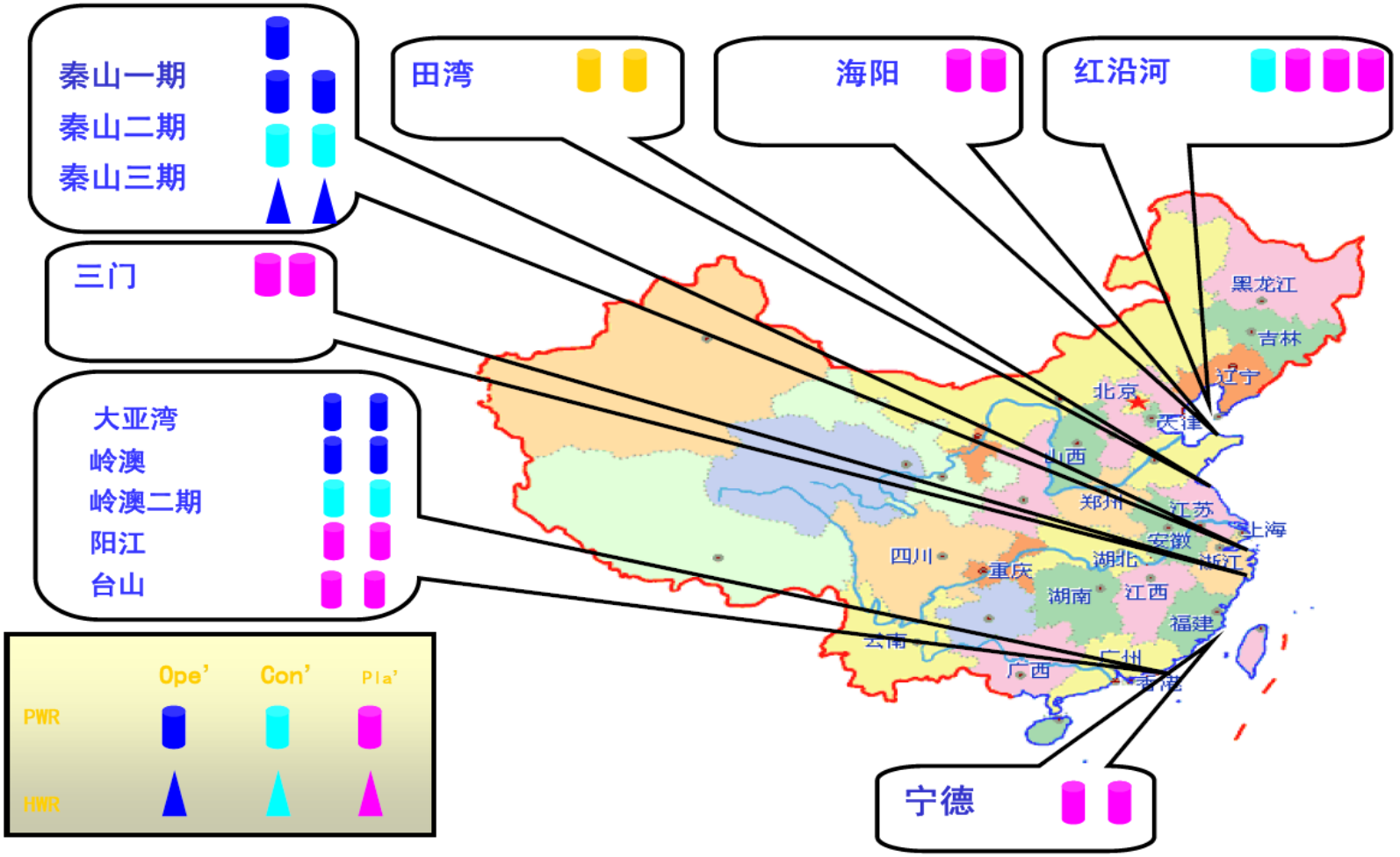
MTA Project
The Belfer Center of International and Security Studies
Harvard University

