  

The National and International Impacts of Coal-to-Gas Switching in the Chinese Power Sector

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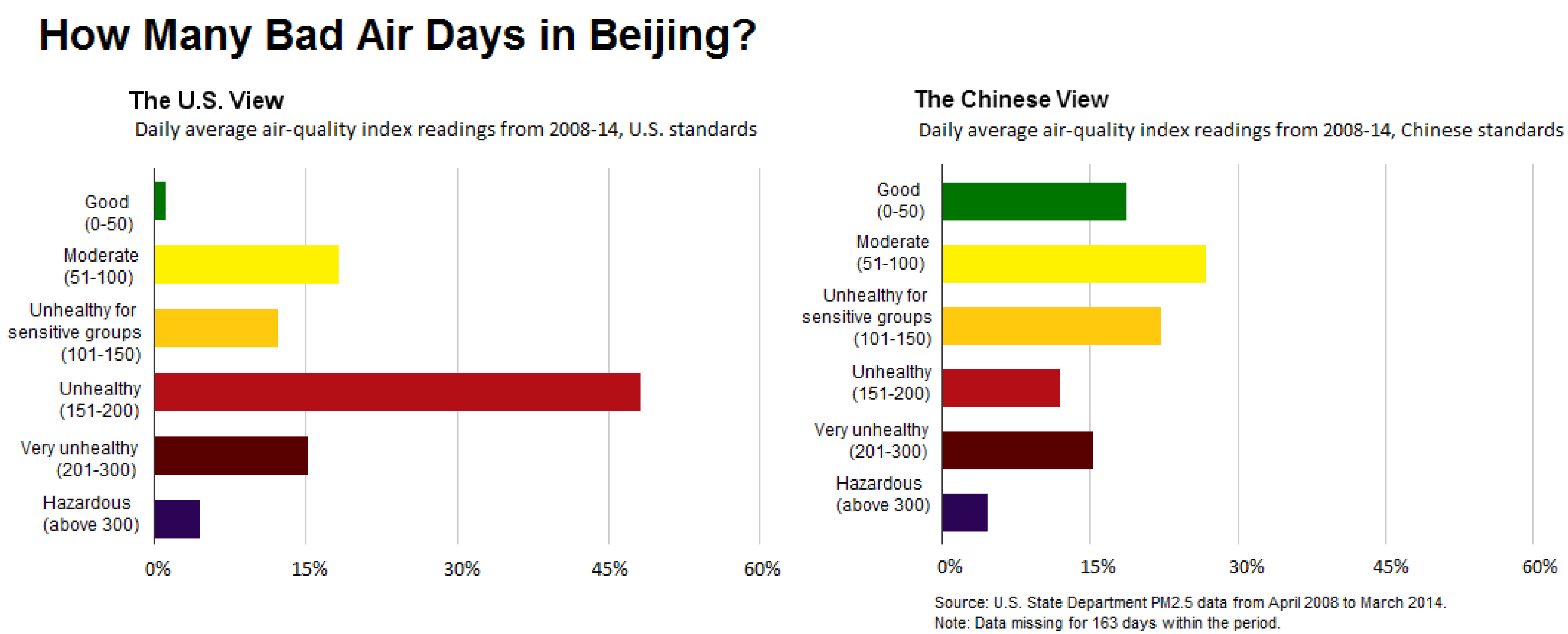
FEEM, Venice, June 2015

Outline of the talk

1. Policy Background
2. Methodology
3. Scenarios
4. Results
5. Implications

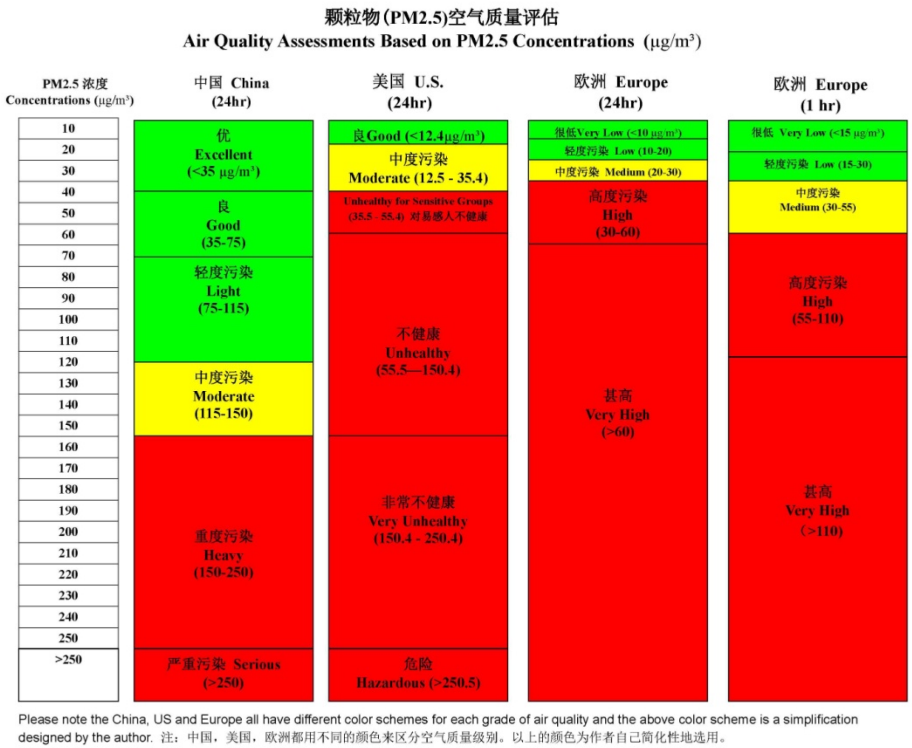
China sees more and more hazy days

How many hazy days?



Source: http://blogs.wsj.com/chinarealtime/2014/04/14/beijings-bad-air-days-finally-counted/

How is it measured?



Source: https://www.chinadialogue.net/article/show/single/en/6856-China-s-air-pollution-reporting-is-misleading

The Chinese people are getting concerned

A report by Peking Univ. and Greenpeace (2015) warns that a quarter million of Chinese people could die of pre-mature death in the next decade, if smog is left uncontrolled.

Source: http://www.greenpeace.org/eastasia/press/releases/climate-energy/2015/dangerous-breathing-2/

