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Biophysical Economics in China

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More and more voice against neoclassical economics recently in China

- As environmental problems, excess capacity problems, business ethics problems, etc… occur together with stagnation of economy, people starts to rethink of the neoclassical economic theory we have borrowed decades ago.

- Limitations and suitability of neoclassical economics in China is being discussed more and more.
- But, Biophysical Economics is still weak in China.

➢ China is going to the transform from fossil fuel to “renewable energy”

- Recent government policy already pay more attention to climate change since “New Normal” theory and Paris agreement of climate change. But the problem is many experts and Economists turn to believe New Energy can save us.

  - Experts are expected to formulate a new energy framework which is dominated by renewable energy;

  - The proportion of renewable energy in total energy consumption of China even could be reached 60% in 2050.

➢ China is a good venue for academic exploration of Biophysical Economics theory

- The current practices of China is meaningful to Biophysical Economics.
- China economy could be a good practical area to formulize the theory of Biophysical Economics.

❖ How to Bring Biophysical Economics theory to classes and trigger more young people's interests to BPE???

CUP

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Research introduction and key findings

1. China's conventional oil & gas production peak study

Main findings:

(1) China's conventional oil production has already peak around 2010.

(2) China's conventional gas production will peak around 2030.

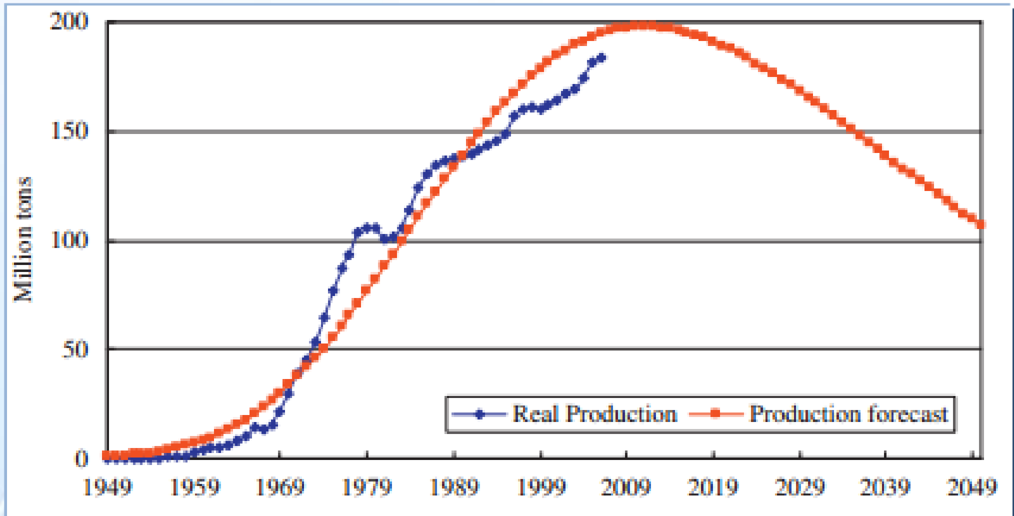


Fig. 7. China oil production forecast.

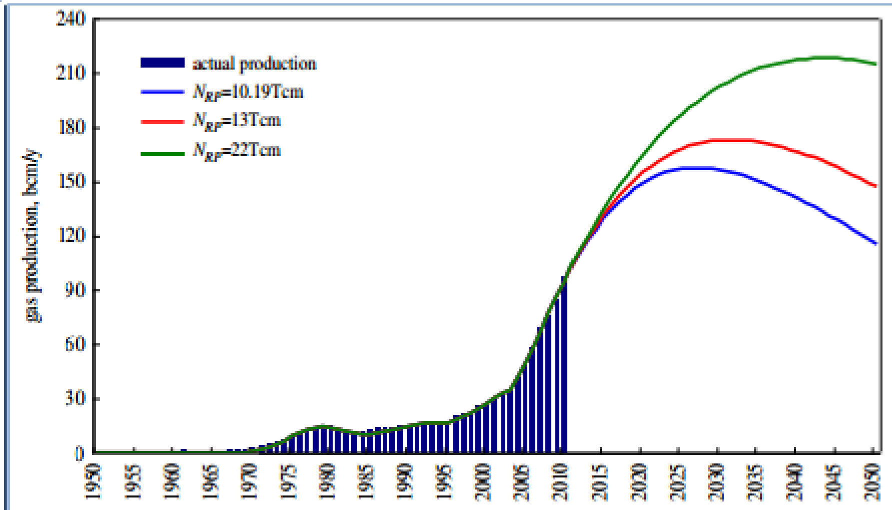


Fig. 3. Forecasting China's gas production based on different URR.

Such as:

[1] Feng L, Li J, Pang X. China's oil reserve forecast and analysis based on peak oil models[J]. Energy Policy, 2008, 36(11): 4149-4153.

[2] Wang J, Feng L, Zhao L, et al. China's natural gas: Resources, production and its impacts[J]. Energy Policy, 2013, 55: 690-698.

2. China's coal production peak study

Main findings:

China's coal production capacity will peak before 2025.

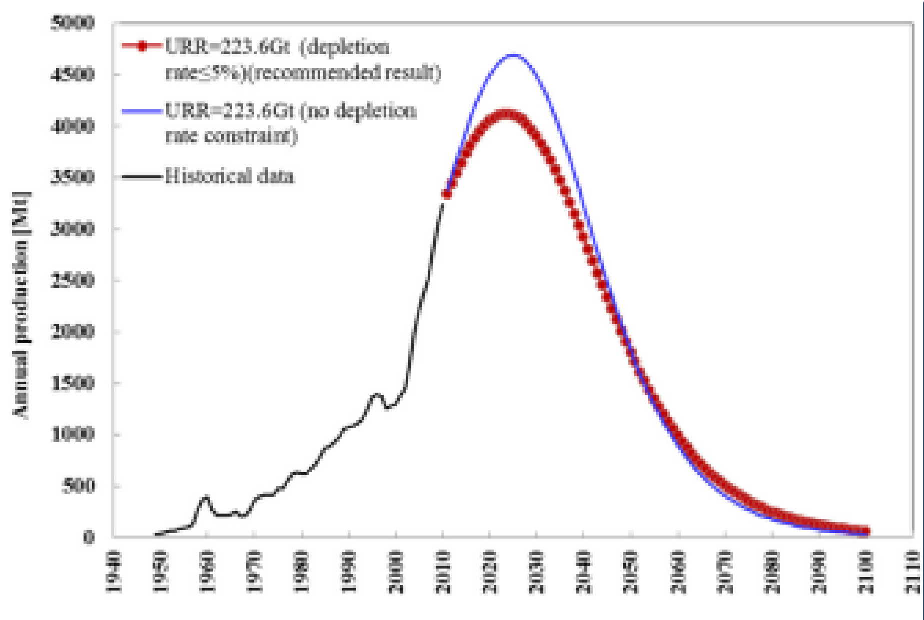


Fig. 7. Forecast results for Chinese coal production.

