Low carbon economy 2030 in China

- Jiangxi Province as an example

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AIM ASIA-PACIFIC INTEGRATED MODEL NIES

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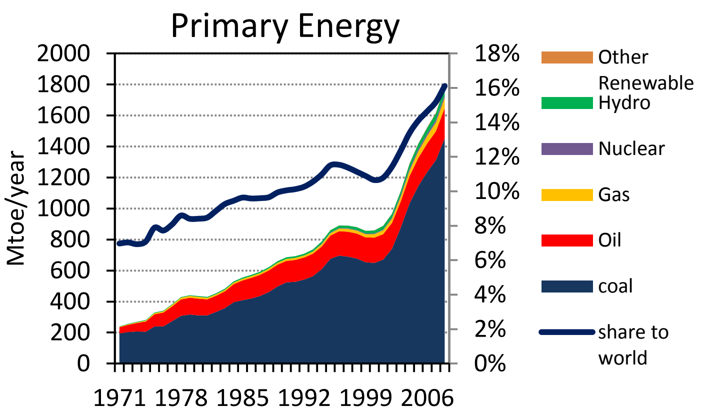
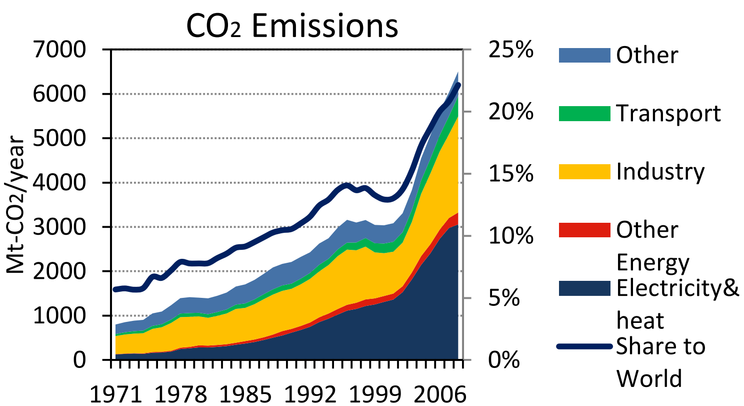
Overview

- **Motivation:** develop methodology for provincial level low-carbon studies;
- **Questions**
  - Future scenario of energy & emissions without policy intervention;
  - Economic cost of carbon reduction;
  - Measures to lower the economic cost;
  - Co-benefits of low carbon economy.
- **Methodology**
  - A 2-region CGE model including Jiangxi province and rest of China;
  - A hybrid model including various technologies in power sector;
  - 2005-2030 period;
- **Findings**
  - Energy and emission would increase due to GDP growth
  - carbon price and GDP loss would be quite high in the most stringent carbon reduction scenarios
  - With low-carbon countermeasures, carbon price and GDP loss would be lowered substantially.
  - A lot of co-benefits associated with low-carbon economy, including air pollutants reduction and energy security improvement
  - This model is relatively robust and can be applied to any other province given the data.

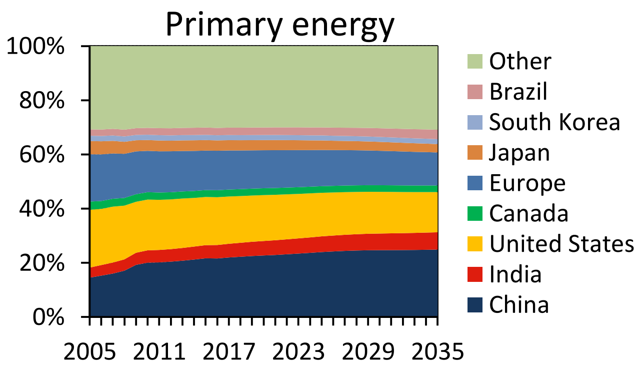
1. Introduction: energy and emissions in China

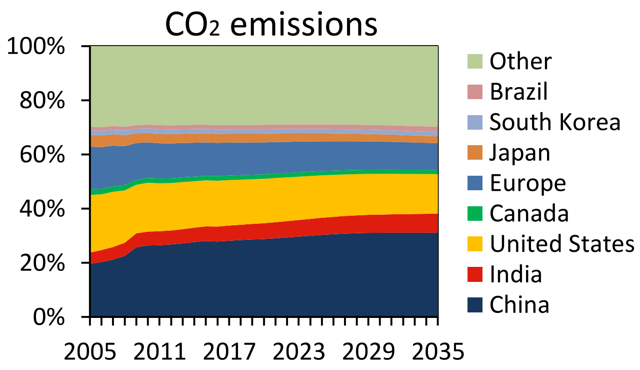
— **Past** (IEA, 2009)





— **Future** (EIA, 2011)





1. Introduction: Motivation and objective

1. To develop methodology at provincial level
2. To develop a framework for integrated and quantitative assessment of low-carbon policies
3. To assess the effectiveness and economic impacts of low-carbon policies
4. To provide policy recommendations for promoting low carbon economy (LCE)

1. Introduction: Question Statement

1. Future scenario of energy & emissions under BaU
2. Key technologies /countermeasures to achieve LCE
3. Economic cost of LCE
4. How to soften the economic cost?
5. Benefits and co-benefits ofof LCE

