国家能源集团
CHN ENERGY

NATIONAL INSTITUTE OF CLEAN AND-LOW-CARBON ENERGY
北京低碳清洁能源研究院

AMERICA

Flexible CO_2 capture in China

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China Energy

国家能源集团 CHN ENERGY

Corporate profile

- Delivers 15% of China's electricity
- Fortune 100
- Assets: 1.8TT RMB ($286B)
- 350K employees

World's largest ...

500 MM MT/yr Coal production	180 GW Coal-fired power capacity	38 GW wind 19 GW hydro	15 MM MT/yr Coal-chemicals production

National Institute of Clean and low-carbon Energy

Corporate RD&D lab

- *Mission ... To become a world-class R&D institute supporting China Energy's transition to a clean and low carbon energy supplier*
- Founded in 2009 ... ~700 researchers
- Sites ... Beijing, China; Mountain View, CA; Schwabisch Hall, Germany

Mission-driven research platforms

- Catalysis
- Clean coal
- Coal-based materials
- Advanced technologies
- Distributed Energy
- Hydrogen Energy
- Water Treatment

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... Emissions/carbon management

Estimated CO_2 footprint for China Energy

2020 (BAU)

CO_2 emissions (MM MT $CO_{2,eq}$/yr)

700+

Transport

Rail
Shipping

Power generation

Coal-fired power

2018:
163 plants
478 units
180 GW

Mining

Coal mine operations
Fugitive emissions

Chemicals

Direct coal liquefaction
Coal to methanol to olefins

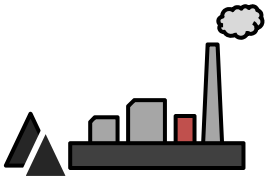
Carbon management roadmap

Enable CE to affordably reduce CO_2 emissions by 100+ MM tons per year by 2030.

Fleet modeling

system trade-offs and data

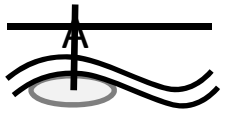
- Identify "lowest cost" paths for system-wide CO_2 reduction
- clarify and quantify "highest impact" RD&D opportunities



CO_2 capture

power retrofits

- Validate technology under "China-specific" conditions
- Accelerate maturation of practical capture for China



CO_2 offtake

supply chain/enablers

- Create a close-out process for saline aquifer storage in China
- Prove value proposition for near-term utilization options

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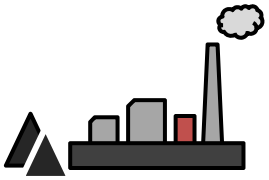

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“China-specific” conditions

Hardware

- Retrofits ... Over 50% of generation capacity < 15 yrs old
- Water stress ... Significant generation located in arid regions
- ULE pollution controls ... SCR, FGD, ESP by 2020

Operations

- Low capacity factor ...4300h or 50% (national average, 2017)
- Load-following ... changing CO_2 concentration in flue gas

Market

- ETS market definitions ... 2020 target = 550 g/kWh for power plants
- Electricity market operation ... Regulated dispatch and power tariffs

Flexible capture

Dynamic operation of the CO_2 capture system to maximize operating profit of a power plant in response to variable electricity prices.

Strategy	Principle	Benefit	Disadvantage
Reduced load / flue gas bypass	Reduce capture rate + pay CO_2 "tax" during high electricity price periods	Capture value from high electricity price	Pay CO_2 "tax" during low capture/bypass periods to offset lower capture rate
Solvent storage	Store solvent during high electricity prices; regenerate when electricity price is low	Capex savings from undersized regenerator	Pay for solvent storage tanks and extra solvent
Time-varying solvent regeneration	Vary lean loading with electricity price	Avoid costs for solvent storage tank	Process control could be more challenging; Pay CO_2 "tax" during low capture periods

Domenichini, Energy Procedia 37(2013)
Dowell, IJGGC 48 (2016)

Flexible capture in China

Drivers	Western	China	Implication for flexibility in China
Market structure	Dispatch pricing	Regulated power tariffs	Much weaker electricity price signal
Capture rate target	90%	50-60% 550 g/kWh (Nat'l ETS)	Reduced economic penalty at lower rates of CO_2 capture
Power plant load profile	Dispatch priority	Scheduled dispatch profiles	Variability in power plant loads driven by regulation (details vary by provinces)
ETS	Mass-Based	Rate-based	Possible enhanced benefit from carbon credit trading

A weaker electricity *price signal* and *CO_2 emissions penalty* will favor flexible CCS strategies that minimize cost of capture...

... but how will the strategies differ?