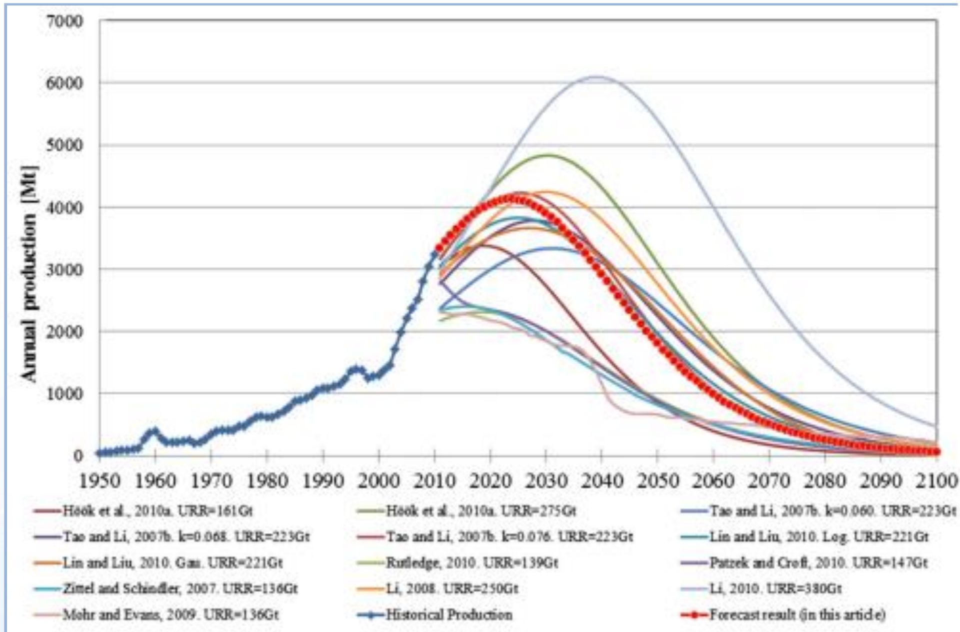


Fig. 9. Comparison of different results seen in published studies.

Such as:

[1] Wang J, Feng L, Tverberg G E. An analysis of China's coal supply and its impact on China's future economic growth[J]. Energy Policy, 2013, 57: 542-551.

[2] Wang J, Feng L, Davidsson S, et al. Chinese coal supply and future production outlooks[J]. Energy, 2013, 60: 204-214.

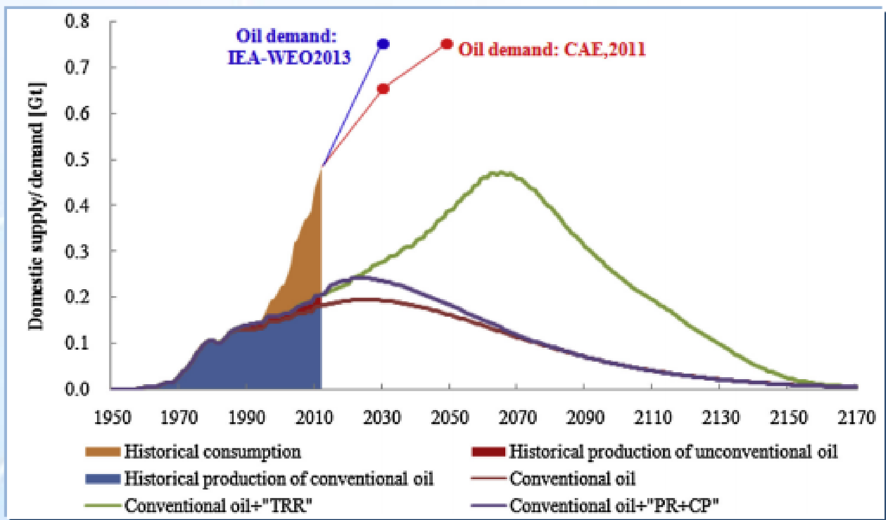
3. China's unconventional oil and gas production peak study

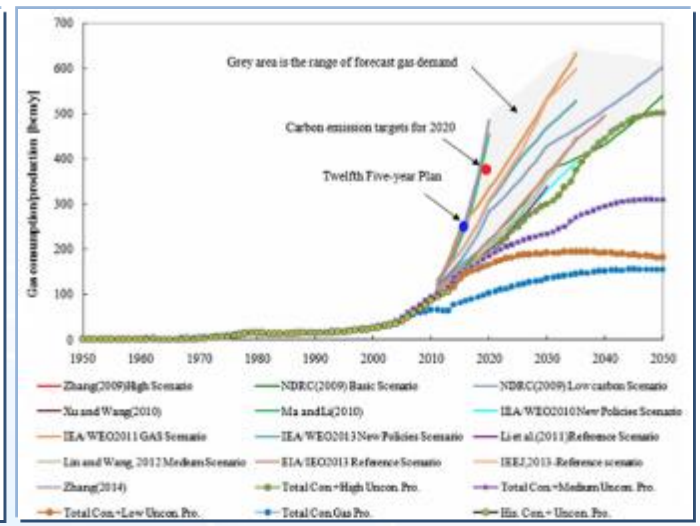
Main findings:

(1) Peak year and peak production for China's unconventional oil & gas differ sharply under different scenarios;

(2) In the low scenario (i.e. only current reserves are considered), both unconventional oil and gas has little impacts on total production.

(3) Even in the very high scenario, the unconventional oil and gas development can't solve the shortage of oil and gas supply in China.





Such as:

[1] Wang J, Mohr S, Feng L, et al. Analysis of resource potential for China's unconventional gas and forecast for its long-term production growth[J]. Energy Policy, 2016, 88: 389-401.

[2] Wang J, Feng L, Tang X, et al. China's unconventional oil: A review of its resources and outlook for long-term production[J]. Energy, 2015, 82: 31-42.

4. EROI study

Main findings:

(1) The EROI for China's oil and natural gas production sector fluctuated from 12 to 14:1 in the mid-1990s, and declined to 10:1 in 2007-2010.

(2) EROI for the coal production sector has declined from 35:1 in 1995-1997 to about 27:1 in 2010.

(3) EROI for Daqing oil field was 7.3 in 2013 and will continue to decline to 4.7 in 2025.

(4) EROI for China's shale gas is from 34 to 50.