The concerns are escalating

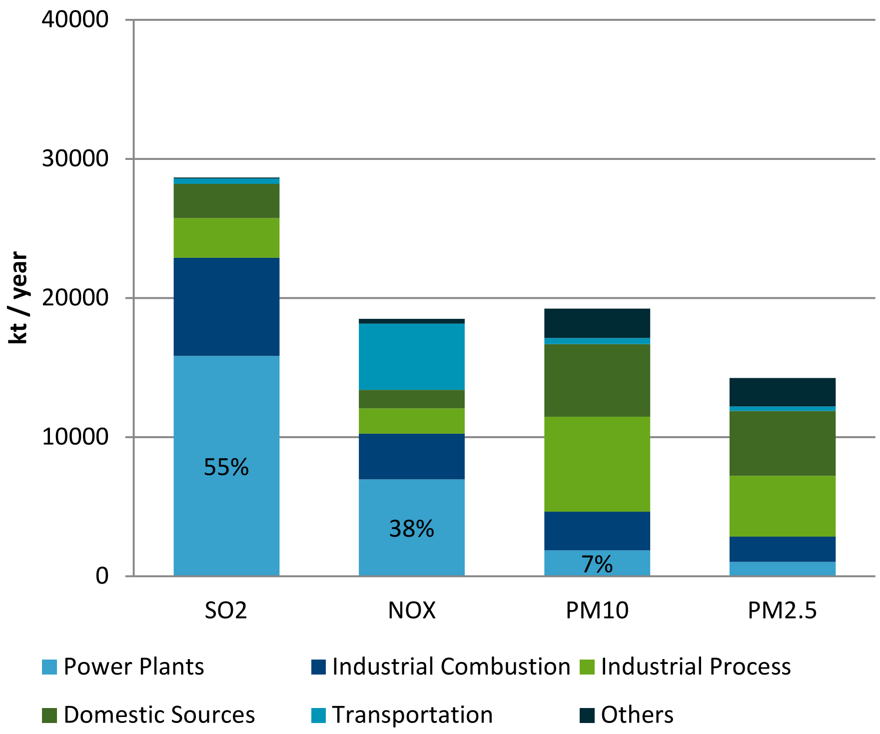
Documentary by former CCTV host and reporter Jing Chai was released on 28 Feb 2015, the day after the appointment of China's new environment minister. It attracted 200+ million hits in the first week, before it disappeared…

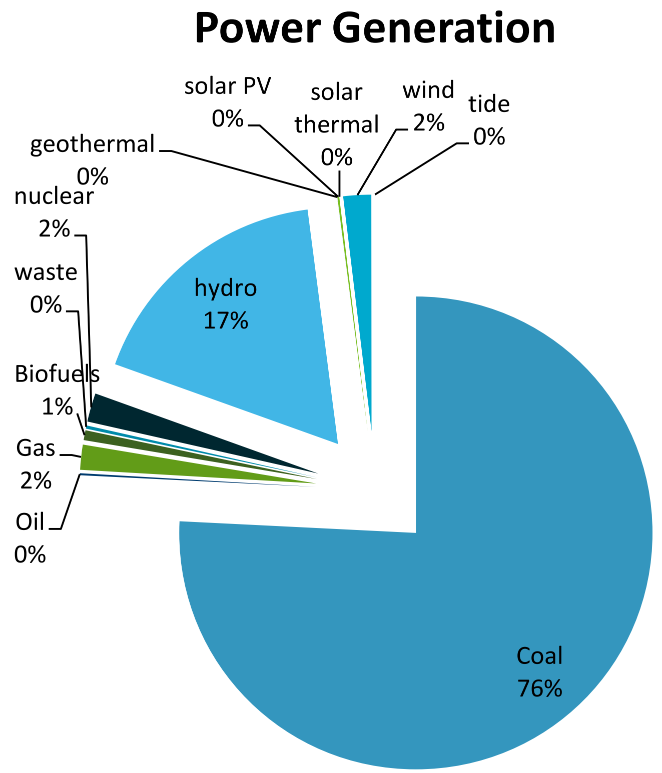
The Chinese government is getting serious about it

- The Action Plan for Air Pollution Prevention and Control was announced on 10 September 2013.
  - The Plan mandates reduction in PM2.5 in three regions: Beijing-Tianjin-Hebei 25%, the Yangtze River Delta 20%, and the Pearl River Delta 15%.
  - It bans the construction of new coal-fired power plants in these regions (roughly 30% of national total).

Source: http://english.mep.gov.cn/News_service/infocus/201309/t20130924_260707.htm

The role of coal power in Chinese air pollution





Source: Wang et al., Atmospheric Environment, 2011, 45: 6347-6358.

Source: US EIA.

What are the consequences of reducing coal power?

- The government plans to stimulate the development of coal power in the inner West.
  - But this takes time to build.
  - There are ongoing concerns about water shortage in West China.
- Therefore, the government's action plan is anticipated to contain the growth of China's coal power generation.
- The energy gap needs to be filled up by something else.

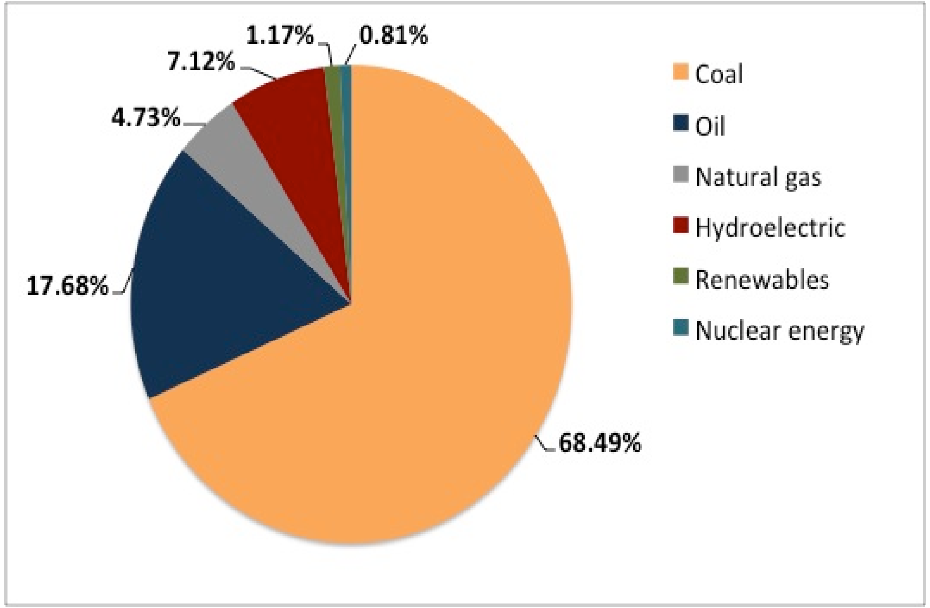
What can replace Chinese coal power?

Technology	Online Year[1]	Size (MW)	Lead time (years)	Base Overnight Cost in 2013 (2012 $/kW)	Project Contingency Factor[2]	Technological Optimism Factor[3]	Total Overnight Cost in 2013 (2012 $/kW)	Variable O&M (2012 $/MWh)	Fixed O&M (2012$/kW)	Heatrate[6] in 2013 (Btu/kWh)	nth-of-a-kind Heatrate (Btu/kWh)
Scrubbed Coal New	2017	1300	4	2,734	1.07	1.00	2,925	4.47	31.18	8,800	8,740
Integrated Coal-Gasification Comb Cycle (IGCC)	2017	1200	4	3,525	1.07	1.00	3,771	7.22	51.39	8,700	7,450
IGCC with carbon sequestration	2017	520	4	5,958	1.07	1.03	6,567	8.45	72.84	10,700	8,307
Conv Gas/Oil Comb Cycle	2016	620	3	871	1.05	1.00	915	3.60	13.17	7,050	6,800
Adv Gas/Oil Comb Cycle (CC)	2016	400	3	945	1.08	1.00	1,021	3.27	15.37	6,430	6,333
Adv CC with carbon sequestration	2017	340	3	1,856	1.08	1.04	2,084	6.78	31.79	7,525	7,493
Conv Comb Turbine[8]	2015	85	2	924	1.05	1.00	971	15.45	7.34	10,817	10,450
Adv Comb Turbine	2015	210	2	641	1.05	1.00	673	10.37	7.04	9,750	8,550
Fuel Cells	2016	10	3	6,099	1.05	1.10	7,044	42.99	0.00	9,500	6,960
Adv Nuclear	2019	2234	6	4,763	1.10	1.05	5,501	2.14	93.28	10,464	10,464
Distributed Generation - Base	2016	2	3	1,414	1.05	1.00	1,485	7.76	17.45	9,027	8,900
Distributed Generation - Peak	2015	1	2	1,698	1.05	1.00	1,783	7.76	17.45	10,029	9,880
Biomass	2017	50	4	3,590	1.07	1.02	3,919	5.26	105.64	13,500	13,500
Geothermal[7,9]	2016	50	4	2,375	1.05	1.00	2,494	0.00	112.92	9,716	9,716
Municipal Solid Waste	2014	50	3	7,751	1.07	1.00	8,294	8.75	392.81	18,000	18,000
Conventional Hydropower[9]	2017	500	4	2,213	1.10	1.00	2,435	2.65	14.83	9,716	9,716
Wind	2014	100	3	2,061	1.07	1.00	2,205	0.00	39.55	9,716	9,716
Wind Offshore	2017	400	4	4,503	1.10	1.25	6,192	0.00	74.00	9,716	9,716
Solar Thermal[7]	2016	100	3	4,715	1.07	1.00	5,045	0.00	67.26	9,716	9,716
Photovoltaic[7,10]	2015	150	2	3,394	1.05	1.00	3,564	0.00	24.69	9,716	9,716