2. Literature review: existing studies on LCE

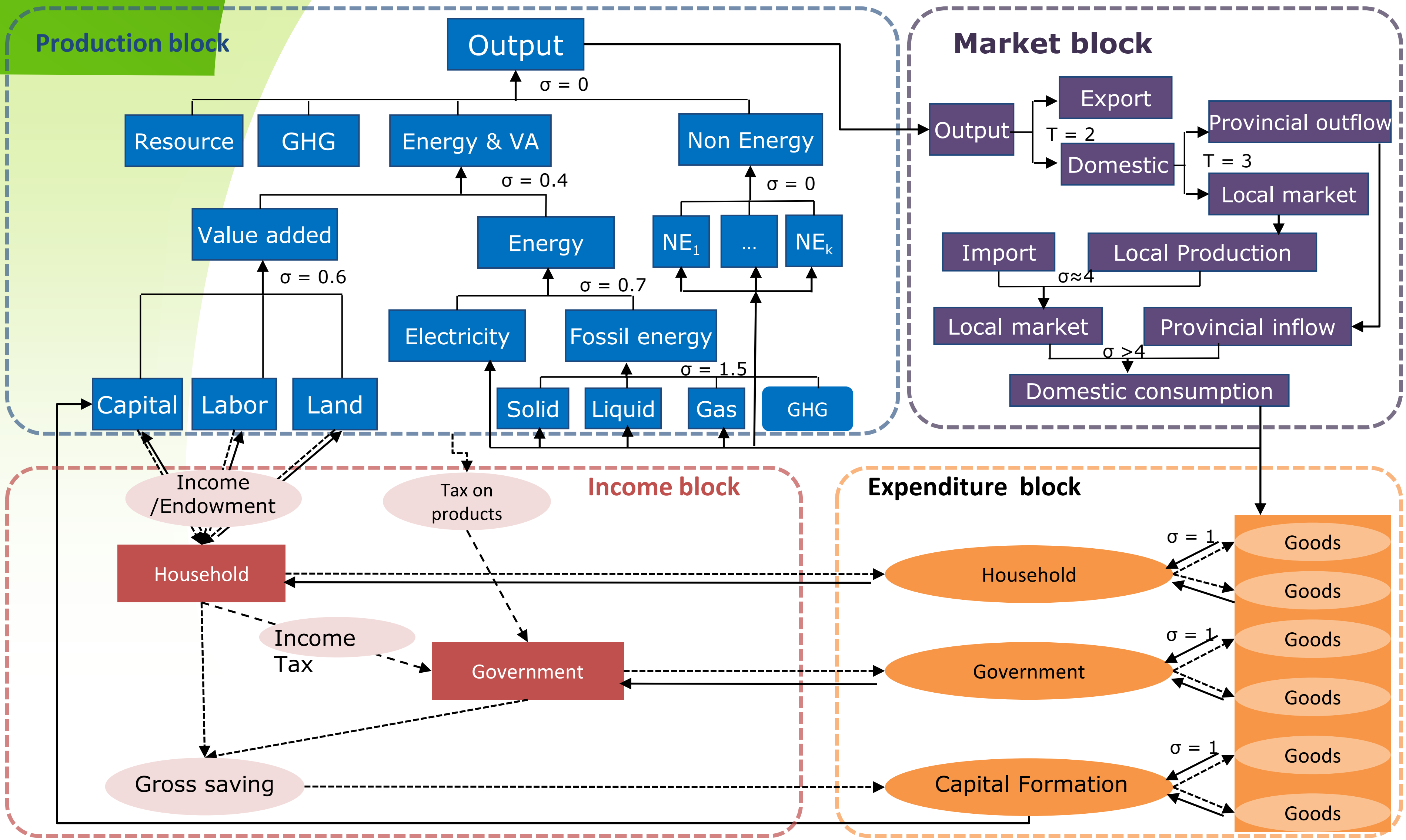
– **Country level**

- Japan: it has the technological potential to reduce its CO_2 emissions by 70% compared to the 1990 level in 2050, quantitative roadmaps which include over 600 options. (NIES, 2008) ;
- China: possible for China to reduce its emissions to 2005 levels in 2050 (Jiang, 2009).
- India: transiting to low carbon future either through advanced technologies like CCS and nuclear energy, or through renewable technologies on the supply side and dematerialization, sustainable consumption and end use device efficiency on the demand side (Shukla, 2009) ;
- South Korea: "Low Carbon, Green Growth Policy", reduce carbon emissions by 30% by 2020 relative to BaU (Jones and Yoo, 2010);
- Vietnam: low carbon society for Vietnam in 2030 for the residential, commercial, industrial, passenger and freight transport sectors, emissions can be decreased by approximately 45% from BaU (Nguyen et al, 2010);
- Indonesia: LCS visions 2050, emissions would be 48-85% lower than the BAU, clean energy, low carbon lifestyle, electricity and fuels in industry and sustainable transport (Dewi et al, 2010);
- Thailand: emissions in 2030 can be decreased approximately by 42.5% to 324 million t-CO_2 (Limmeechokchai, 2010).

2. Literature review: existing studies on LCE

- **Country level**
  - UK: Pathways to a low-carbon economy, the CO2 reduction by 40%, 60% and 80% by 2050 compared to 1990 levels, deep reduction in power and transport sectors. Higher GDP in mitigation scenario due to faster adoption of new carbon- reducing technologies and higher investment (Dagoumas, 2010);
  - Australia: reduce accumulated CO_2 during 2006–2051 by 50%, through renewable electricity or advanced fossil fuel with CCS, nuclear and natural gas, GDP loss 14-37% (Foran, 2011).
- **Sub-country level**
  - Ahmedabad, India: low carbon vision toward 2035 through "Eight Actions‟, by 67% over 2035 BaU level (Shukla, 2009);
  - Iskandar, Malaysia: Low-carbon Region by 2025, emission decreasing by 60% and suppressed to 19.6 million t-CO_2 (Ho, 2009);
  - Australia: transitioning to low carbon communities through behaviour change in households which result in less carbon intensive lifestyles & institutional and infrastructure systems (Moloney et al., 2009);
  - Broward, USA: policies and responses on planning for low carbon city at county level (Feliciano, 2011);
  - Jilin city, China: emissions reduction by 25-42% in 2030 against BaU (Jiang et al, 2009);
  - Guangdong Province, China: CO_2 lowered by 29-50% in 2030 against BaU (Jiang, 2009).

3. A two-region CGE model for Jiangxi Province



3. Methodology: CGE model

Region & time & GHGs

- **Two regions**: Jiangxi Province, rest of China
- **Time**: 2005-2030, one year time step
- **Gas type**
  - CO_2, CH_4, N_2O, CO, NH_3, NMVOC, NO_X, SO_2;
  - Energy related, process related, biomass related.

Data

- **Input-output table**
- **Energy balance table**
- **GHG emission factors of fossil fuels**
- **Data on characteristics of electricity generation technologies**;
- …

Production: 40 sectors (excl. electricity)

- **Input**: Intermediate inputs, capital, labor, land, resource, traditional biomass;
- **Land reliant**: *Agriculture, Forest, Livestock;*
- **Resource reliant**: *Coal mining, natural gas, crude oil, mineral mining, other agriculture*
- **Energy transformation** : *Coking, oil refinery, town gas*
- **Other sectors**

Technology

Power generation

• Five Coal	• Nuclear
• Oil power	• Wind
• Natural gas	• Solar
• Hydro	• Biomass

CCS technology

- *Coal, Gas, Biomass with CCS;*
- *Cement, Chemistry, Iron and Steel*

Bio-fuel

- *Biomass to liquid, to gas*
- *Need land inputs (competing with agriculture)*

3. Data requirement of CGE model

Base year

- Input-output table: Statistics;
- Energy balance table: Statistics;
- CO_2 emission factors: IPCC recommendation;
- Energy price of coal, oil and gas: Statistics;
- Cost of renewable energy technology: Investigation & estimation.