Contact: yun_zhou@hks.harvard.edu

China's current nuclear program

- 11 nuclear reactors in operation (9.2 GWe)
  - Technologies from France, Russia, and Canada
  - Qinshan Phase I, II, III (N/A, $1330/kW, $1791/kW)
  - Daya Bay (2 reactors) (France) ($2000/kW)
  - Ling Ao (2 reactors) (France) ($1800/kW)
  - Tianwan (2 reactors) (Russia) ($1500/kW)
- 17 nuclear reactors under construction since 2005 (16 GWe)

China’s nuclear map

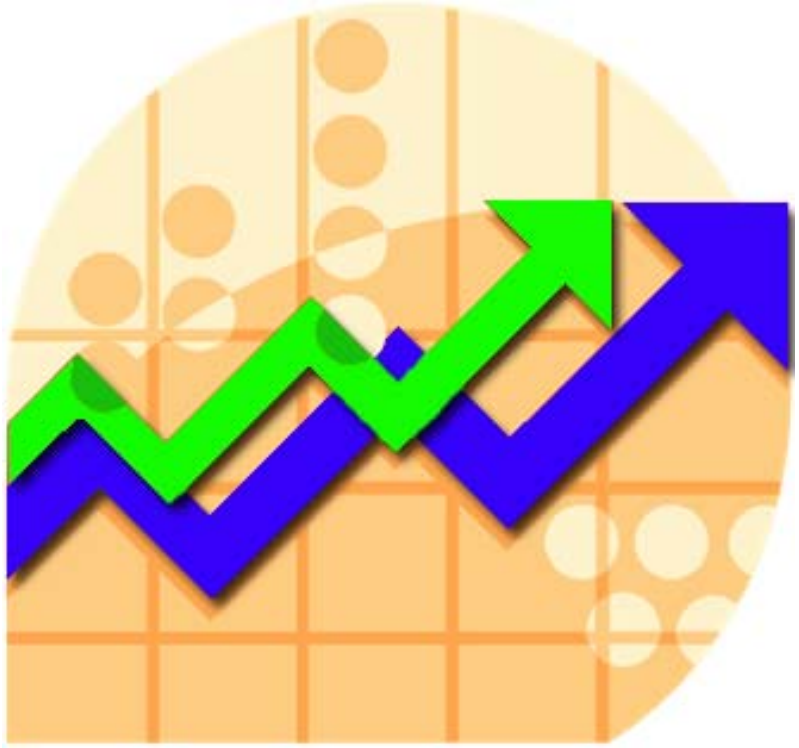


China’s nuclear expansion plan

- The medium and long-term plan (2004)
  - Officially 40 GW by 2020
- The “Rapid growth” reality
  - 60 GW by 2020 (March, 2008)
  - Possibly 70 GW (March, 2009)
- Gen II (CPR1000) and Gen III (EPR+ AP1000) PWRs

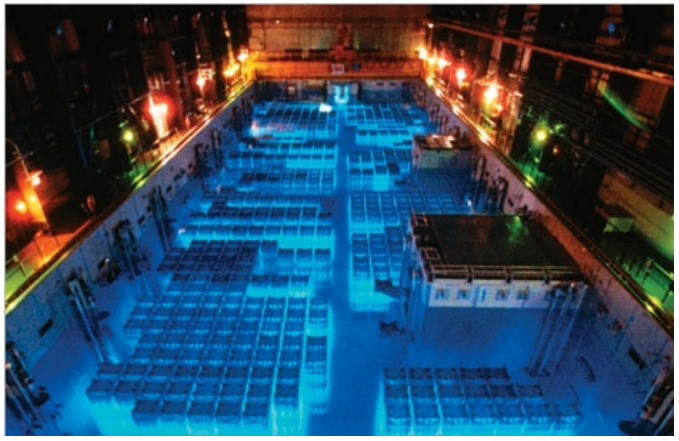
How much can nuclear energy contribute by 2050 in a total capacity of 1800 GWe?