Technical

Hypotheses:

1. Cost of capture will be, on average, lower relative to other parts of the world.
2. Cost drivers for flexible operation in China will be comparable to trends observed elsewhere, but market drivers will differ.

Approach:

1. Estimate costs for selected post-combustion CO_2 capture scenarios for retrofitted coal-fired power plants.
2. Compare magnitudes of cost drivers and market signals.
3. Infer general principles for flexible capture strategy in China.

Scenarios

	No load following	load following (50%,70%)
On/off capture (0, 90%)	**Baseline & Case 1:** BL1 CF 50%, Load 100%, Cap 0% BL2 CF 70%, Load 100%, Cap 0% 1.1 CF 50%; Load 100%, Cap 90% 1.2 CF 70%, Load 100%, Cap 90%	**Case 3:** 3.1 CF 50%, Load 50%, Cap 0% 3.2 CF 70%, Load 70%, Cap 0% 3.3 CF 50%, Load 50%, Cap 90% 3.4 CF 70%, Load 70%, Cap 90%
Partial capture (30, 50, 70%)	**Case 2:** 2.1 CF 50%; Load 100%, Cap 30% 2.2 CF 50%, Load 100%, Cap 50% 2.3 CF 50%, Load 100%, Cap 70%	**Case 4:** 4.1 CF 50%, Load 50%, Cap 30% 4.2 CF 50%, Load 50%, Cap 30% 4.3 CF 50%, Load 50%, Cap 70%

Post combustion capture, Retrofit, MEA solvent capture system
China costing assumptions: S. Singh, IJGGC, 78 (2018): 429-436.

Cost estimation

Description of costing methodology

1. Cost basis ... IJGGC reference

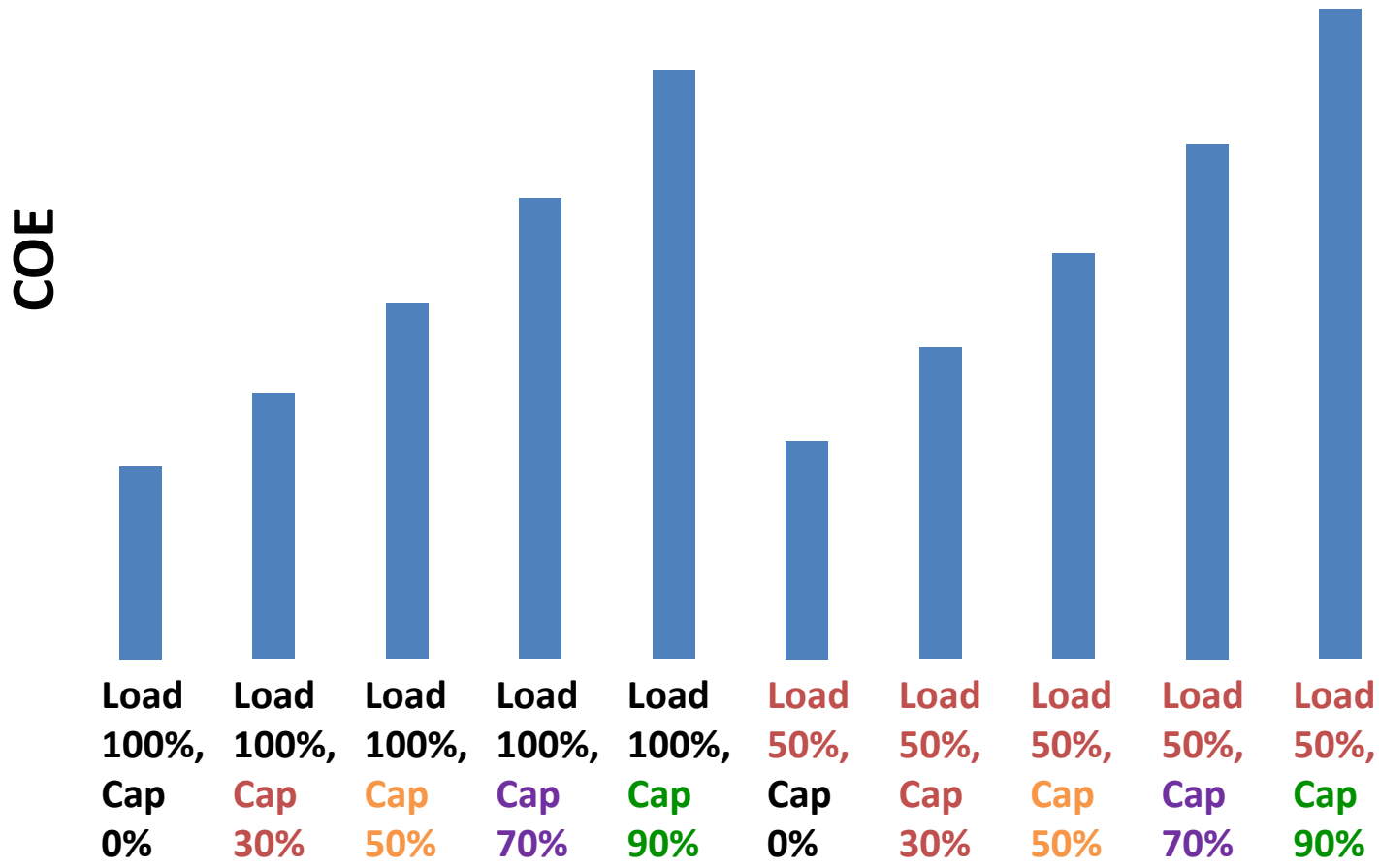
2. Turndown ... efficiency correction; scaling by plant output