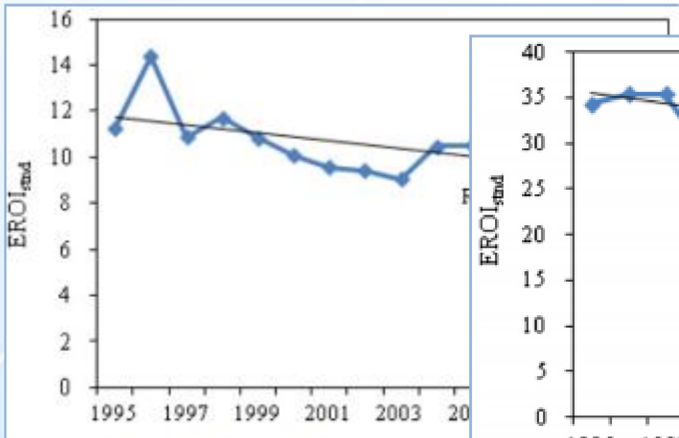


Fig. 3. EROI$_{stnd}$ of oil and natural gas extraction in Chi

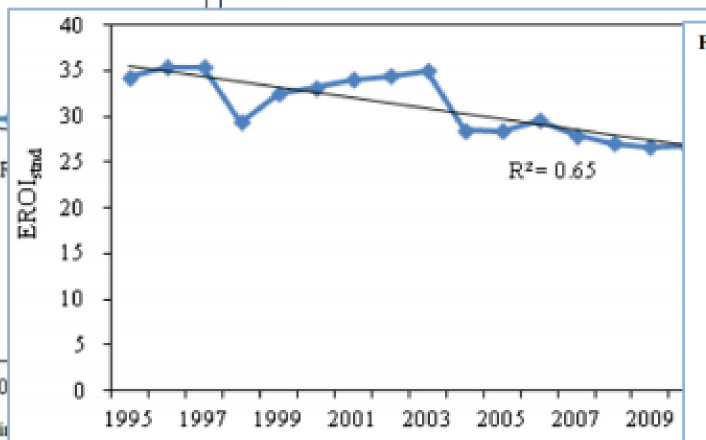
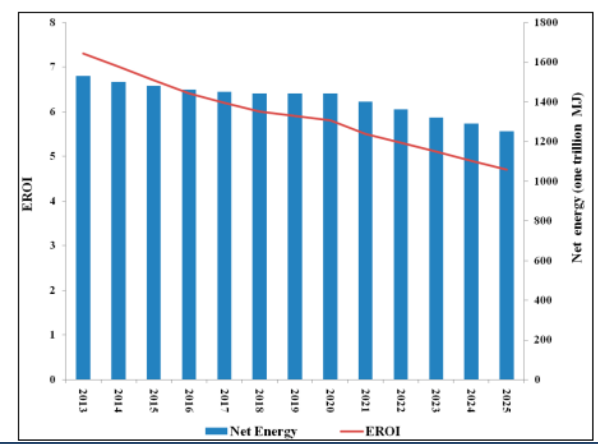


Fig. 7. EROI$_{stnd}$ of coal production sector in China with linear best fit.

Figure 7. Forecast results of Daqing's EROI and net energy from 2013–2025.



Such as:
[1] Hu Y, Hall C A S, Wang J, et al. Energy Return on Investment (EROI) of China's conventional fossil fuels: Historical and future trends[J]. Energy, 2013, 54: 352-364.
[2] Xu B, Feng L, Wei W X, et al. A Preliminary Forecast of the Production Status of China's Daqing Oil field from the Perspective of EROI[J]. Sustainability, 2014, 6(11): 8262-8282.
[3] Wang J.L., Feng L.Y. Energy use and GHG emissions of shale gas development in China. Manuscript, 2016

4. EROI study

Main findings:

(4) EROI for China's shale gas is from 34 to 50.

Table S26. Summary of direct fuels inputs and GHG emissions for an individual shale gas well

Stages		Fuel-combustion[kg]	CO_2[t]	CH_4[kg]	CO_2e[t]*
Site preparation	Diesel	3170(1955-4515)	10(6-14)	-	10(6-14)
Drilling					
Fracturi					
Comple					
Product					
Total					

Note: E

"-" mea

"*"conv

Table S28. Estimated embodied energy for an individual shale gas well in China

Stages	Inputs	Coal[kg]	Coke[kg]	Crude oil[kg]	Gasoline[kg]	Kerosene[kg]	Diesel[kg]	Fuel oil[kg]	Natural Gas[	Electricity[k	CO_2e[t]
Site preparation	Waterproof f	249(110-319)	8(4-10)	47(2							
	Cement-for c	3975(2765-55	181(126-252)	328(							
	Sand	676(470-940)	31(21-43)	56(3							
	Gravel	2597(1933-35	118(88-161)	214(							
	Diesel	2836(1749-40	67(41-95)	2109							
	Sub-total										
Drilling	Bentonite	2434(1391-34	111(63-159)	201(							
	lime	850(688-1093	39(31-50)	70(5							
	CaCl2	7665(6283-10	439(360-576)	1446							
	Casing	600528(34916	195943(113928-	6210							
	Cement-for c	67128(38909-	3061(1774-3771	5334							
	Diesel	655251(43949	15420(10343-20	4872							
	Sub-total										
Fracturing & Completion	Sand	7675(1861-11	350(85-533)	633(							
	Diesel	193929(76050	4564(1790-7037	1441							
	Sub-total										
Production	Diesel	1064(811-132	25(19-31)	791(							
	Sub-total										
Total											

Total Energy Output [TJ]		
Low	Basic	High
3.13	4.11	5.11
Total Direct Energy Input [TJ]		
Best	Basic	Worst
0.013	0.027	0.037
Total Indirect Energy Input [TJ]		
Best	Basic	Worst
0.049	0.082	0.109
EROI for shale gas		
Best	Basic	Worst
50.015	37.687	34.836

Such as:

[1] Hu Y, Hall C A S, Wang J, et al. Energy Return on Investment (EROI) of China's conventional fossil fuels: Historical and future trends[J]. Energy, 2013, 54: 352-364.

[2] Xu B, Feng L, Wei W X, et al. A Preliminary Forecast of the Production Status of China's Daqing Oil field from the Perspective of EROI[J]. Sustainability, 2014, 6(11): 8262-8282.

[3] Wang J.L., Feng L.Y. Energy use and GHG emissions of shale gas development in China. Manuscript, 2016

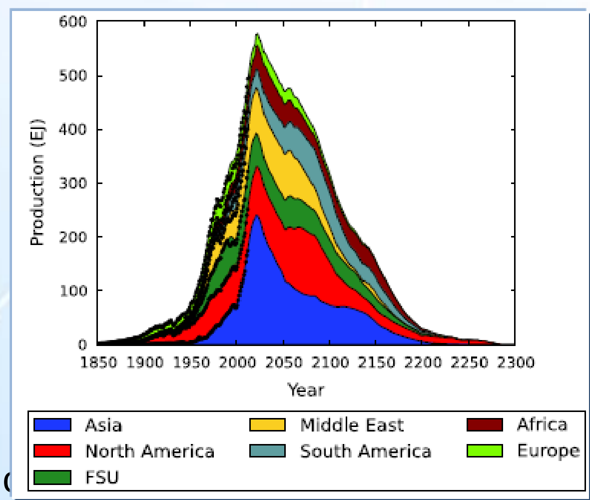
5. World fossil fuel supply and its impacts on Climate change