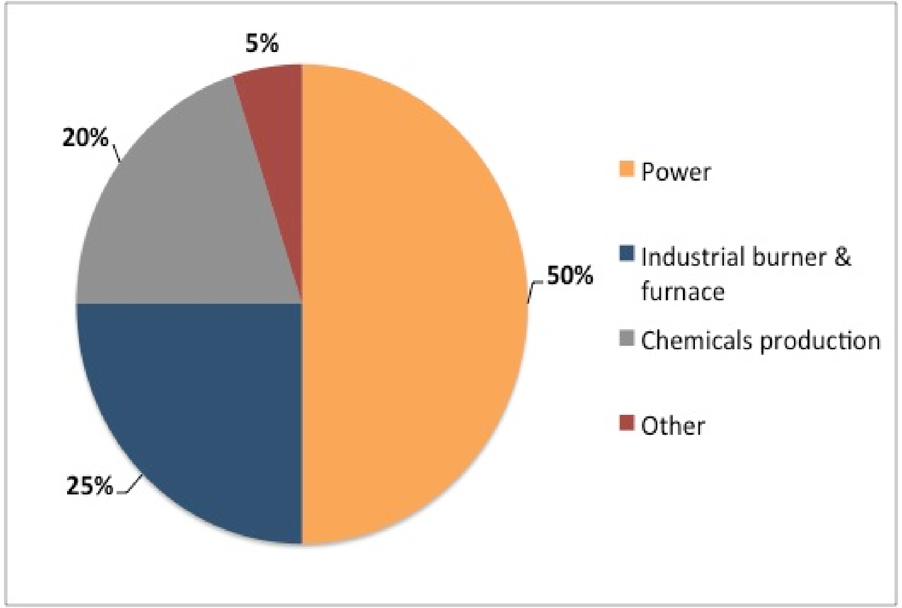
Source: US EIA.

The role of coal in national energy markets

China's Primary Energy Consumption, 2012



China's Coal Consumption, 2012

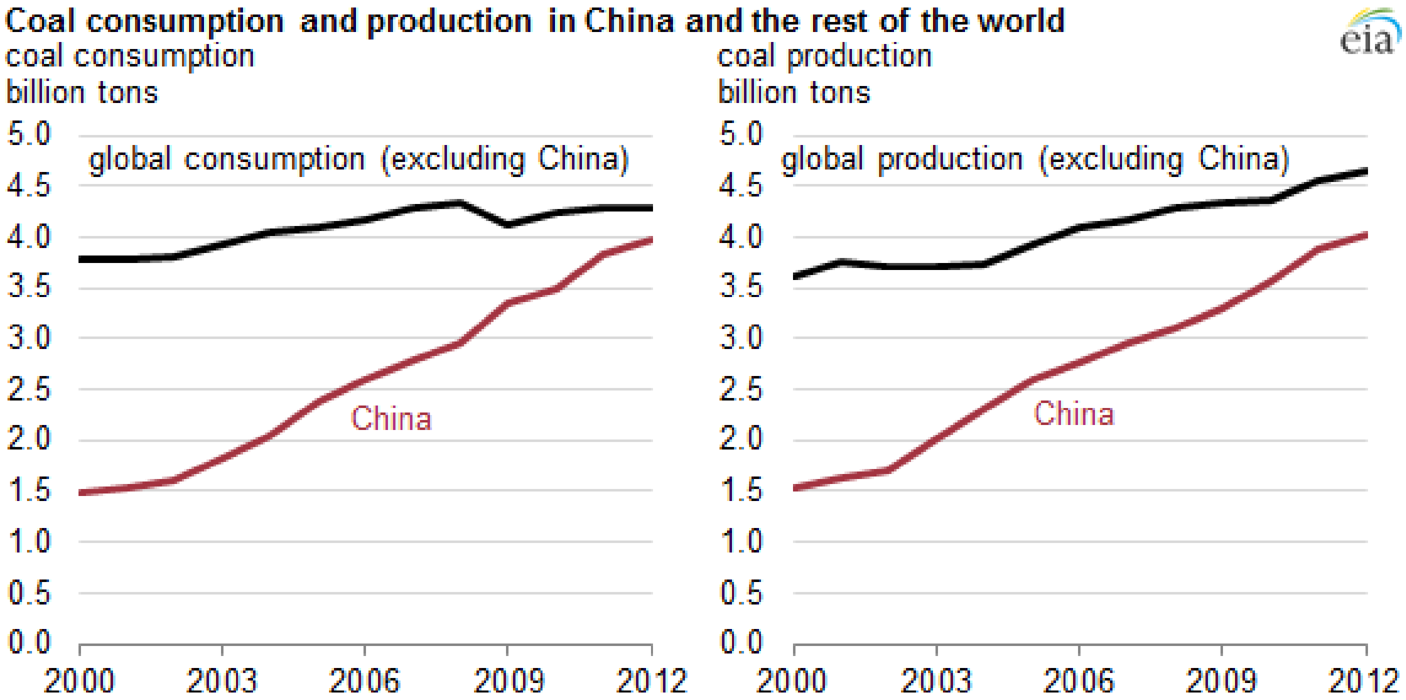


Source: http://www.worldcoal.org

So the questions to ask

- What would be the environmental impacts of coal-to-gas switching?
- What would be the co-benefit of carbon mitigation?
- What does it mean for the Chinese energy markets and economy?
- What does it mean for other countries?

The role of coal in global energy markets



And coal provides 30% of global primary energy needs.