Future scenario

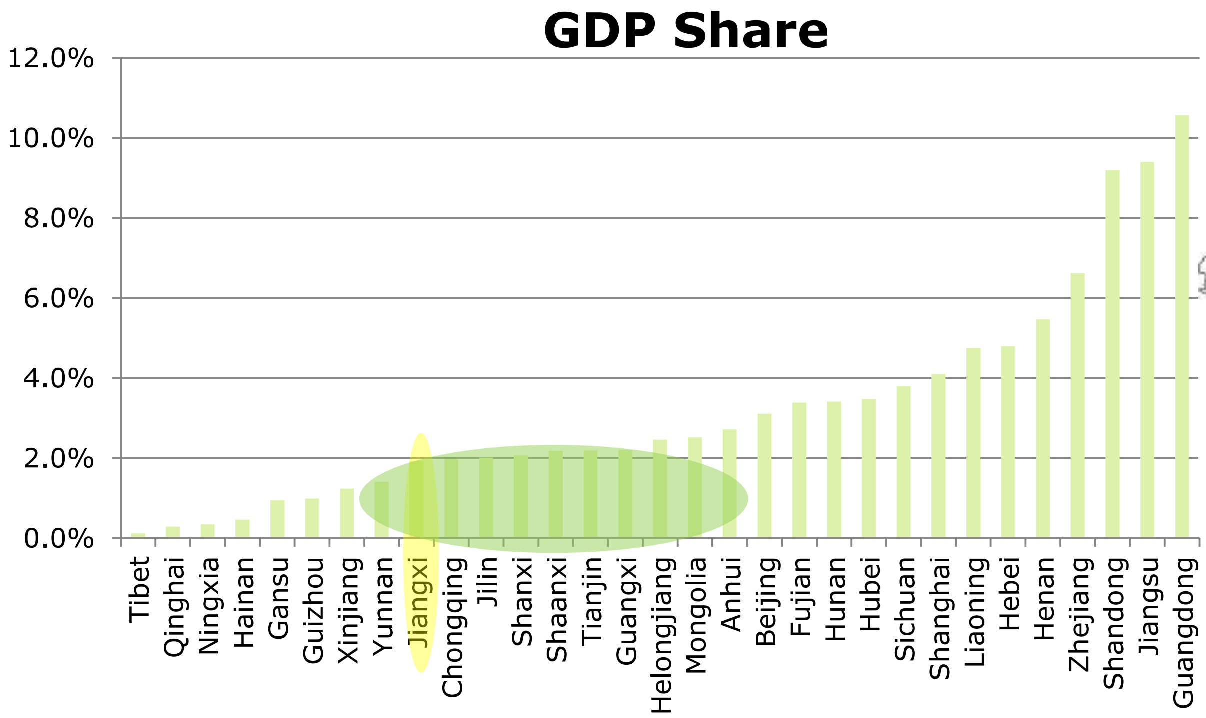
Economy

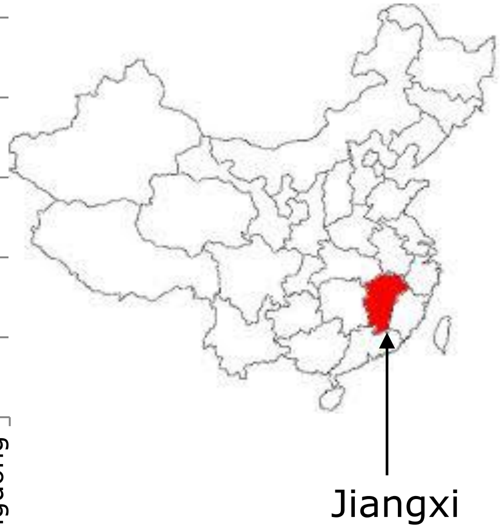
- GDP growth rate;
- Labor force growth rate;
- Elasticity of substitution among inputs;
- Total factor productivity (TFP) improvement;
- Production trend of key energy intensive products (cement, iron & steel etc.);
- Domestic consumption scenario;

Energy & Technology

- Autonomous energy efficiency improvement;
- Future international energy price;
- Extraction cost change of fossil fuels;
- Resource potential of renewable energy.
- Utilization target of each renewable energy type in different years;

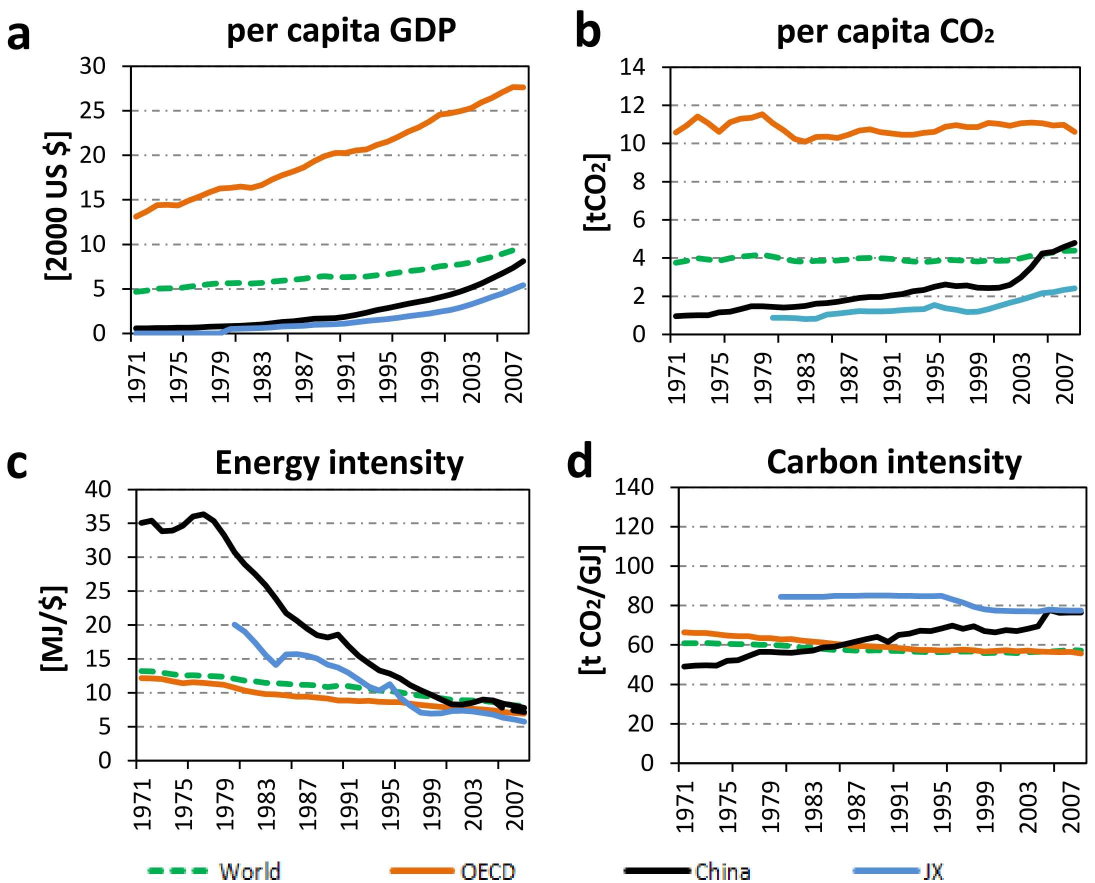
3. Jiangxi Province





Jiangxi Province and Rest of China

- Evolution of Kaya factors of world, OECD, China and Jiangxi



Per capita GDP steady increases
- Jiangxi < China < World < OECD

Per capita CO2 increases
- Jiangxi < China ≈ World < OECD

Energy intensity falls
- OECD < World < Jiangxi < China
- In 2007 almost the same

Carbon intensity
- China increases
- Jiangxi slightly decreases
- Higher than world and OECD

4. Scenario towards 2030

- **Consumption pattern (2 types)**
  - High carbon style
  - Low carbon style

Reference Scenario

- **Carbon constraints (3 types)**
  - Level 1: carbon intensity of GDP reduces as Copenhagen target
  - Level 2: ERI's Enhanced Low Carbon Scenario
  - Level 3: Global collective reduction derived from 2 degree target
- **Counter measures (4 types)**
  - None
  - Non-fossil energy development
  - Low carbon consumption pattern
  - Carbon Capture and Storage (CCS) technology
  - Inter-provincial emissions trading