- Reference scenario:
  - 360 GW
  - 20%
- High growth scenario:
  - 540 GW
  - 30%
- Low growth scenario:
  - 180 GW
  - 10%



Current spent fuel storage

- Not a wide-spread concern
  - ~7500 tons by 2020
  - 11,000 tons in Japan (current)
  - 49,000 tons in USA (current)
- Over-packed storage pools at Qinshan reactor power plant
- On-site dry storage at the CANDU site
- A 550 ton off-site spent fuel storage pool at the reprocessing pilot site



Spent Nuclear Fuel

Qinshan Phase I, II, and III

- Qinshan Phase I (1 unit)
  - Dense-pack wet and pool size expansion
  - On-site storage capacity: 35 years
  - Storage capacity will be filled up by 2025
- Qinshan Phase II (2 units)
  - Dense-pack wet and pool size expansion
  - On-site storage capacity: 20 years
  - Storage capacity will be filled up by 2022
- Qinshan Phase III (2 units)
  - Dry / wet storage
  - On-site storage capacity: 40 years
  - Storage capacity will be filled up by 2042

Qinshan Phase III

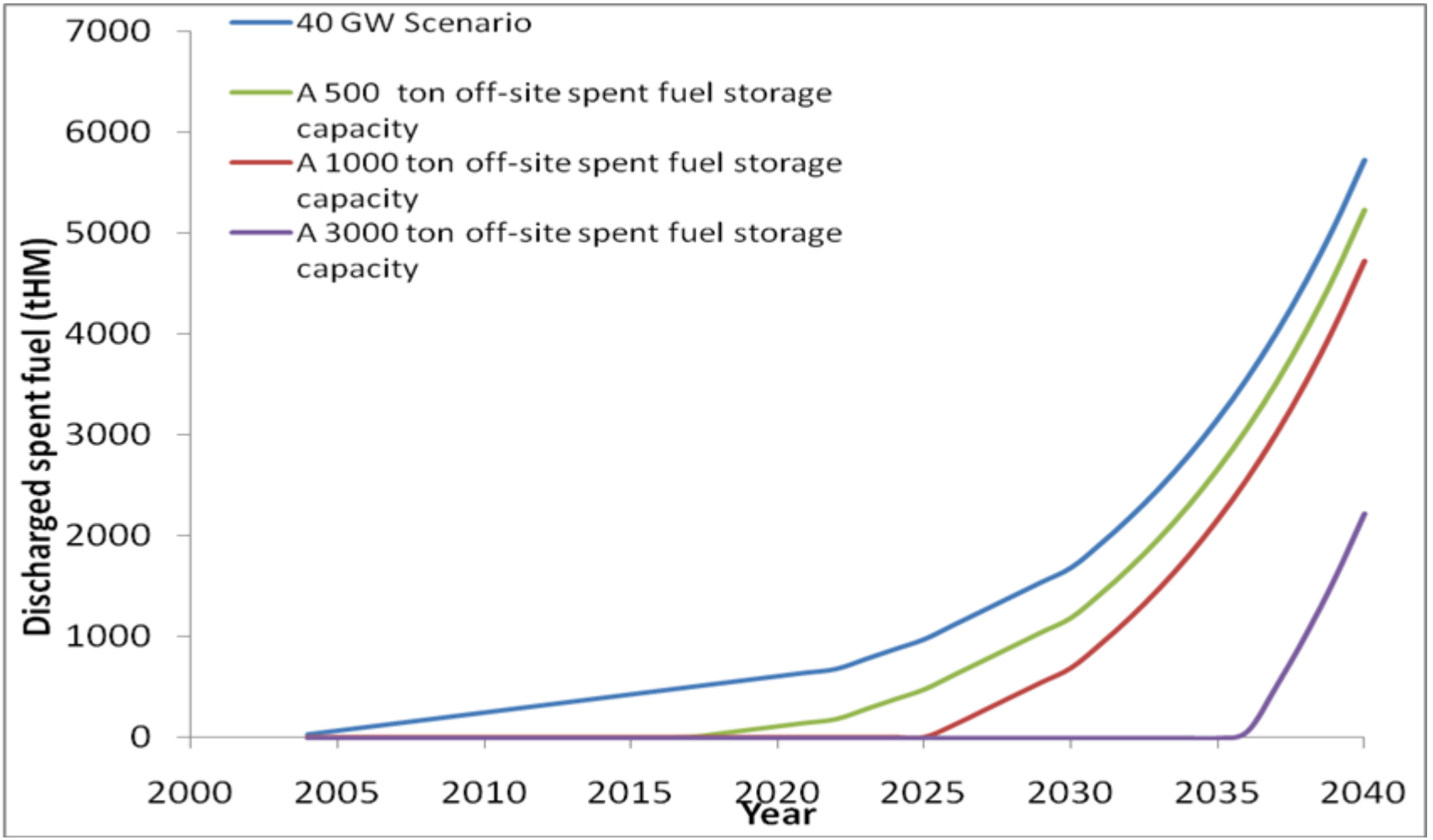
Daya Bay, LingAo, and Tianwan

- Daya Bay I (2 unit)
  - Wet storage
  - On-site storage capacity: 10 years
  - Storage capacity has been filled by 2003
  - Annual spent fuel transport to the reprocessing pilot site

- LingAo (2 units)
  - Dense-pack wet
  - On-site storage capacity: 20 years
  - Storage capacity will be filled by 2022
- Tianwan (2 units)
  - Wet storage and Pool size expansion
  - On-site storage capacity: 20 years