Modelling Approach

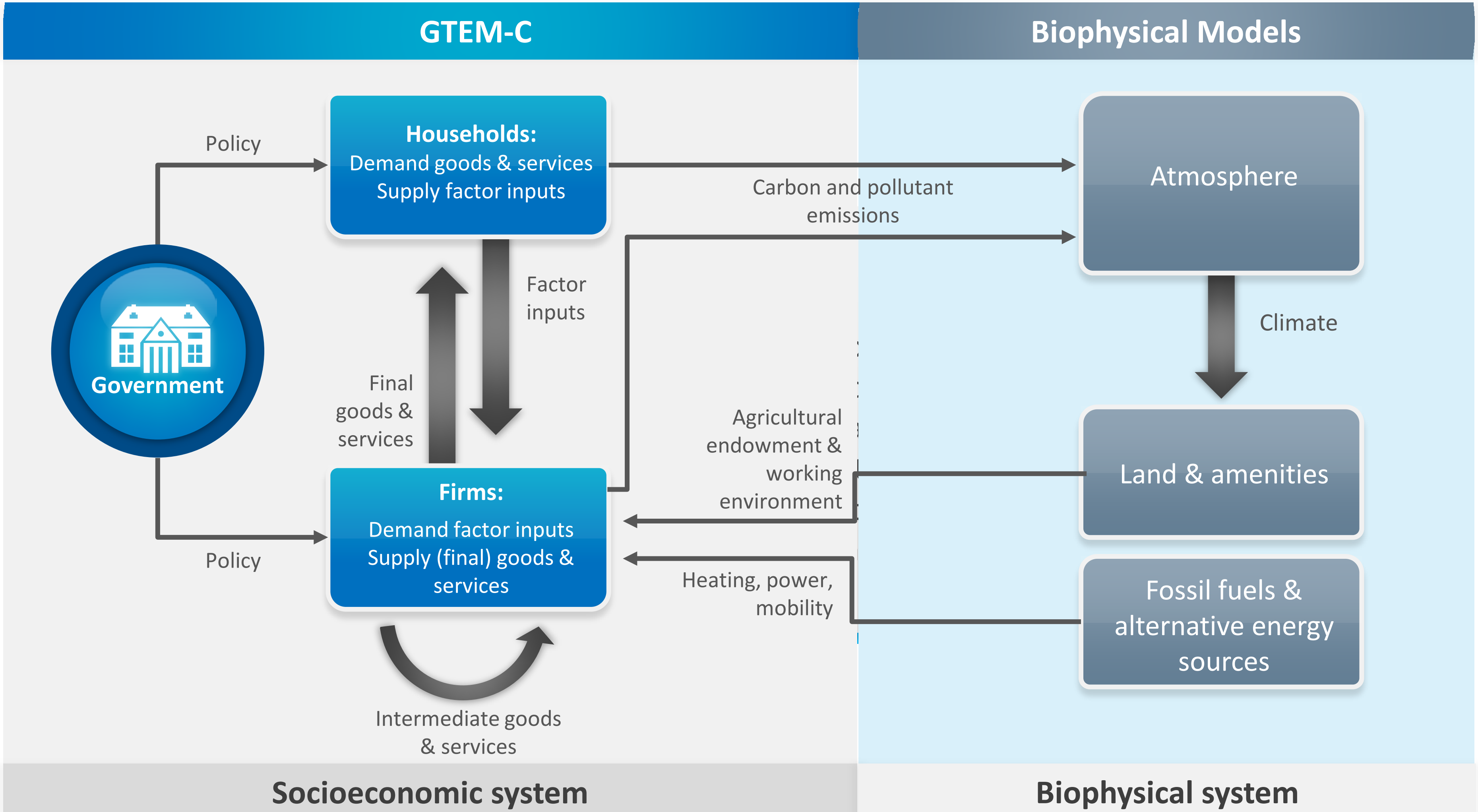
GTEM-C is a global-scale multi-sector dynamic CGE model designed to analyze economic tradeoffs associated with production and use of fossil fuels and GHG emissions.

GTEM-C features careful representation of major geographic regions and economic activities that are most relevant to climate change, carbon mitigation and energy transformation.

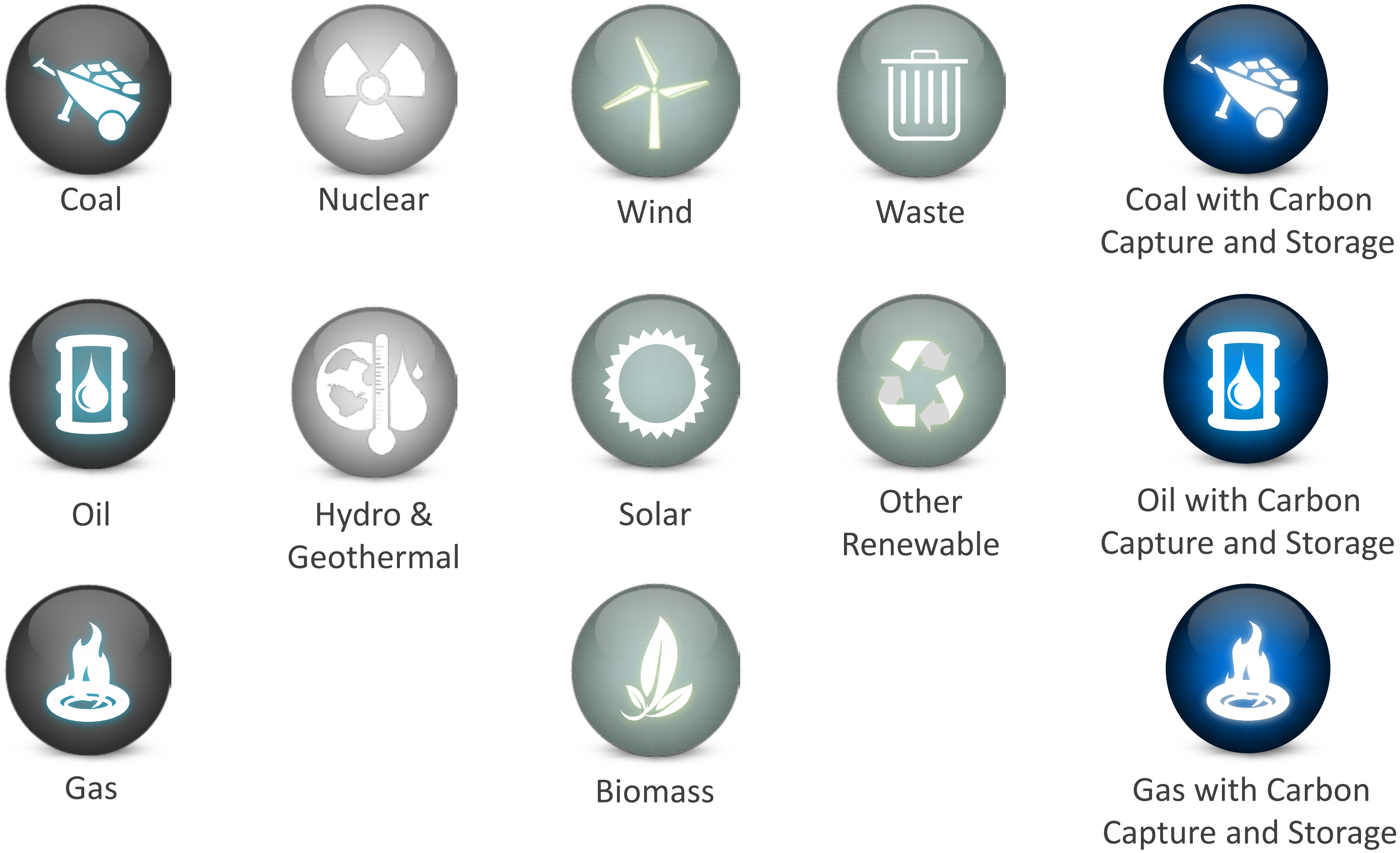
GTEM-C has detailed accounting of commodity-embedded energy flows and carbon emissions from various sources.