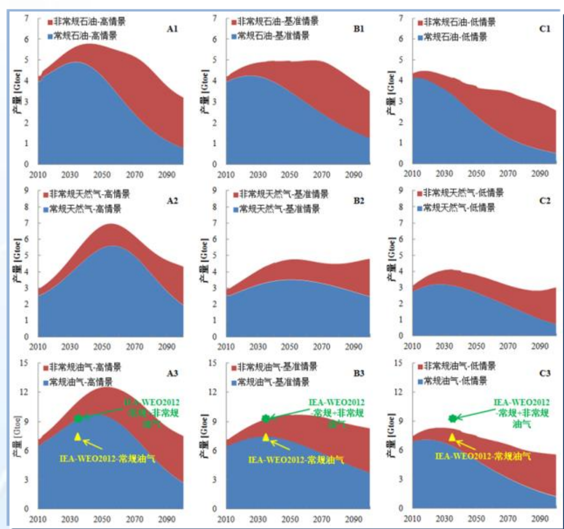
Main findings:

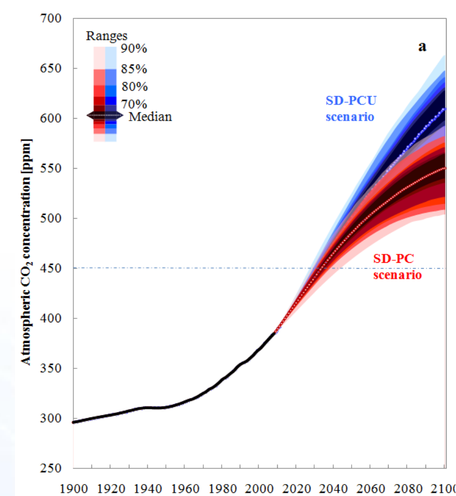
(1) The Best Guess (BG) scenario suggests that world fossil fuel production may peak before 2025 and decline rapidly thereafter.

(2) Unconventional oil and gas development will not change the total production curve significantly.

(3) Fossil fuel supply constraints are possible and will lower the climate change projection considerable.







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[1] Mohr S H, Wang J, Ellem G, et al. Projection of world fossil fuels by country[J]. Fuel, 2015, 141: 120-135.
[2] Wang J.L., Feng L.Y. The implications of fossil fuel supply constraints on climate change projections: A supply-side analysis, Futures(2016), http://dx.doi.org/10.1016/j.futures.2016.04.007
[3] Wang J, Feng L.A comparison of two typical multicyclic models used to forecast the world's conventional oil production[J]. Energy Policy, 2011, 39(12): 7616-7621.

6. Impacts of unconventional oil and gas extraction on environment

Main findings:

(1) Water use in China is 24220 m3/well (90% CI: 14430-34095 m3/well)

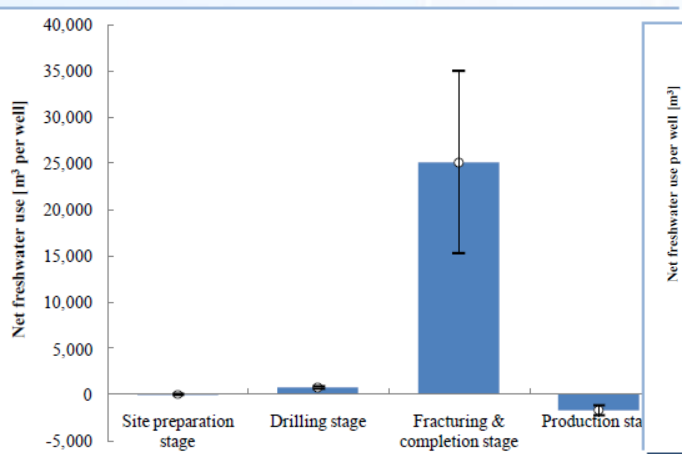
(2) Water use in China's shale gas well is higher than US

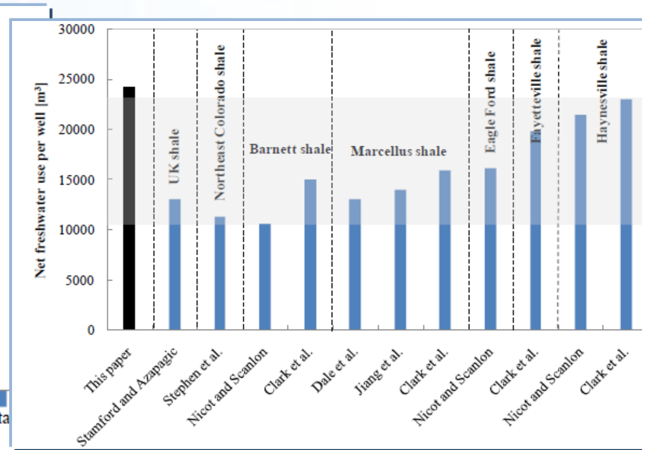
(3) GHG emissions for shale gas well development in China:

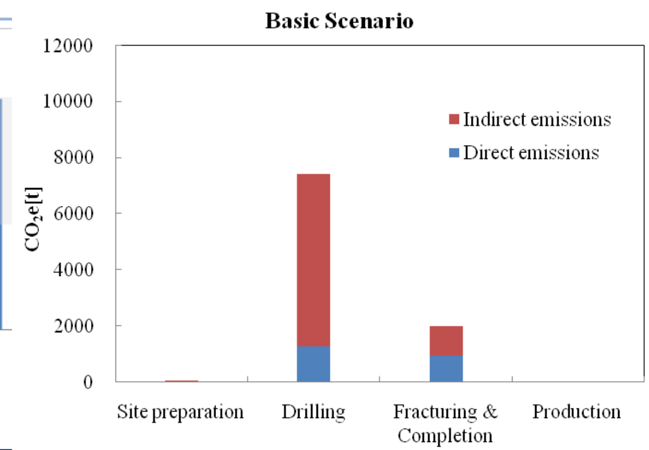
Best Scenario: 5343 tCO2e/well (direct: 1021 tCO2e, Indirect 4322 tCO2e)

Basic Scenario: 9488 tCO2e/well (direct: 2256 tCO2e, Indirect 7232 tCO2e)

Worst Scenario: 13485 tCO2e/well (direct: 3905 tCO2e, Indirect 9580 tCO2e)