  - Storage capacity will be filled by 2026

Tianwan Reactors

Future spent fuel management



Future spent fuel management (cont'd)

Offsite storage space (tons)	Estimate of when the storage will reach full capacity
500	2017
1000	2025
3000	2035

China will experience very little pressure to reduce the burden of storing spent fuel.

Factors to impact reprocessing

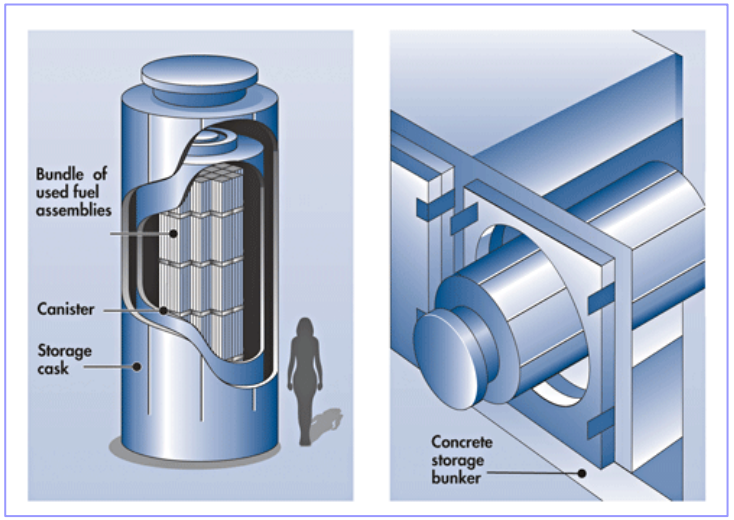
- Uranium resources
- Economics of reprocessing and recycling
- Fast reactor technologies

Uranium resources, reprocessing economics, and uncertainties of fast reactor technologies

- Red book (2007) estimated 5.5 million tons of uranium resources exist globally, 130 times the global production of uranium estimated for 2007
- China's multi-strategies on uranium resources
- Reprocessing and recycling is currently more expensive than once-through cycle (INL 2009)
- Fast reactors need to show long term reliability and economy

Interim dry storage could be a temporary solution

- Economically attractive ($100 - 200/kgU) as compared to reprocessing ($3000/kgHM)
- Technical maturity
- Flexible deployment
- Reduce safeguards risk



Spent Fuel Dry-Storage

Recommendations and Strategies

- Flexible and dynamic frameworks needed
- Active R&D on fuel cycle options and technologies
- Maintain an economic reprocessing operation to meet the needs of fast reactor R&D activities
- Interim dry storage could serve as a temporary option before technologies and economics are demonstrated.