Source: Cai et al. (2015).

Theoretical structure of GTEM-C



GTEM-C Electricity Technologies



Source: Cai and Arora (2015).

Accounting for air pollutants from industrial combustion

Coal emission factors

Kt / Mtoe	Electricity	Transportation	Other Industries	Coking	Household
SO2	22.0[b]	19.8	19.8[a]	1.5	25.2[a]
NOx	9.6[a]	11.0[c]	11.0[c]	1.0[c]	4.0[c]
PM10	1.9[e]	1.9	1.9	1.1[e]	3.8[e]
PM2.5	1.7[b]	1.7	1.7	0.7[e]	3.4

Gas emission factors

Kt / Mtoe	Electricity	Transportation	Other Industries	Conversion	Household
SO2	0.04[d]	0.04	0.04	0.04	0.04
NOx	2.0[a]	22.0[c]	3.0[c]	0.3[c]	1.0[c]
PM10	0.004[e]	0.004[e]	0.004[e]	0.004[e]	0.004[e]
PM2.5	0.004[e]	0.004[e]	0.004[e]	0.004[e]	0.004[e]

Oil emission factors

Kt / Mtoe	Electricity	Transportation	Other Industries	Refining	Household
SO2	11.0[a]	1.1[a]	11.0[a]	0.7	1.0[a]
NOx	10.0[a]	23.0[c]	4.0[a]	0.3[c]	17.0[a]
PM10	0.1[e]	2.5[e]	0.05[e]	1.0[e]	0.04[e]
PM2.5	0.03[e]	2.10[e]	0.01[e]	1.0[e]	0.04[a]

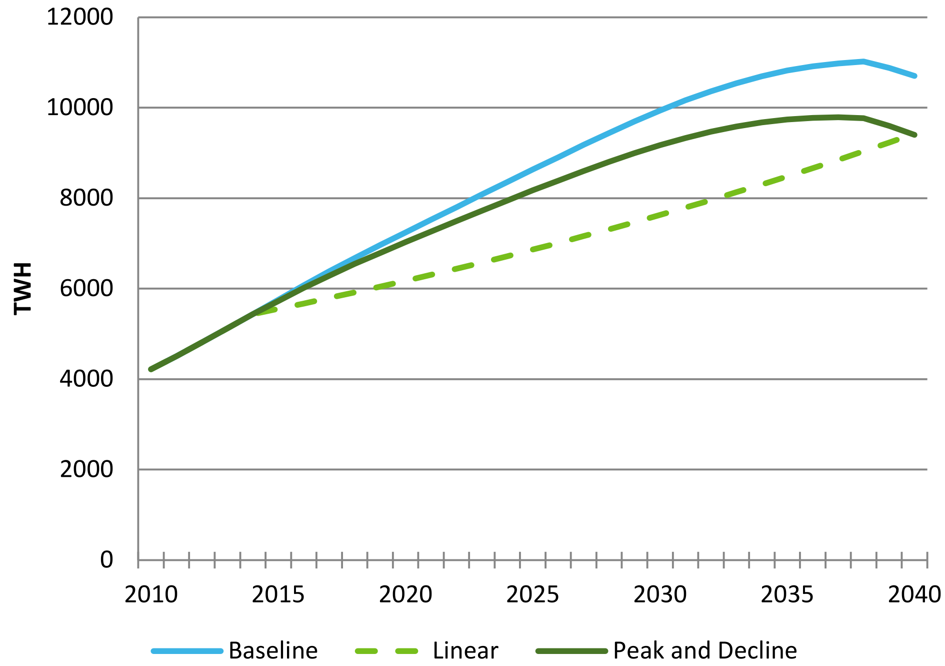
Source: a. Klimont et al. (2009); b. Zhang et al. (2009); c. Wang et al. (2011); d. de Gouw et al. (2013); e. IIASA, http://www.iiasa.ac.at/~rains/PM/docs/documentation.html.

Note: Household includes private transportation.

Baseline assumptions

Variable	Benchmark
Population Growth	IEO 2013
GDP	IEO 2013
Fossil Fuel Supply	IEO 2013
Energy Efficiency Improvement	Coal: 0.5-1% Oil: 2.5-3% in transport, 0.5% in others Gas: 0.5-1% Electricity: 1%
Carbon/Environment Policy	Business as usual

Counter-factual experiment



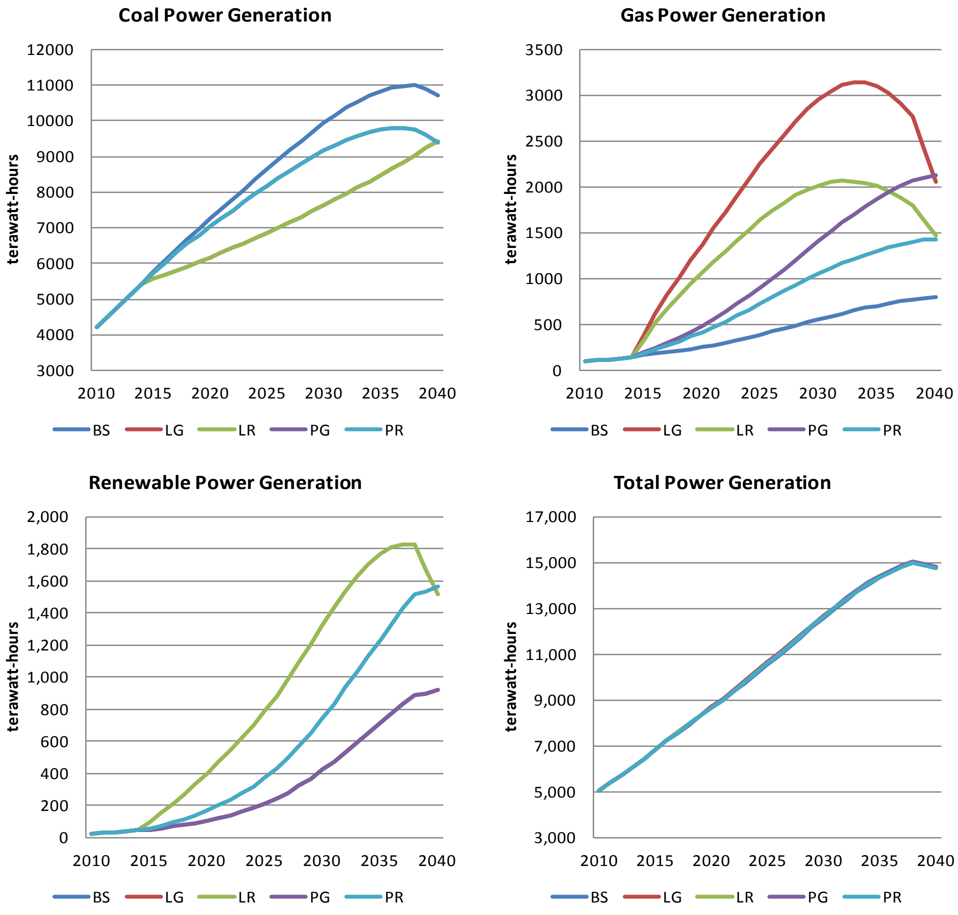
Baseline: Chinese coal power generation increases by 2.5% per annum on average.