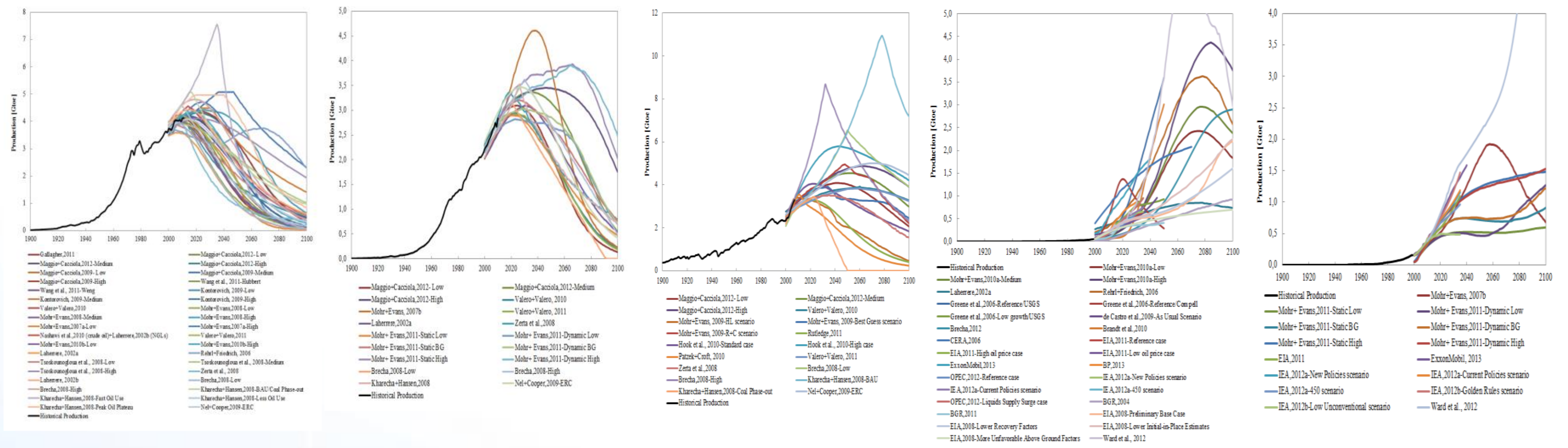
Such as:
[1] Wang J.L., Feng L.Y. Water Use for Shale Gas Extraction in Sichuan Basin, China. Submitted. 2016.
[2] Wang J.L., Feng L.Y. Energy use and GHG emissions of shale gas development in China. Manuscript, 2016

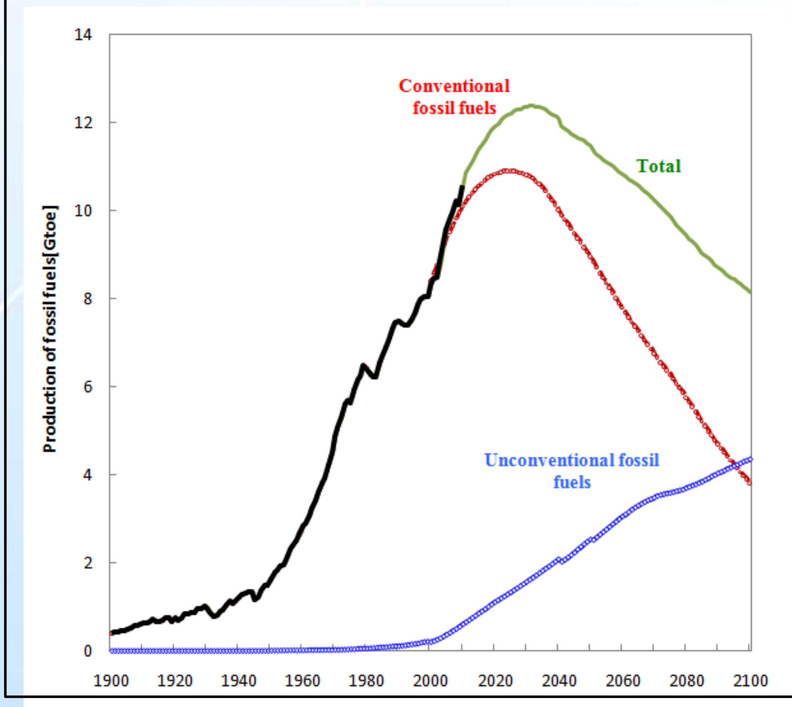
Two cases

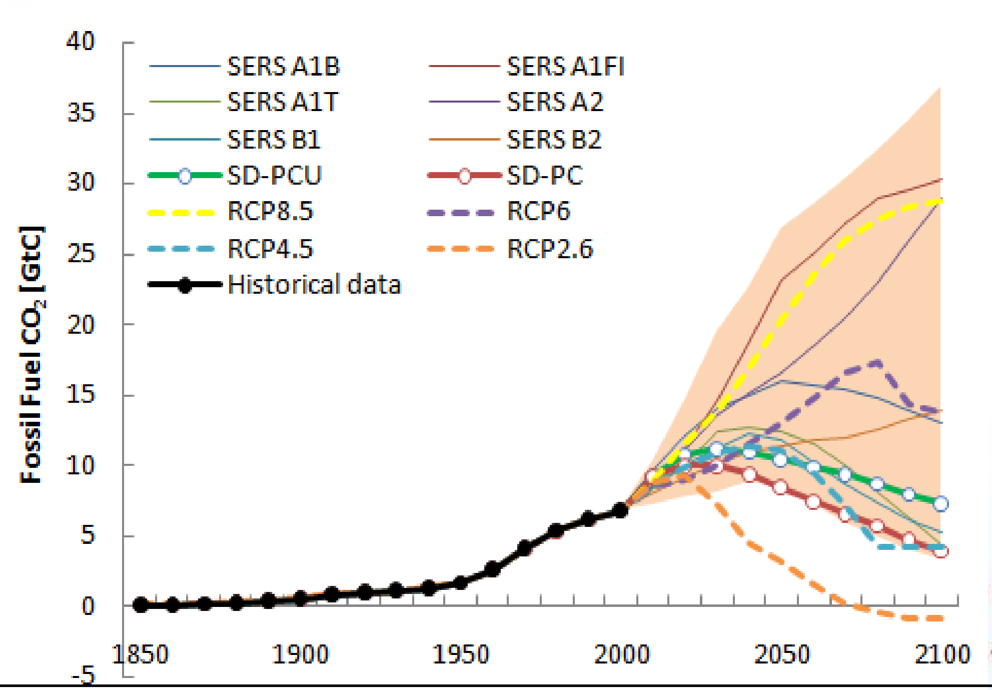
Case 1. The implications of fossil fuel supply constraints on climate change projections: A supply-side analysis