Mitigation Scenario

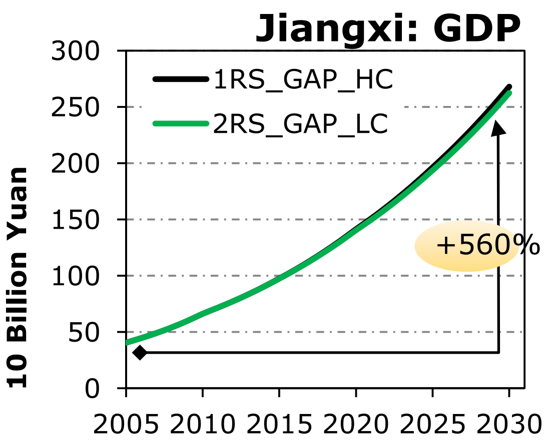
4. Scenario towards 2030

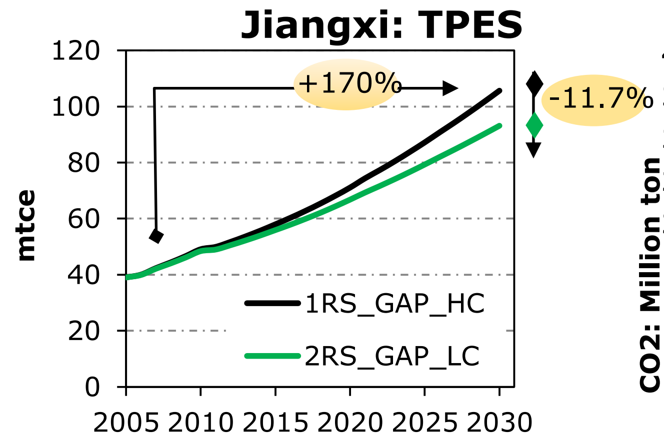
Nr.	Scenario	Non-fossil energy	Consumption pattern	CCS	Emission trading	CO_2 emission constraint		
1	RS_HC	conventional scale	High carbon	off	off	off	No constraint	Reference
2	RS_LC	conventional scale	Low carbon	off	off	off	No constraint	
3	CM_CAP1	2005 level	High carbon	off	off	on	Level1: intensity target	Carbon constraints
4	CM_CAP2	2005 level	High carbon	off	off	on	Level2: mild reduction	
5	CM_CAP3	2005 level	High carbon	off	off	on	Level3: most stringent	
6	CM_CAP3_HC	2005 level	High carbon	off	off	on	Level3, GDP intensity convergence	Counter-measure
7	CM_CAP3_HC_RE	Large scale develop	High carbon	off	off	on	Level3, GDP intensity convergence	
8	CM_CAP3_LC_RE	Large scale develop	Low carbon	off	off	on	Level3, GDP intensity convergence	
9	CM_CAP3_LC_CCS	Large scale develop	Low carbon	on	off	on	Level3, GDP intensity convergence	
10	CM_CAP3_LC_ET	Large scale develop	Low carbon	on	on	on	Level3, GDP intensity convergence	

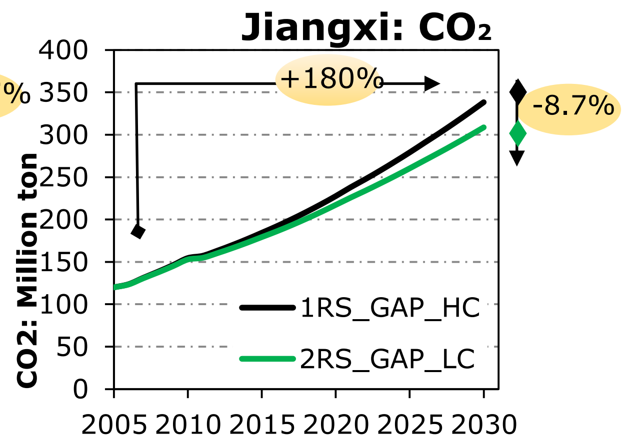
4. Scenario: household consumption pattern

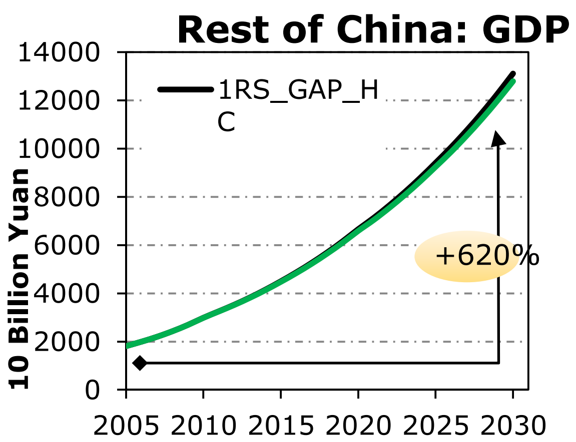
	2005		2030			Direction	
Jiangxi	Urban	Rural	Urban	Rural	Whole Region	High Carbon	Low Carbon
Per capita expenditure (2005 US dollar)	746	303	5446	2214	4250	4250	4250
Food	40.8%	49.1%	27.8%	32.4%	28.7%	28.0%	32.0%
Clothing	10.6%	5.0%	10.1%	5.9%	9.3%	10.0%	6.0%
Housing	10.6%	13.1%	9.7%	22.8%	12.2%	10.0%	12.0%
Furnishings	7.0%	3.9%	8.0%	5.3%	7.5%	8.0%	5.0%
Health care and Medical services	5.3%	6.2%	6.5%	6.6%	6.5%	6.6%	6.5%
Transport and Communications	9.3%	9.2%	18.5%	13.0%	17.4%	18.0%	13.0%
Education and recreation	13.2%	11.1%	14.6%	11.3%	13.9%	15.0%	11.0%
Miscellaneous goods and services	3.2%	2.2%	5.0%	2.7%	4.5%	4.4%	14.5%
Rest of China							
Per capita expenditure (2005 US dollar)	970	312	10280	3307	7700	7700	7700
Food	36.7%	45.1%	26.5%	31.7%	27.4%	26.0%	32.0%
Clothing	10.1%	5.8%	10.1%	5.9%	9.4%	10.0%	6.0%
Housing	10.2%	14.3%	9.6%	23.0%	11.7%	10.0%	12.0%
Furnishings	5.6%	4.4%	8.2%	5.3%	7.8%	8.0%	5.0%
Health care and Medical services	7.6%	6.4%	6.4%	6.5%	6.4%	6.4%	6.5%
Transport and Communications	12.6%	9.8%	19.1%	13.3%	18.2%	19.0%	13.0%
Education and recreation	13.8%	12.0%	14.9%	11.5%	14.4%	15.0%	12.0%
Miscellaneous goods and services	3.5%	2.3%	5.1%	2.7%	4.8%	5.6%	13.5%

