Low carbon economy 2030 in China
- Jiangxi Province as an example

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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)

Primary Energy

- Mtoe/year
- Share to world

- 0% 2% 4% 6% 8% 10% 12% 14% 16% 18%
- Other
- Renewable
- Hydro
- Nuclear
- Gas
- Oil
- Coal
- Share to world

CO₂ Emissions

- Mt-CO₂/year
- Share to World

- 0% 5% 10% 15% 20% 25%
- Other
- Transport
- Industry
- Energy
- Electricity & heat
- Share to World

— **Future** (EIA, 2011)

Primary Energy

- Share to World

- 2005 2011 2017 2023 2029 2035
- 0% 20% 40% 60% 80% 100%
- Other
- Brazil
- South Korea
- Japan
- Europe
- Canada
- United States
- India
- China

CO₂ emissions

- Share to World

- 2005 2011 2017 2023 2029 2035
- 0% 20% 40% 60% 80% 100%
- Other
- Brazil
- South Korea
- Japan
- Europe
- Canada
- United States
- India
- China
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 of LCE
2. Literature review: existing studies on LCE

**Country level**

- **Japan**: it has the technological potential to reduce its CO₂ emissions by 70% compared to the 1990 level in 2050, quantitative roadmaps which include over 600 options. ([NIES, 2008](http:));
- **China**: possible for China to reduce its emissions to 2005 levels in 2050 ([Jiang, 2009](http:)).
- **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](http:));
- **South Korea**: "Low Carbon, Green Growth Policy", reduce carbon emissions by 30% by 2020 relative to BaU ([Jones and Yoo, 2010](http:));
- **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](http:));
- **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](http:));
- **Thailand**: emissions in 2030 can be decreased approximately by 42.5% to 324 million t-CO₂ ([Limmeechokchai, 2010](http:)).
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 CO2 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-CO2 (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**: CO2 lowered by 29-50% in 2030 against BaU (Jiang, 2009).
3. A two-region CGE model for Jiangxi Province

**Production block**

- **Resource**
- **GHG**
- **Energy & VA**
- **Non Energy**

**Value added**

- **Capital**
- **Labor**
- **Land**

**Output**

- **Energy**
- **Fossil energy**
- **Electricity**

**Energy & VA**

- **Solid**
- **Liquid**
- **Gas**

**GHG**

**Income block**

**Household**

- **Income / Endowment**

**Government**

- **Income Tax**

**Expenditure block**

- **Household**
- **Government**
- **Capital Formation**

**Environment**

- **GHG**

**Market block**

- **Output**
  - **Export**
  - **Domestic**
  - **Local market**

- **Local Production**

**Import**

- **Provincial outflow**
- **Provincial inflow**

**Local market**

- **Domestic consumption**

**T = 2**

**T = 3**

- **σ ≈ 4**
- **σ > 4**
- **σ = 0**
- **σ = 0.4**
- **σ = 0.7**
- **σ = 1.5**
- **σ = 0.6**
- **σ = 1**
- **σ = 1**
- **σ = 1**
- **σ = 1**
3. Methodology: CGE model

Region & time & GHGs

- **Two regions**: Jiangxi Province, rest of China
- **Time**: 2005-2030, one year time step
- **Gas type**
  - \( \text{CO}_2, \text{CH}_4, \text{N}_2\text{O}, \text{CO}, \text{NH}_3, \text{NMVOC}, \text{NO}_x, \text{SO}_2; \)
  - Energy related, process related, biomass related.

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**

Data

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

Technology

Power generation

- Five Coal
- Oil power
- Natural gas
- Hydro
- Nuclear
- Wind
- Solar
- 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;
- CO₂ 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

GDP Share

Jiangxi
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

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
## 4. Scenario towards 2030

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Scenario</th>
<th>Non-fossil energy</th>
<th>Consumption pattern</th>
<th>CCS</th>
<th>Emission trading</th>
<th>CO\textsubscript{2} emission constraint</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>RS_HC</td>
<td>conventional scale</td>
<td>High carbon</td>
<td>off</td>
<td>off</td>
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<tr>
<td>2</td>
<td>RS_LC</td>
<td>conventional scale</td>
<td>Low carbon</td>
<td>off</td>
<td>off</td>
<td>off No constraint</td>
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<tr>
<td>3</td>
<td>CM_CAP1</td>
<td>2005 level</td>
<td>High carbon</td>
<td>off</td>
<td>off</td>
<td>on Level1: intensity target</td>
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<tr>
<td>4</td>
<td>CM_CAP2</td>
<td>2005 level</td>
<td>High carbon</td>
<td>off</td>
<td>off</td>
<td>on Level2: mild reduction</td>
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<tr>
<td>5</td>
<td>CM_CAP3</td>
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<td>High carbon</td>
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<td>on Level3: most stringent</td>
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<tr>
<td>6</td>
<td>CM_CAP3_HC</td>
<td>2005 level</td>
<td>High carbon</td>
<td>off</td>
<td>off</td>
<td>on Level3, GDP intensity convergence</td>
</tr>
<tr>
<td>7</td>
<td>CM_CAP3_HC_RE</td>
<td>Large scale develop</td>
<td>High carbon</td>
<td>off</td>
<td>off</td>
<td>on Level3, GDP intensity convergence</td>
</tr>
<tr>
<td>8</td>
<td>CM_CAP3_LC_RE</td>
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<td>off</td>
<td>off</td>
<td>on Level3, GDP intensity convergence</td>
</tr>
<tr>
<td>9</td>
<td>CM_CAP3_LC_CCS</td>
<td>Large scale develop</td>
<td>Low carbon</td>
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<td>off</td>
<td>on Level3, GDP intensity convergence</td>
</tr>
<tr>
<td>10</td>
<td>CM_CAP3_LC_ET</td>
<td>Large scale develop</td>
<td>Low carbon</td>
<td>on</td>
<td>on</td>
<td>on Level3, GDP intensity convergence</td>
</tr>
</tbody>
</table>
### 4. Scenario: household consumption pattern