Policy: Chinese government has recently announced a cap on the growth of coal use by 18% between 2013 and 2020, which implies an annual growth rate of 2% over the period.

A two-by-two matrix scenarios

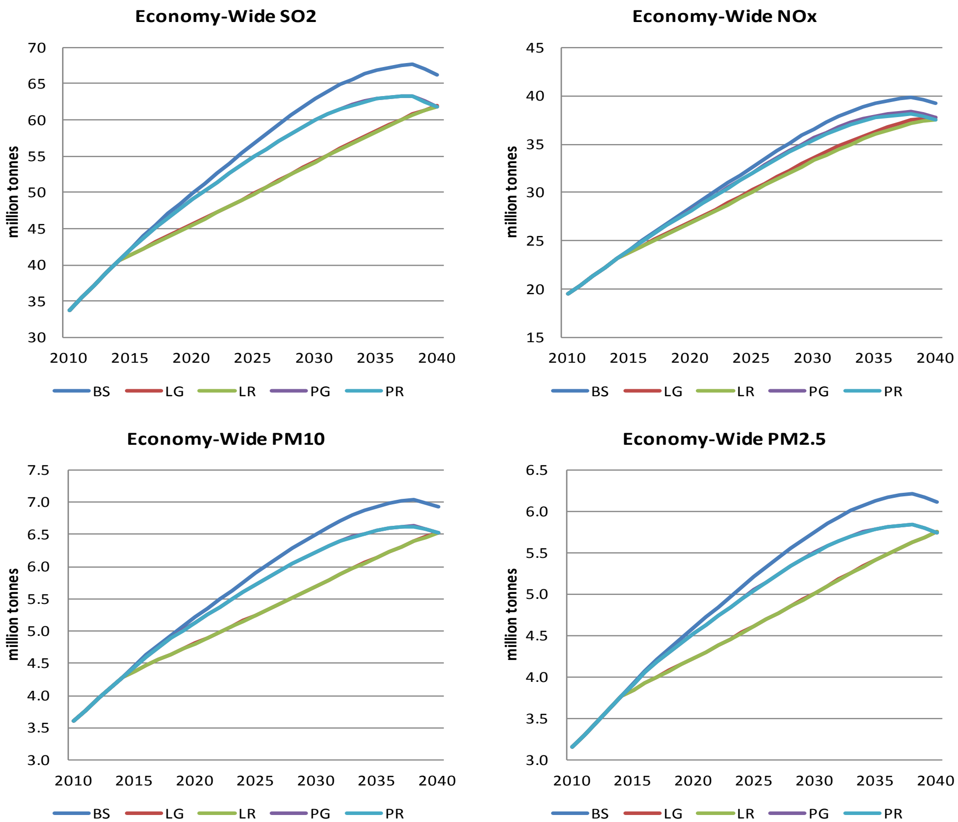
		Catalyst	
		Gas Only	Gas and Renewable
Pathways	Linear	LG	LR
	Peak-and-Decline	PG	PR

Power generation under alternative scenarios



Share of coal power falls down to 63%, i.e., by 10 percent points.

Pollutant emissions under alternative scenarios

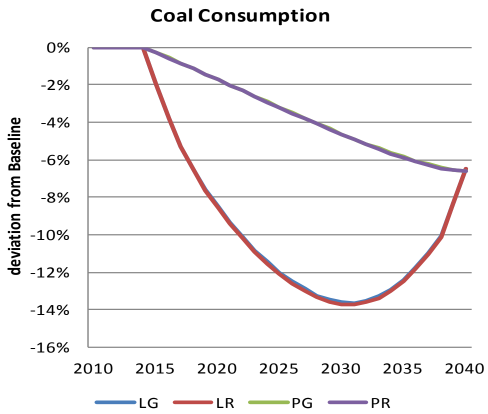


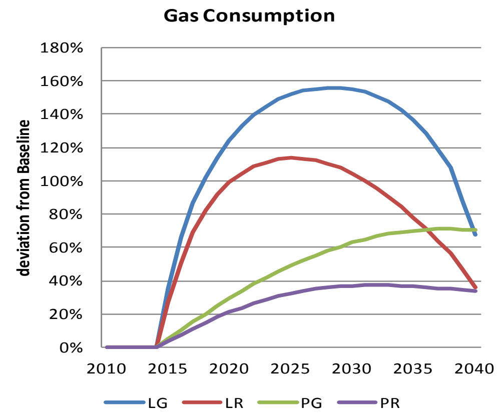
Cumulative emissions of SO2, NOx, PM10, and PM2.5 in China are projected to drop by 160 MT (9.5%), 60 MT (6.0%), 15 MT (8.5%) and 14 MT (9.0%).

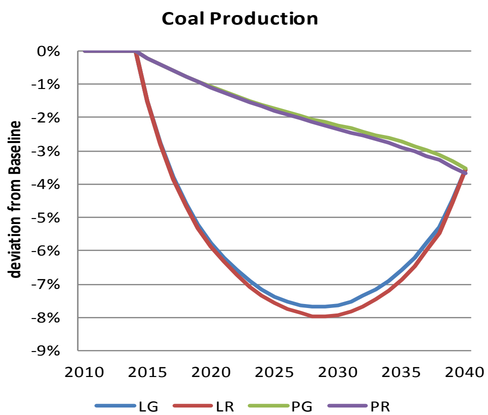
Carbon footprints under alternative scenarios

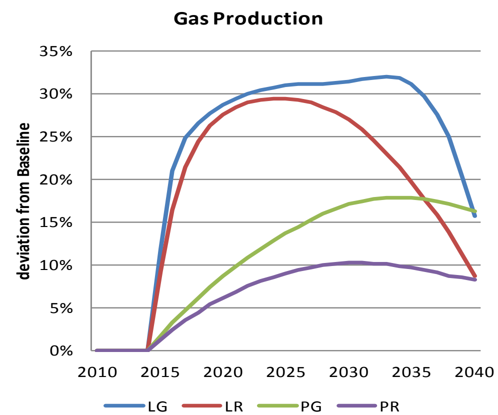
The LR scenario is superior, because cumulative CO2 emissions between 2015 and 2040 are projected to be 18000 MT, or 5% lower than under the baseline scenario, and China is closer to achieving the Copenhagen Commitment.