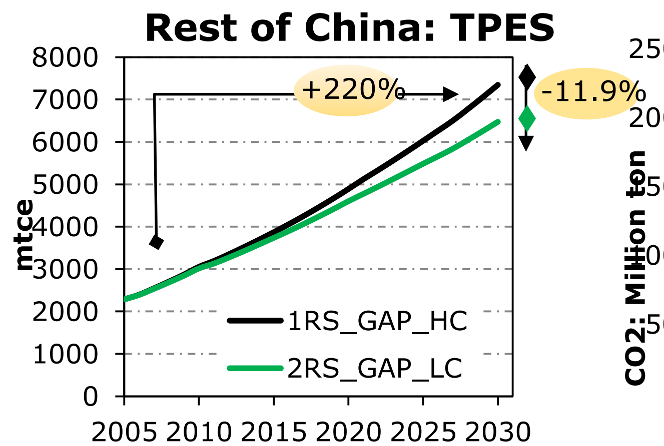
5. Results: Reference scenario

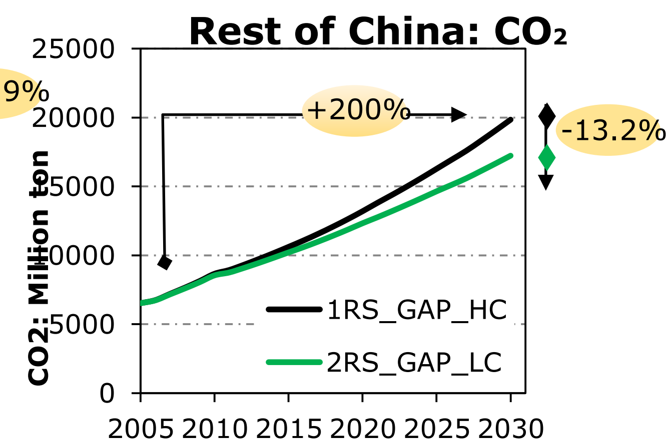












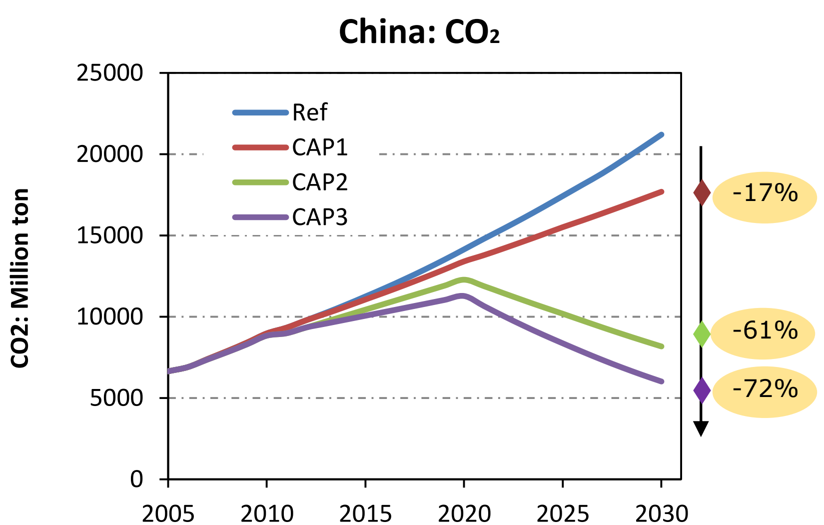
Energy saving and carbon reduction effect by low-carbon consumption.

5. Results: Mitigation scenario

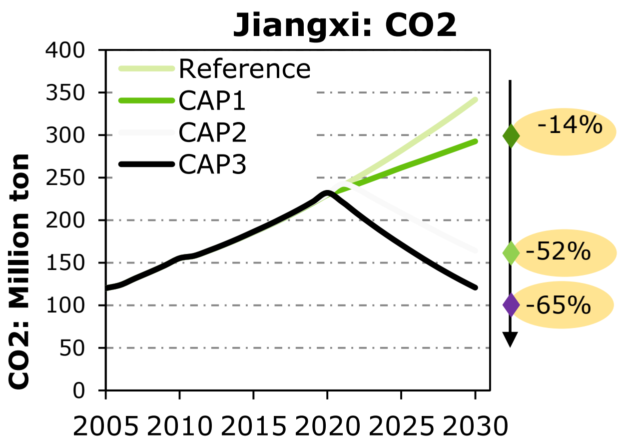
Nr.	Scenario	Non-fossil energy	Consumption pattern	CCS	Emission trading	CO_2 emission constraint	
3	CM_CAP1	2005 level	High carbon	off	off	on	Level1: intensity target
4	CM_CAP2	2005 level	High carbon	off	off	on	Level2: mild reduction
5	CM_CAP3	2005 level	High carbon	off	off	on	Level3: most stringent

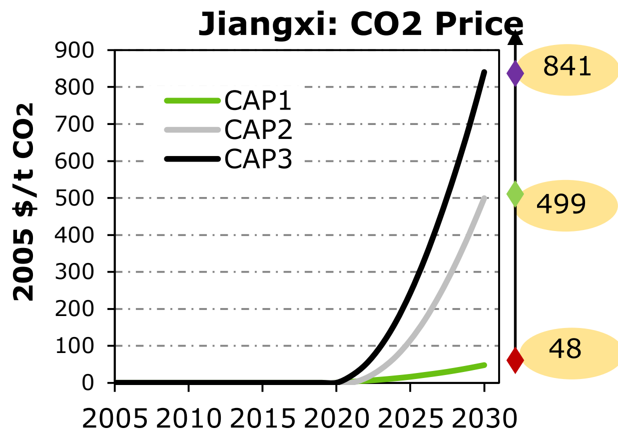
Carbon constraints

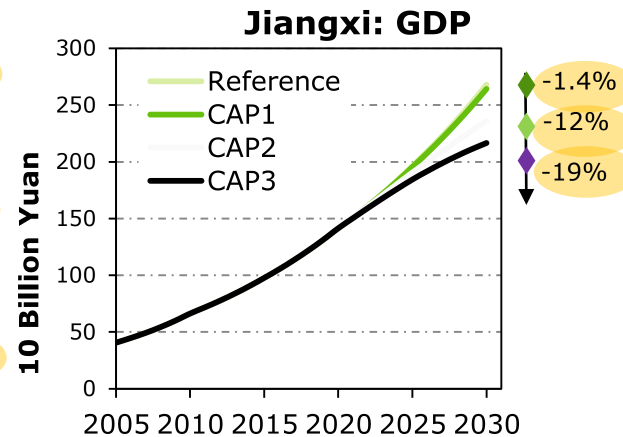
- CAP1: Carbon intensity of GDP reduces as Copenhagen target;
- CAP2: ERI's Enhanced Low Carbon Scenario;
- CAP3: Emissions in 2030 are reduced by 9.5% compared with 2005's level, derived from 2 degree target.

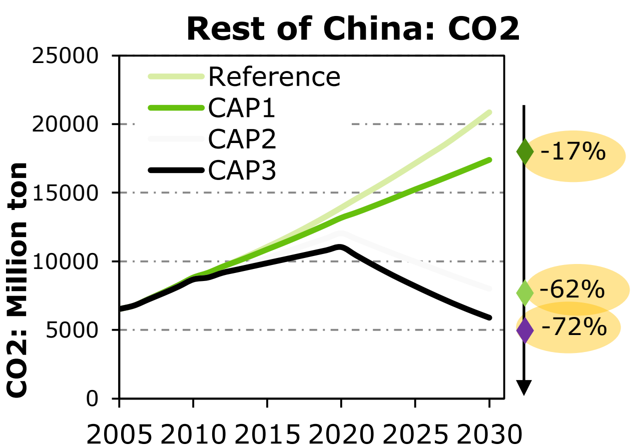


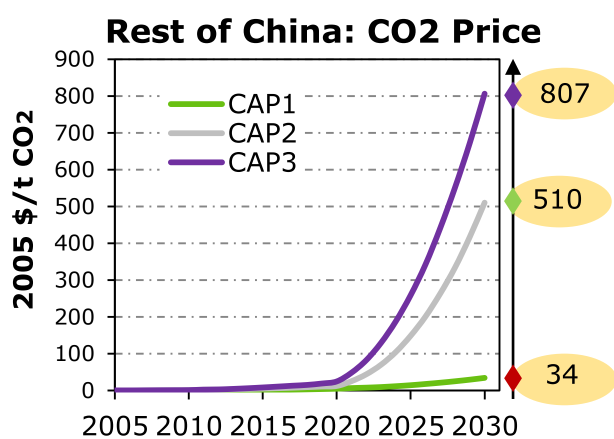
5. Results: Mitigation scenario

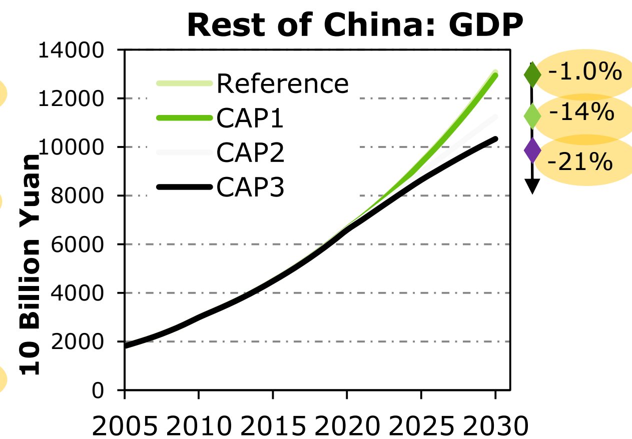












Carbon emissions in mitigation scenarios are exogenously assumed.