#### Jiangxi

<table>
<thead>
<tr>
<th>Per capita expenditure (2005 US dollar)</th>
<th>2005</th>
<th>2030</th>
<th>Whole Region</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>Rural</td>
<td>Urban</td>
<td>Rural</td>
<td></td>
</tr>
<tr>
<td>746</td>
<td>303</td>
<td>5446</td>
<td>2214</td>
<td>4250</td>
</tr>
<tr>
<td>Food</td>
<td>40.8%</td>
<td>49.1%</td>
<td>27.8%</td>
<td>32.4%</td>
</tr>
<tr>
<td>Clothing</td>
<td>10.6%</td>
<td>5.0%</td>
<td>10.1%</td>
<td>5.9%</td>
</tr>
<tr>
<td>Housing</td>
<td>10.6%</td>
<td>13.1%</td>
<td>9.7%</td>
<td>22.8%</td>
</tr>
<tr>
<td>Furnishings</td>
<td>7.0%</td>
<td>3.9%</td>
<td>8.0%</td>
<td>5.3%</td>
</tr>
<tr>
<td>Health care and Medical services</td>
<td>5.3%</td>
<td>6.2%</td>
<td>6.5%</td>
<td>6.6%</td>
</tr>
<tr>
<td>Transport and Communications</td>
<td>9.3%</td>
<td>9.2%</td>
<td>18.5%</td>
<td>13.0%</td>
</tr>
<tr>
<td>Education and recreation</td>
<td>13.2%</td>
<td>11.1%</td>
<td>14.6%</td>
<td>11.3%</td>
</tr>
<tr>
<td>Miscellaneous goods and services</td>
<td>3.2%</td>
<td>2.2%</td>
<td>5.0%</td>
<td>2.7%</td>
</tr>
</tbody>
</table>

#### Rest of China

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<thead>
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<th>Per capita expenditure (2005 US dollar)</th>
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<td>Rural</td>
<td></td>
</tr>
<tr>
<td>970</td>
<td>312</td>
<td>10280</td>
<td>3307</td>
<td>7700</td>
</tr>
<tr>
<td>Food</td>
<td>36.7%</td>
<td>45.1%</td>
<td>26.5%</td>
<td>31.7%</td>
</tr>
<tr>
<td>Clothing</td>
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<td>5.8%</td>
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</table>
5. Results: Reference scenario

**Jiangxi: GDP**
- Reference scenario
- 1RS_GAP_HC: +560%
- 2RS_GAP_LC: +560%

**Rest of China: GDP**
- 1RS_GAP_HC: +620%

**Jiangxi: TPES**
- 1RS_GAP_HC: +170%
- 2RS_GAP_LC: +170%

**Rest of China: TPES**
- 1RS_GAP_HC: +220%
- 2RS_GAP_LC: +220%

**Jiangxi: CO₂**
- 1RS_GAP_HC: -11.7%
- 2RS_GAP_LC: -11.7%

**Rest of China: CO₂**
- 1RS_GAP_HC: -13.2%
- 2RS_GAP_LC: -13.2%

Energy saving and carbon reduction effect by low-carbon consumption.
5. Results: Mitigation scenario

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.

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<td>CM_CAP1</td>
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<td>Level1: intensity target</td>
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<td>Level2: mild reduction</td>
</tr>
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<td>CM_CAP3</td>
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<td></td>
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<td></td>
<td></td>
<td>Level3: most stringent</td>
</tr>
</tbody>
</table>


China: CO₂
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

### Five types of responses

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

### Table: Mitigation scenarios

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</table>

### Graphs:

- **Jiangxi: Non-fossil**
  - Bar graphs showing energy consumption over time.

- **Rest of China: Non-fossil**
  - Bar graphs showing energy consumption over time.

### 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

[Graph showing the import dependency for Jiangxi and China over different years]

- Import (RS)
- Import (LC)
5. Co-benefits: air pollutants

- **CO₂**: Jiangxi
  - Emissions (Million Ton): 1609%, 54%

- **CO₂**: Rest of China
  - Emissions (Million Ton): 179%, -68%

- **NOₓ**: Jiangxi
  - Emissions (Million Ton): 131%, 50%

- **NOₓ**: Rest of China
  - Emissions (Million Ton): 139%, 57%

- **CO**: Jiangxi
  - Emissions (Million Ton): 173%, -39%

- **CO**: Rest of China
  - Emissions (Million Ton): 191%, 54%

- **SO₂**: Jiangxi
  - Emissions (Million Ton): 34%, -60%

- **SO₂**: Rest of China
  - Emissions (Million Ton): 83%, 73%
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.
◆ **Journal papers**  

◆ **Proceeding papers and presentation**  
Thank you for your attention!