Impacts on energy markets under alternative scenarios



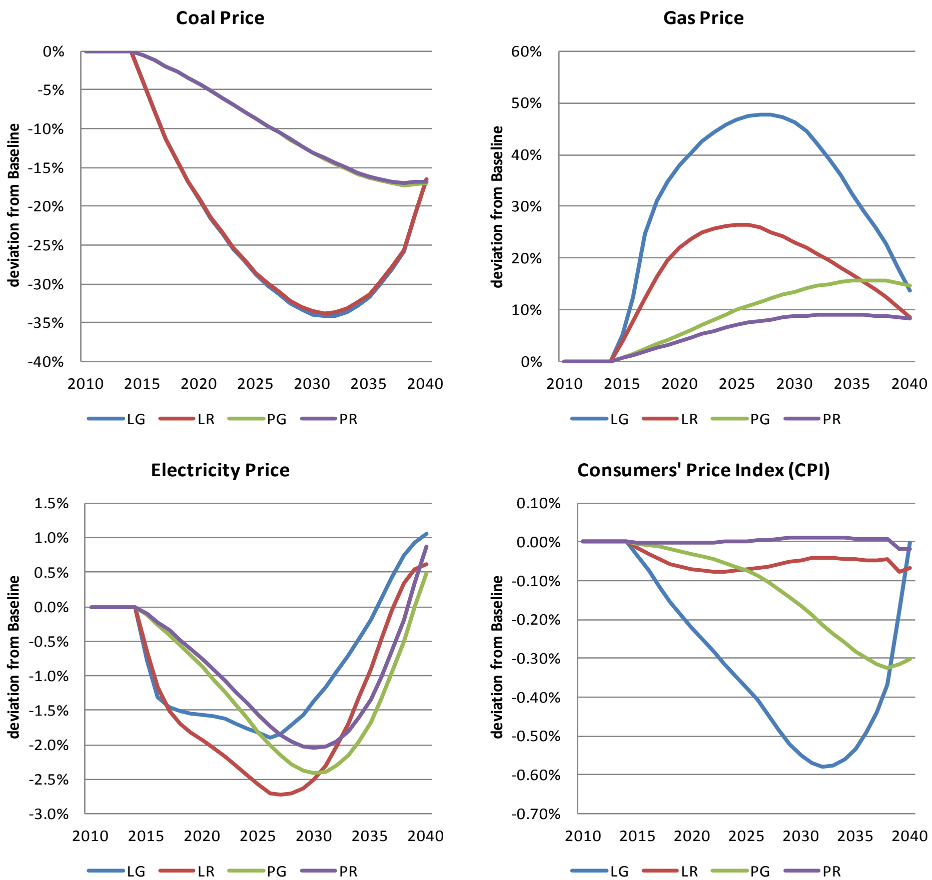






Chinese gas production will not be able to keep up with the increased demand for gas power generation. The gap needs to be filled up by more imports.

Impacts on prices under alternative scenarios

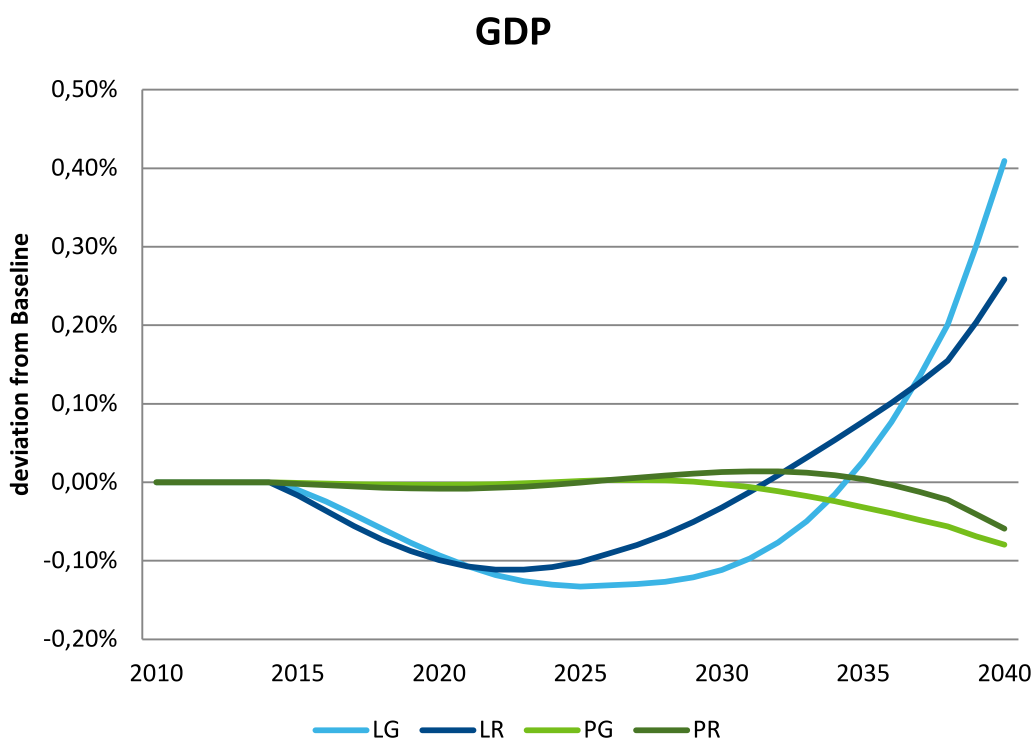


Having more renewable has the potential to reduce the increase in gas price, by half.

Electricity price could be lower in the early stage of switching due to lower coal price.

Learning by doing of the renewable technologies is most significant under LR.

Impacts on macro-economy under alternative scenarios



Which could be a better scenario for China?

Net Present Value of China's GDP Change under Alternative Scenarios
(Unit = billion 2007 US$)

		Discount Rate										
		0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
Scenario	LG	33.5	0.6	-22.4	-38.0	-48.3	-54.7	-58.2	-59.6	-59.6	-58.6	-57.0
	LR	90.6	53.4	25.8	5.6	-9.2	-19.8	-27.3	-32.4	-35.7	-37.6	-38.6
	PG	-90.5	-71.9	-57.4	-45.9	-36.9	-29.7	-24.1	-19.5	-15.9	-13.1	-10.8
	PR	-22.7	-17.5	-13.6	-10.7	-8.6	-6.9	-5.7	-4.7	-4.0	-3.5	-3.1

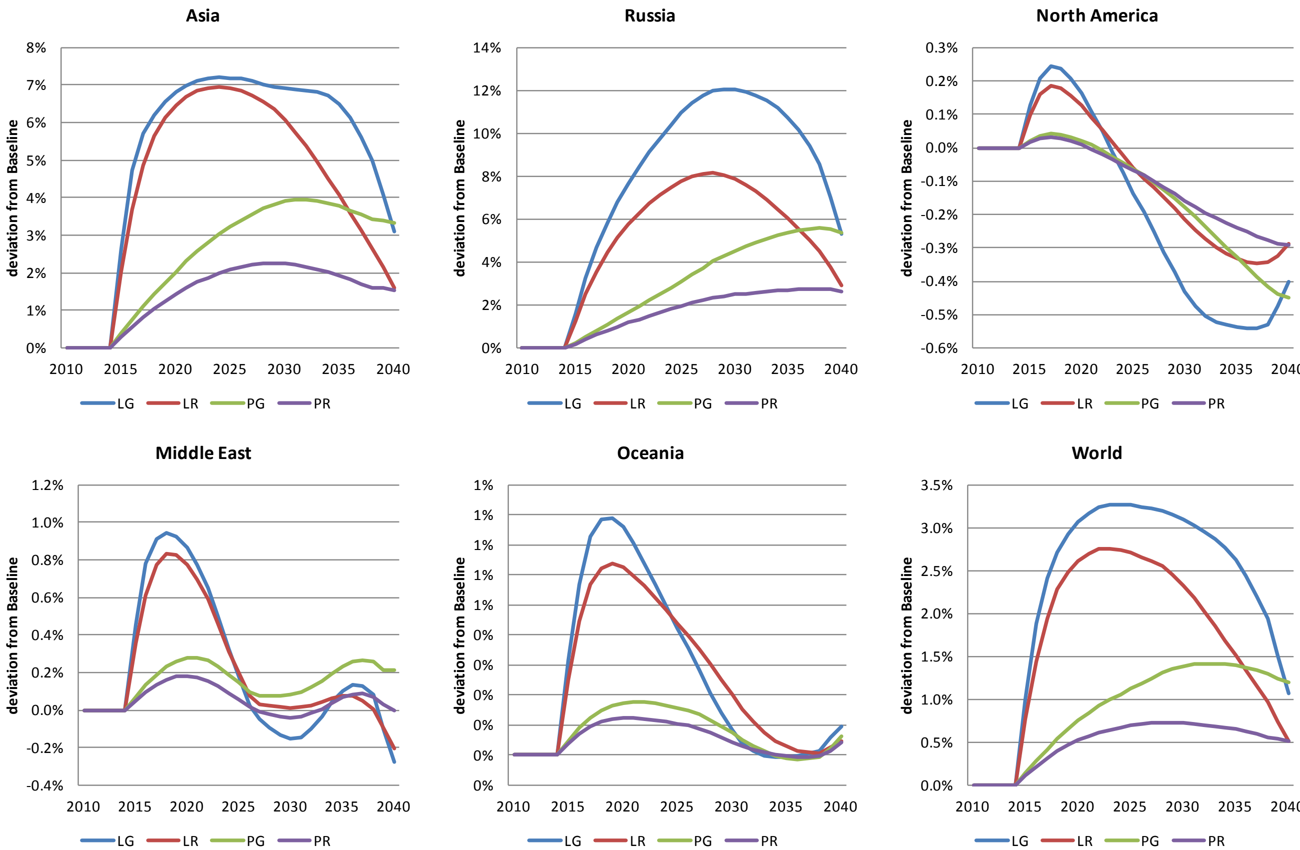
With a discount rate of 3-5%, the "Linear" pathway with development of renewable energies (LR) can result in net GDP gains, or at least reasonably low (although not necessarily the lowest) GDP loss.