Carbon prices increase with more reduction.

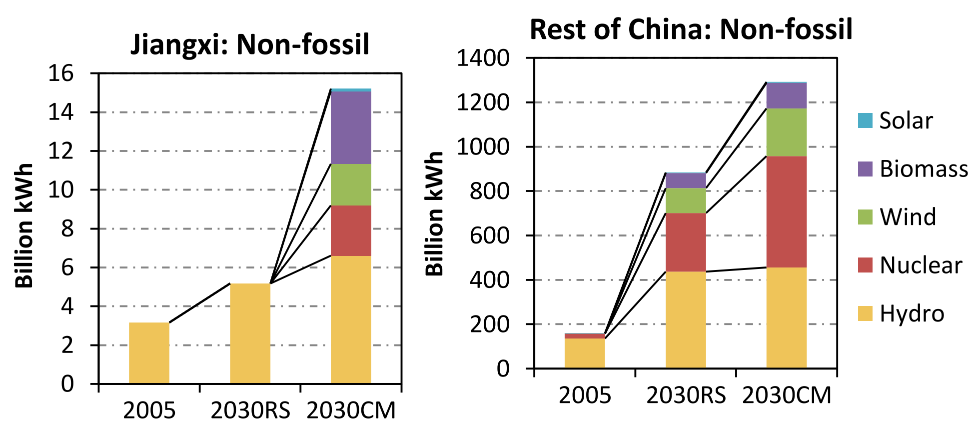
GDP loss is higher under more stringent constraint.

5. Results: Mitigation scenario

Nr.	Scenario	Non-fossil energy	Consumption pattern	CCS	Emission trading
6	CM_CAP3_HC	2005 level	High carbon	off	off
7	CM_CAP3_HC_RE	Large scale develop	High carbon	off	off
8	CM_CAP3_LC_RE	Large scale develop	Low carbon	off	off
9	CM_CAP3_LC_CCS	Large scale develop	Low carbon	on	off
10	CM_CAP3_LC_ET	Large scale develop	Low carbon	on	on

Five types of responses

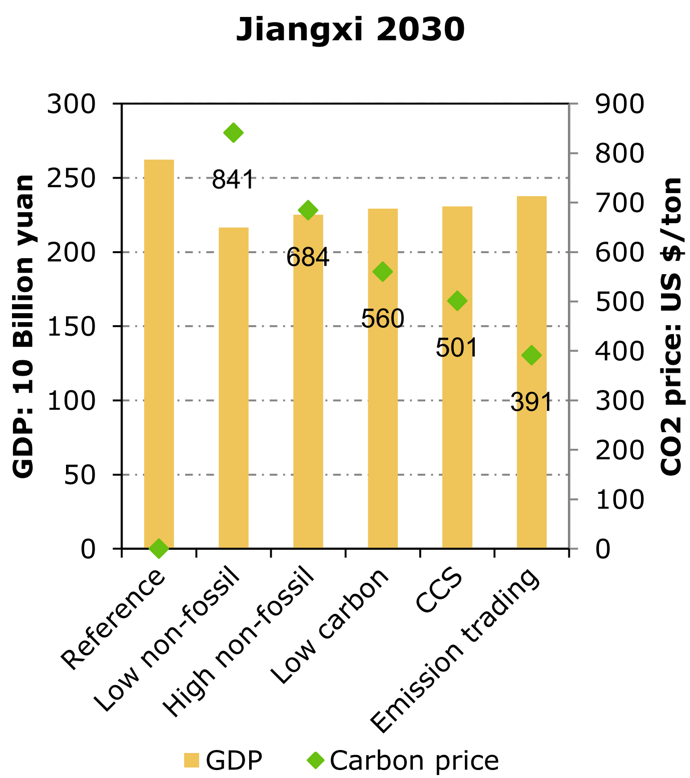
- None;
- Non-fossil energy development;
- Low carbon consumption pattern;
- CCS technology;
- Free inter-provincial emissions trading.

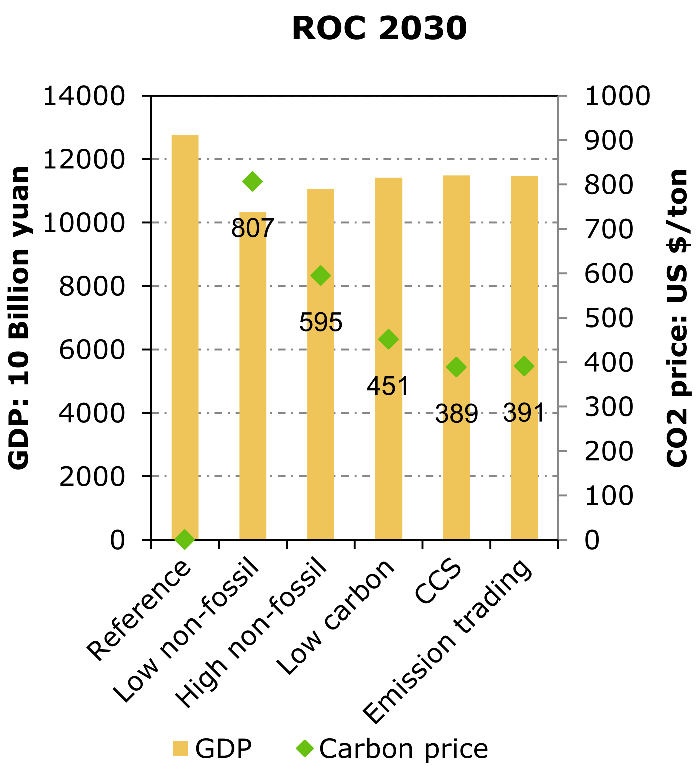


Reference: Energy Research Institute, 2009.

Assumptions on CCS:
- Absorb 80% CO_2;
- Need 1.5-2 times more capital and labor input;
- Need 30% more electricity input;
- Annual penetration rate: less than 2% of existing power plant capacity.