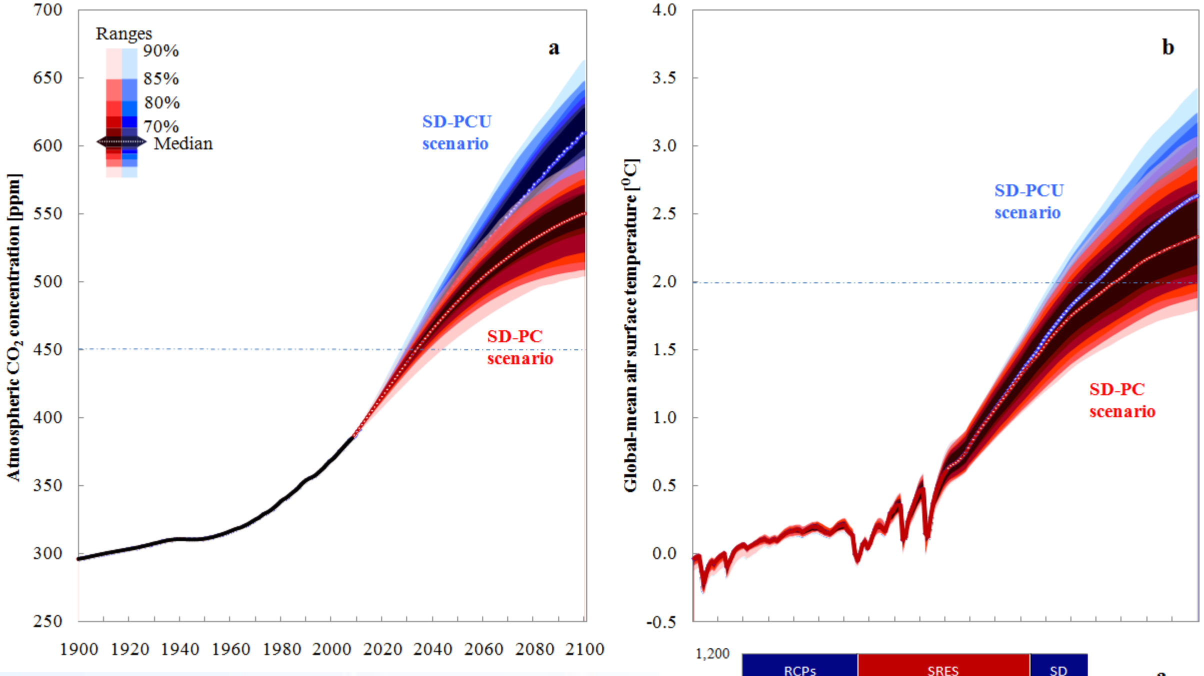
Current climate projections are all demand-side analysis, i.e. assuming that the fossil resources are abundant and affordable, future use of fossil fuels is totally depended by demand. By contrast, this paper analyzes the future fossil fuel usage and its CO2 emissions from a supply-sided analysis. **We made a comprehensive investigation of likely long-term pathways of fossil fuel production drawn from peer-reviewed literature published since 2000.**

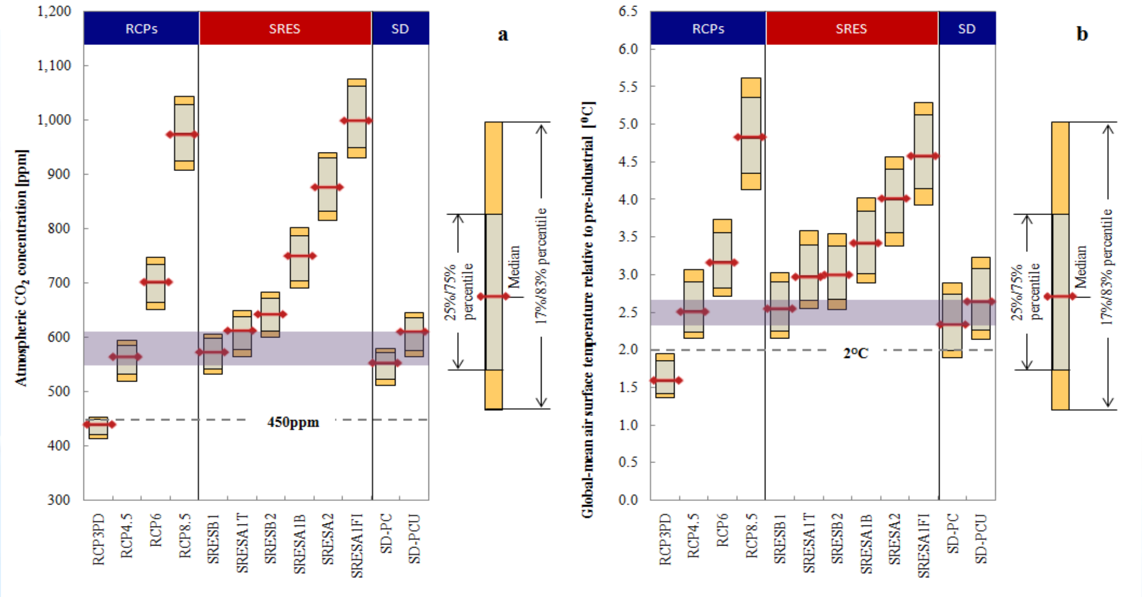
Oil	Gas	Coal	Unconventional Oil and Gas









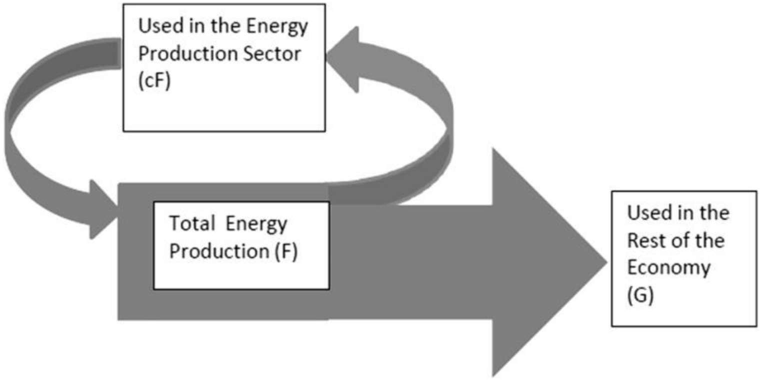


Source: Wang J.L., Feng L.Y. The implications of fossil fuel supply constraints on climate change projections: A supply-side analysis, Futures(2016), http://dx.doi.org/10.1016/j.futures.2016.04.007

Case 2. Net energy for China

Energy Return on Energy Investment (EROI)

[1]. We use Full Fuel Cycle calculate EROI and net energy for coal, oil, gas separately in China