And we haven't accounted from the potential benefit on environment and human health by mitigation air pollutants from coal combustion.

So the LR scenario could be the way ahead.

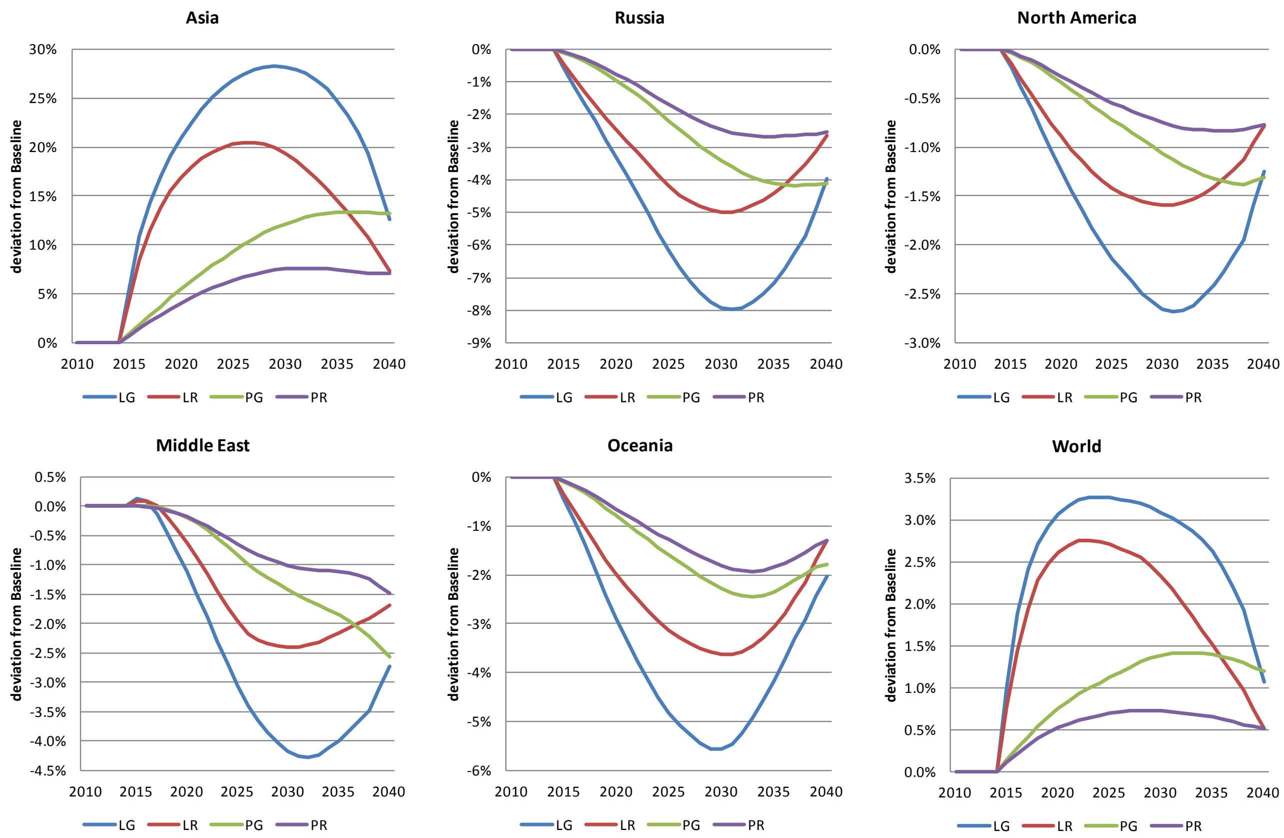
But what would be the impacts on global production?

Global gas production



And global consumption?

Global gas consumption



What about GDP?

	2015	2020	2025	2030	2035	2040
USA	0.00%	0.00%	0.01%	0.01%	0.01%	0.00%
Rest of North America	0.00%	0.00%	-0.01%	-0.03%	-0.05%	-0.08%
South America	0.00%	0.00%	-0.01%	-0.01%	-0.01%	0.00%
Europe	0.00%	0.00%	-0.01%	-0.01%	0.00%	0.00%
China	0.00%	0.00%	0.00%	0.00%	-0.03%	-0.08%
Northeast Asia	0.00%	0.03%	0.05%	0.07%	0.09%	0.08%
India	0.00%	0.00%	0.00%	0.03%	0.05%	0.06%
Rest of Asia	0.00%	-0.04%	-0.11%	-0.21%	-0.34%	-0.40%
Russia	0.01%	0.04%	-0.09%	-0.03%	0.17%	0.36%
Oceania	0.00%	0.02%	0.07%	0.13%	0.22%	0.27%
Middle East	0.00%	-0.06%	-0.15%	-0.30%	-0.56%	-0.80%
Africa	0.00%	-0.03%	-0.10%	-0.19%	-0.31%	-0.42%
world	0.00%	0.00%	-0.01%	-0.02%	-0.04%	-0.07%

Implications

- To tackle air pollution, China will need to reduce its coal power generation in the near future.
- This environmental policy can have co-benefit of CO_2 reduction.
- This will potentially push up the demand for natural gas, but allowing the development of more renewable could reduce the impacts.
- Due to the sheer size of the China, the national environmental policy can have far reaching impacts on the rest of the world.
- Russia and Oceania (gas exporters), and Japan and India (coal importers) could become the winners of the increased gas demand from China, but at the cost of higher global gas price, which could lead to lower global GDP.

Future directions

- To develop a global model that has regional details of China (collaborating with Gabriele at FEEM and Yingying at Shanghai University).
- To further investigate the interaction between China's environmental and carbon policies.

Thank you

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