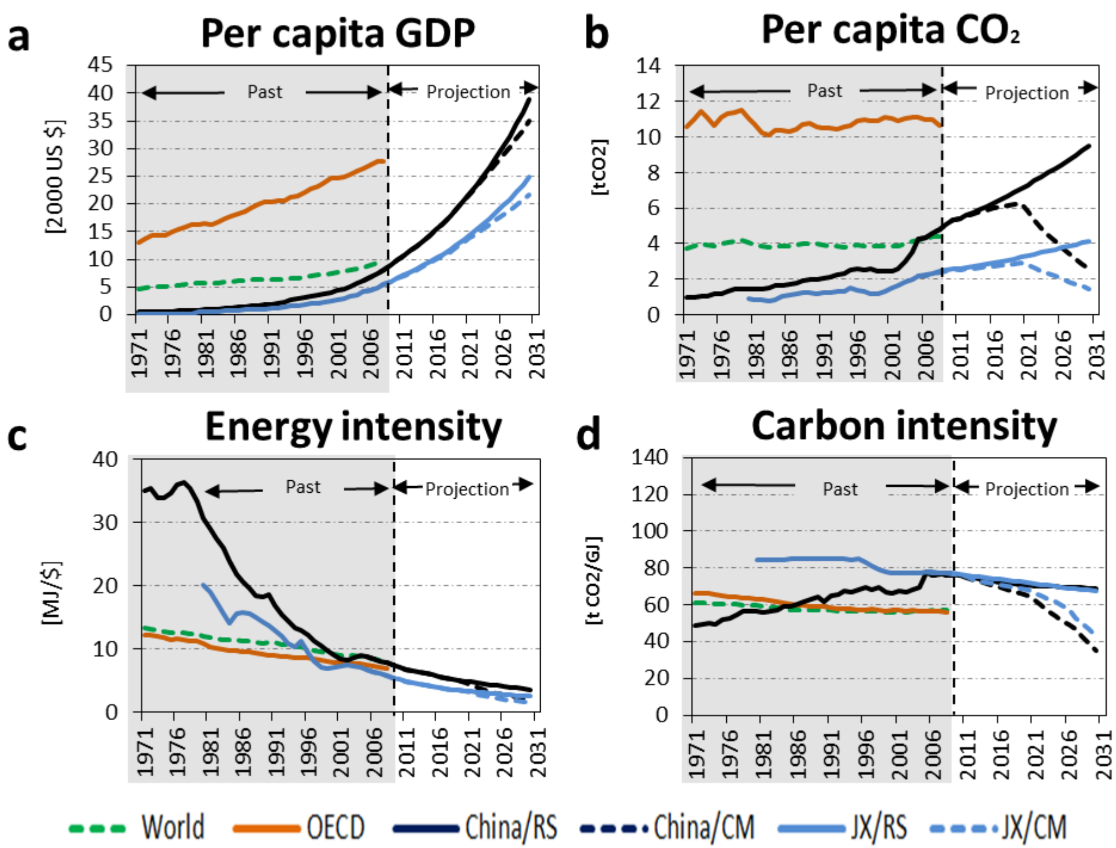
5. Overall impacts of countermeasures





- Under carbon constraint scenario, carbon price and GDP loss would be quite high;
- With all countermeasures introduced, carbon price will fall by half, and GDP loss would be about 9% instead of 20%.

Comparing with historical trends



Per capita GDP steady increases
- China: higher than current OECD;
- Jiangxi: higher than world level

Per capita CO2 increases
- China: close to OECD
- Jiangxi: close to world level
- Falling in mitigation scenario

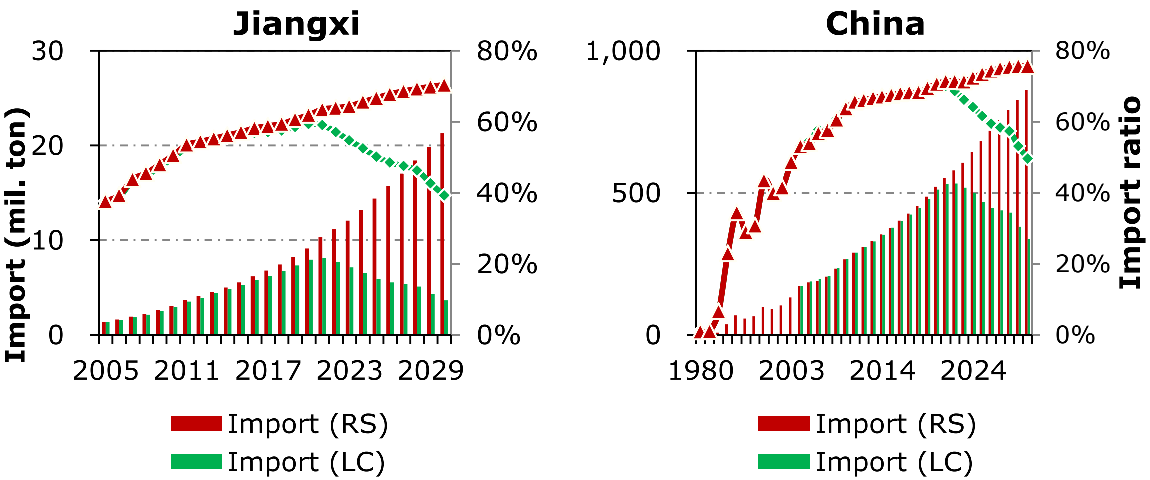
Energy intensity further falls
- China and Jiangxi lower than current world level;
- Jiangxi lower than China

Carbon intensity decreases
- Due to non-fossil energy development.
- But still higher than world and OECD due to coal domination.