a. $EROI_{\mathbf{F}} = \frac{F}{C \cdot F} = \frac{F}{F - G}$

b. $G = F - cF = F \cdot \left(1 - \frac{1}{EROI_{\mathbf{F}}}\right)$

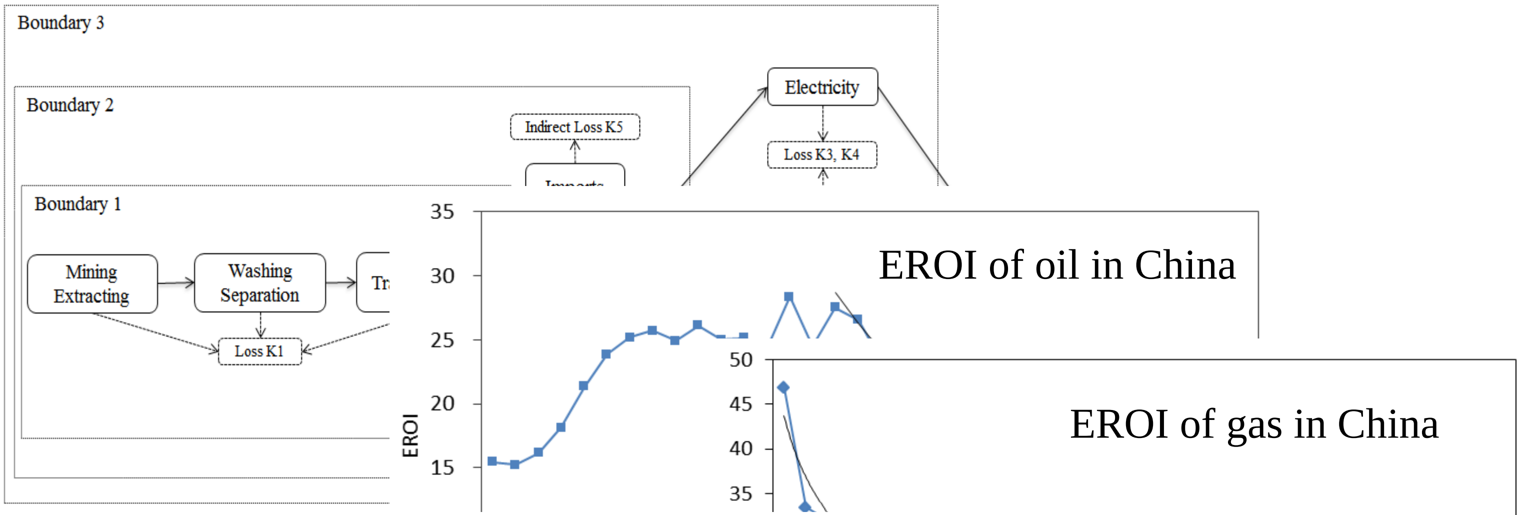
c. $G = F - c \cdot F = P + I - L$

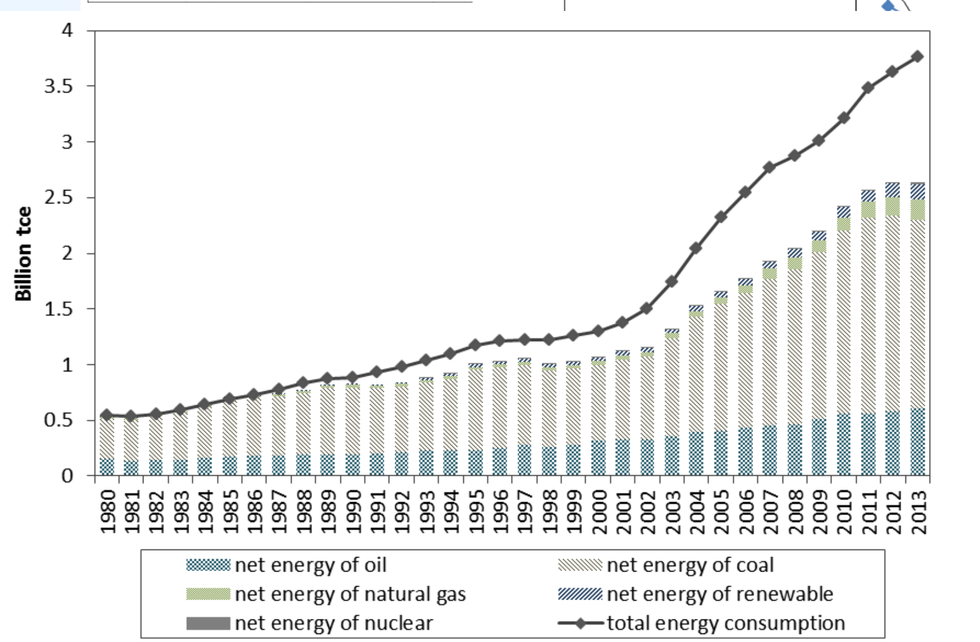
[2]. EROI of fossil fuels and net energy analyzed by method Grey Relational Analysis model

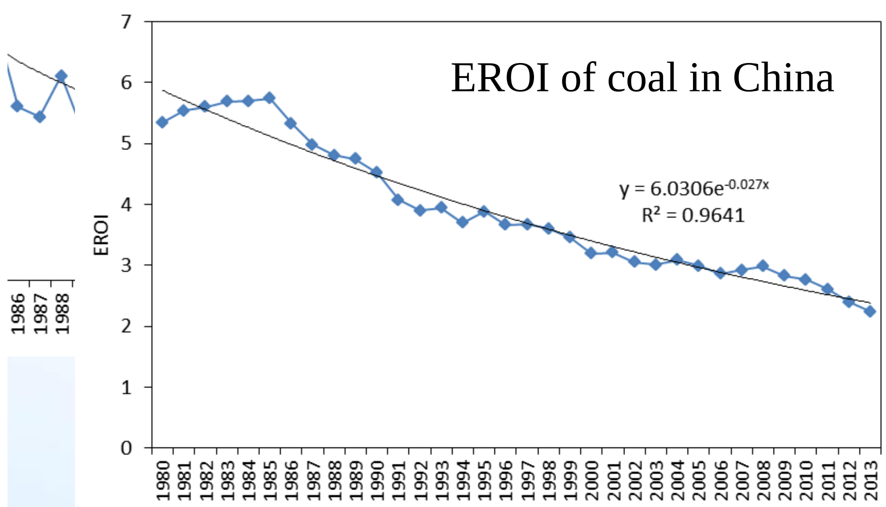
$$L_{0i}(k) = \frac{\min_i \min_k \left|x_0^{(1)}(k) - x_i^{(1)}(k)\right| + \delta \cdot \max_i \max_k \left|x_0^{(1)}(k) - x_i^{(1)}(k)\right|}{\left|x_0^{(1)}(k) - x_i^{(1)}(k)\right| + \delta \cdot \min_i \min_k \left|x_0^{(1)}(k) - x_i^{(1)}(k)\right|}$$

[3]. Here we analyzed the optimization of China's energy structure. (Based on carbon pinch analysis)