3. Partial capture ... reduced capture trains

4. Turndown and partial capture ... superposition of effects from (2) and (3)

Notes:
- error bars of ± 20%
- interaction terms ignored for first estimate of (4)

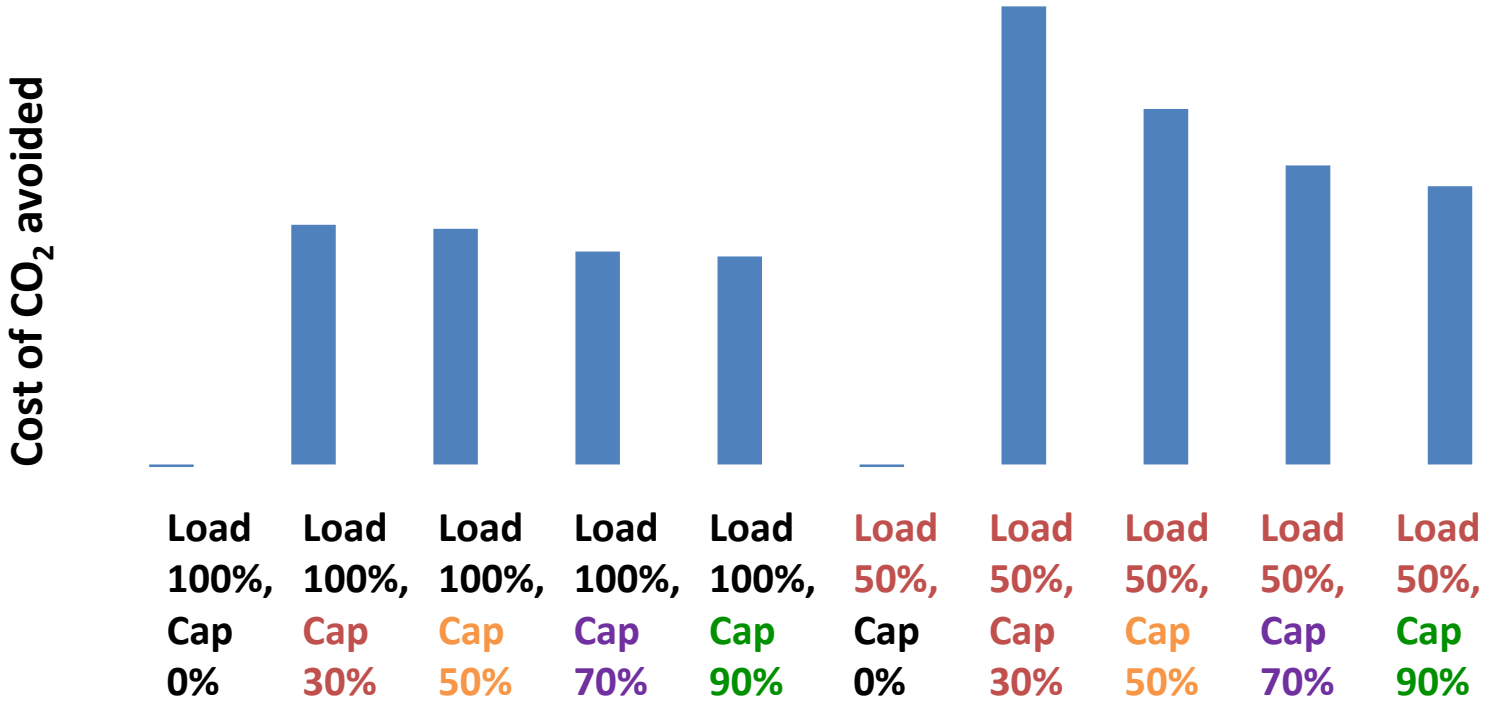
Preliminary results



COE increases with load following and capture rate

Hao, IJGGC, In preparation

Results for flexible capture

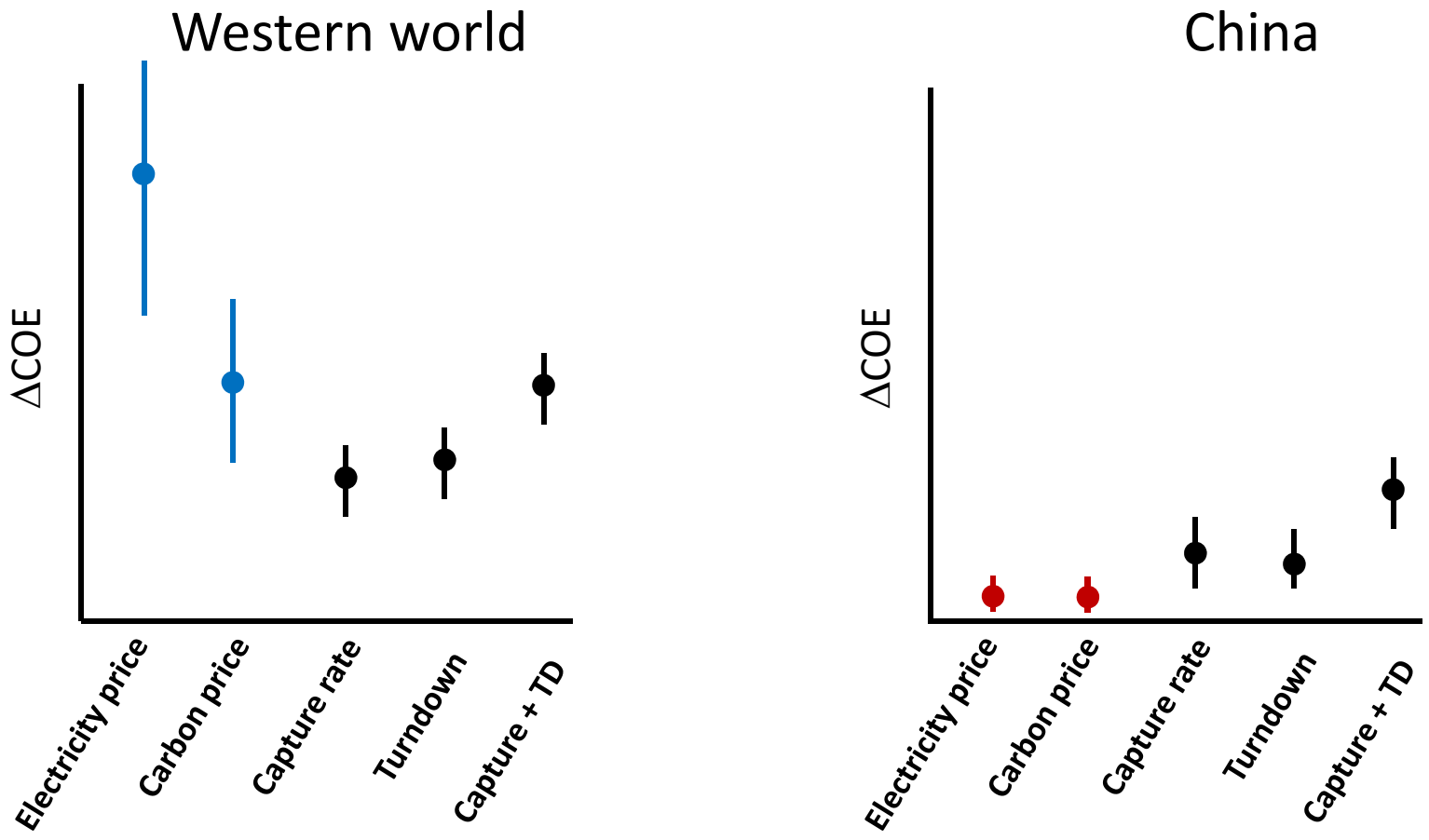


Cost of CO_2 avoided increases with load following; decreases with capture rate

Hao, IJGGC, In preparation

Preliminary results

Magnitude of cost drivers vs market signal



Cost of capture drives flexible capture in China.

Hao, IJGGC, In preparation

Summary

Flexible capture can be different *in China.*

- **Lower impact of market drivers has not been recognized.**
- Optimal strategies for flexible capture in China will favor operating plants at high capture rates and high capacity factors.

Future work includes:

- Detailed modeling to understand province level variability in optimal strategies
- Effects of 2nd generation capture technology
- Fleet-level optimization through ETS trading
- How will electricity market reform impact the optimal strategy?

Thanks !