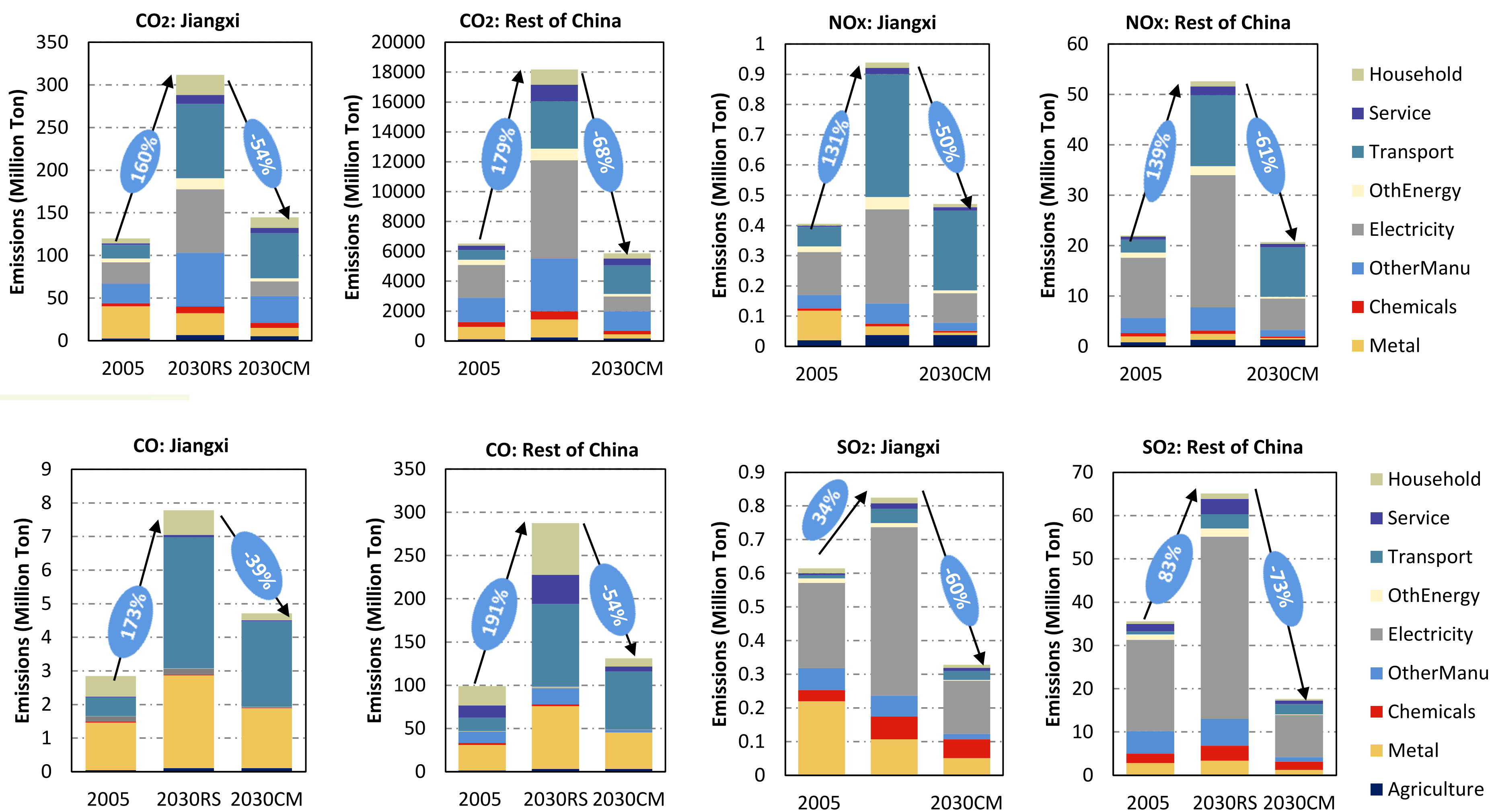
Co-benefits of low-carbon economy

- Oil import dependency
- Air pollutants emission

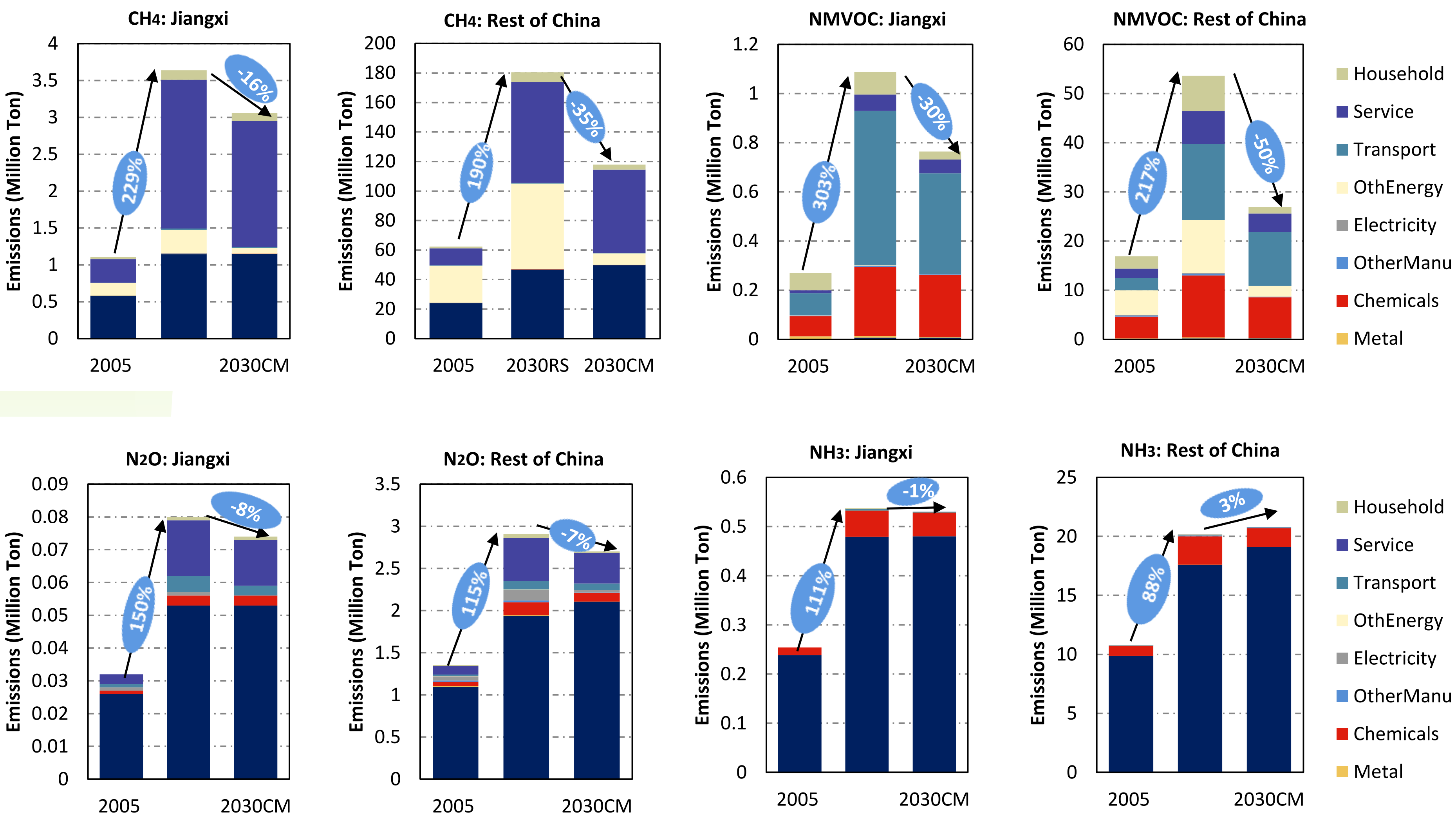
5. Co-benefits: Oil import dependency



5. Co-benefits: air pollutants



5. Co-benefits: air pollutants



Conclusions

- Energy and emission would increase due to GDP growth in future reference scenarios; therefore, China's participation is crucial for global climate mitigation;
- At national level, economic impacts are closely related to stringency of carbon constraints; at provincial level, economic impacts are also determined by burden sharing scheme;
- Without additional low-carbon countermeasures, carbon price and GDP loss would be quite high in the most stringent carbon reduction scenarios;
- With introduction of the low-carbon countermeasures, carbon price and GDP loss would be lowered substantially.
- There are a lot of co-benefits associated with low-carbon economy, including air pollutants reduction and energy security improvement.

Future work

- Inter-provincial flow of labor and capital;
- Technology in transport sector;
- Apply to other provinces, or developing 31-region model.

Publications

- **Journal papers**

  Dai Hancheng, Masui Toshihiko, Matsuoka Yuzuru, Fujimori Shinichiro (2012). "The Impacts of China's Household Consumption Expenditure Patterns on Energy Demand and Carbon Emissions towards 2050." Energy Policy **50**(Special Issue): 736-750.

  Dai Hancheng and Masui Toshihiko (2012). "Assessing the Contribution of Carbon Emissions Trading in China to Carbon Intensity Reduction." Energy Science and Technology **4**(1): 1-8.

  Dai Hancheng, Masui Toshihiko, Matsuoka Yuzuru, Fujimori Shinichiro (2011). "Assessment of China's Climate Commitment and Non-Fossil Energy Plan towards 2020 Using Hybrid AIM/CGE Model." Energy Policy **39**(5): 2875-2887.

- **Proceeding papers and presentation**

  Assessing the Contribution of Inter-provincial Carbon Emissions Trading in China to Carbon Intensity Reduction in 2020. The 2nd Congress of the East Asian Association of Environmental and Resource Economics, Bandung, Indonesia, Feb 2-5, 2012.

  Contribution of China's Renewable Energy Development in Power Generation to Carbon Intensity Reduction. The 1st Congress of the East Asian Association of Environmental and Resource Economics, Sapporo, Hokkaido, Aug. 18-19, 2010.

  Impact Assessment of China's Climate Target towards 2020. The 15th Asia-Pacific Integrated Model International Workshop, Tsukuba, Japan, Feb. 20-22, 2010

Thank you for your attention!