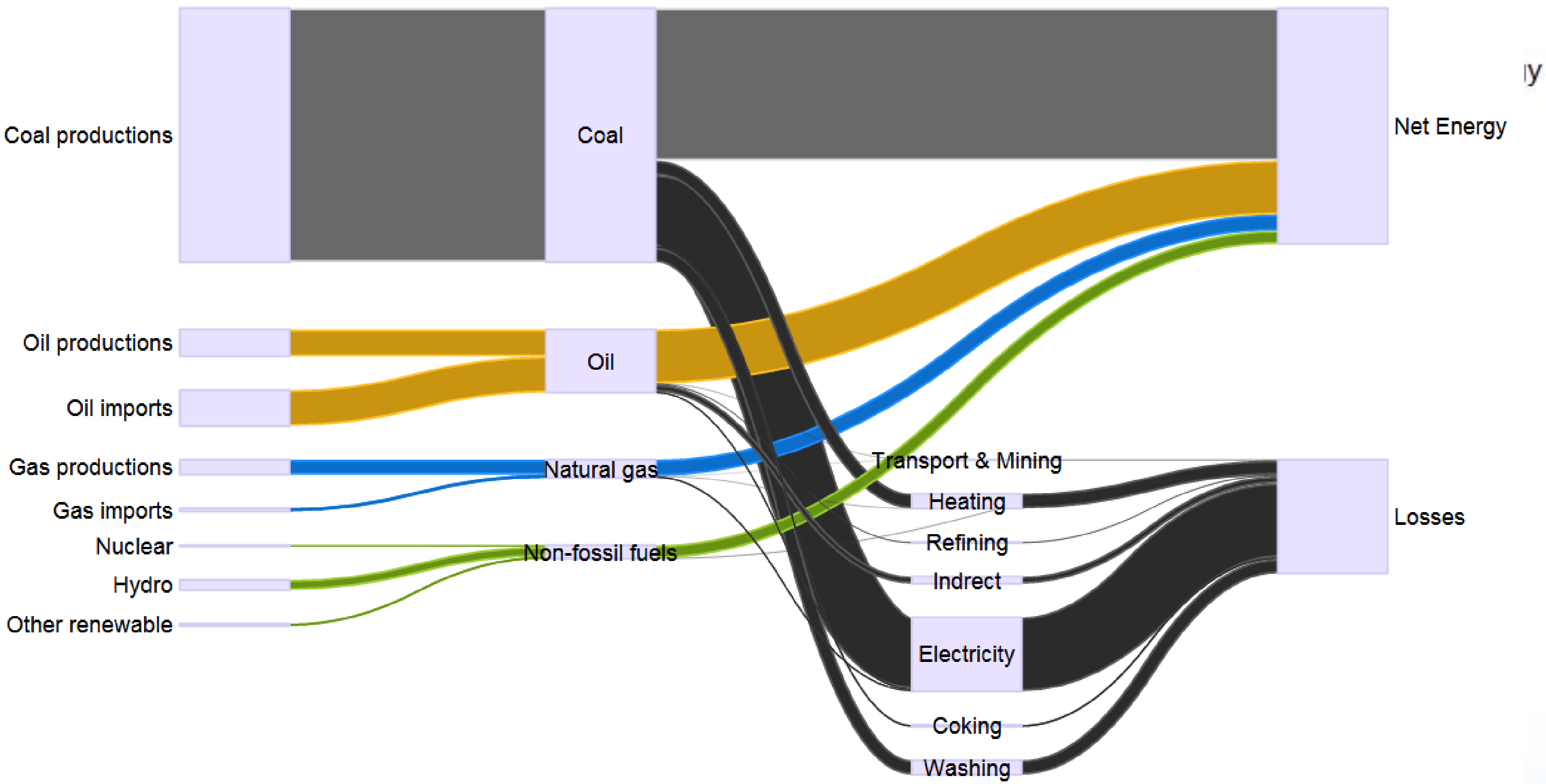
EROI and Net Energy in China







Net energy flow



Net energy flow in China by 2003, 2013（units: billion tce）

[1]. Renewable energy holds the dominant position for net energy growth between 1990-2013

[2]. Most energy losses come from extraction process, imports, and heating

Grey Relational Analysis of net energy consumption (1990-2013)

Comparison \ Reference	Net Energy growth	Energy loss from Oil	Energy loss from Natural gas	Energy loss from Coal
Net energy from renewable	**0.78**	-	-	-
Net energy from nuclear	0.74	-	-	-
Net energy from coal	0.71	-	-	-
Net energy from natural gas	0.73	-	-	-
Net energy from oil	0.65	-	-	-
Extract, Transport, Separate, Washing	-	**0.72**	0.68	0.71
Refining, Coking	-	0.66	-	0.74
Electricity	-	0.67	0.62	0.73
Heating	-	0.67	0.69	**0.84**
Imports	-	0.59	**0.73**	-

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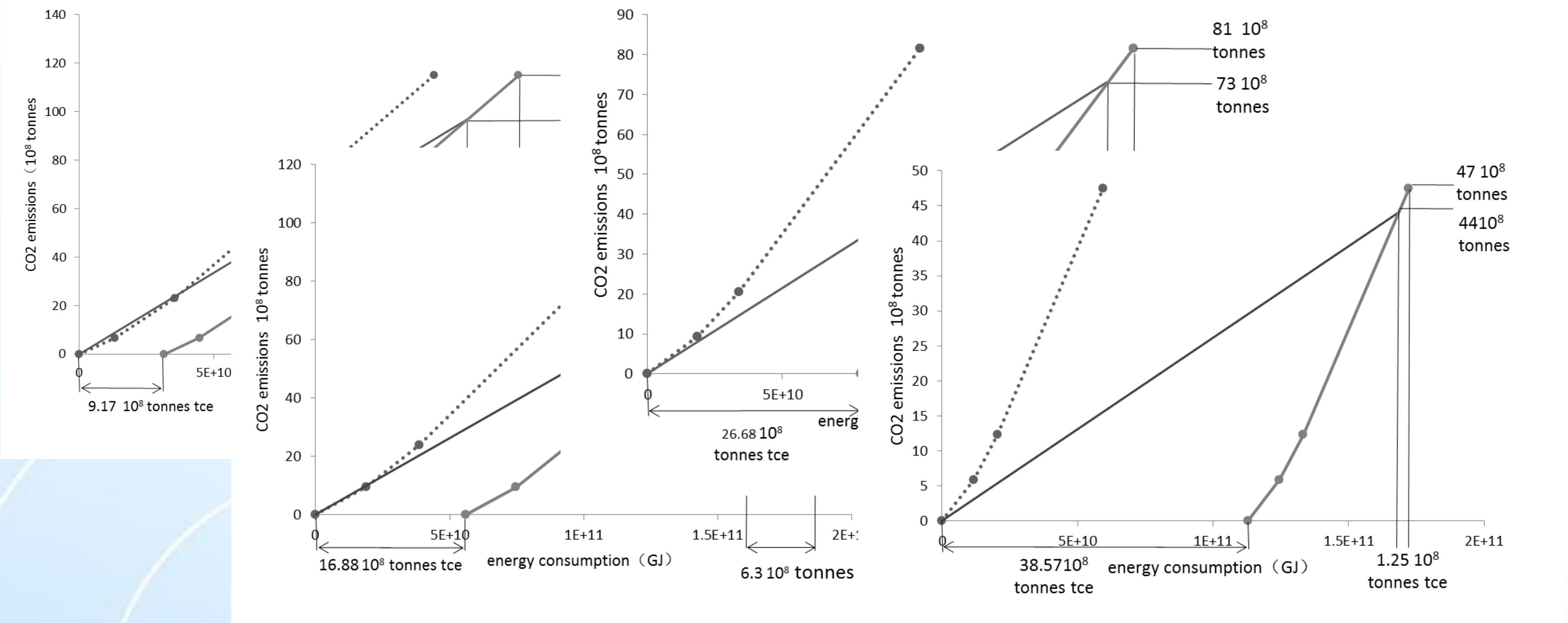
Carbon pinch analysis

[1]. We study on national energy structure and CO_2 emission under carbon targets from 2020-2050

[2]. We optimization of China's energy structure and made a possible road map for non-fossil fuels based on carbon pinch analysis

Road Map of non-fossil fuels in China

	2020	2030	2040	2050
Non-fossil fuels proportion	18%	31%	46%	67%
Non-fossil fuels consumption（btce）	0.92	1.69	2.67	3.86
CO2 emissions Billion ton	9.85	9.08	7.32	4.41



National energy structure and CO2 emission under carbon targets from 2020-2050

Thank you!

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