2050 Simulator 中国

Simulating the evolution of the Chinese energy system

Pedro Neves Ferreira
EDP
Head of Energy Planning Department
pedro.nevesferreira@edp.pt
The 2050 simulator is a simplified model of reality.

The objective of this exercise is simply to convey, in an intuitive and educational form, the key variables of the energy sector and the way to reach its sustainability.

As a consequence, the simulator’s results should not be interpreted as exact estimations, and they do not necessarily represent EDP’s vision regarding the Energy Policy options that should be taken in the 2050 timeframe.
Agenda

Brief overview of the Chinese energy system

EDP's 2050 Simulator for China

China's energy outlook: Three scenarios
China is already the top energy consumer in the world, despite still having low levels per capita

Primary energy demand
Gtoe, 1970-2010

- ’00-’10 China growth equals to 80% EU or 60% US consumption by ’10
- Yearly growth equal to UK annual consumption

Primary energy consumption top countries
% total cons. and toe/cap, 2010

<table>
<thead>
<tr>
<th>Country</th>
<th>Total</th>
<th>Per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>20%</td>
<td>1.8</td>
</tr>
<tr>
<td>US</td>
<td>19%</td>
<td>7.3</td>
</tr>
<tr>
<td>EU</td>
<td>14%</td>
<td>3.5</td>
</tr>
<tr>
<td>Russia</td>
<td>6%</td>
<td>4.8</td>
</tr>
<tr>
<td>India</td>
<td>4%</td>
<td>0.4</td>
</tr>
<tr>
<td>Japan</td>
<td>4%</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Source: BP Statistical Review of World Energy (Jun’11) and IEA World Energy Outlook 2011
© Copyright EDP – Energias de Portugal, S.A. 2013

X% China 10 years CAGR
Chinese primary energy mix is mainly focused on coal, while the US and EU are much more dependent on oil and gas

Chinese primary energy demand
Mtoe, 1971-2009

Primary energy demand per fuel
Mtoe and %, 2009

Source: IEA World Energy Outlooks 2004 and 2011
© Copyright EDP – Energias de Portugal, S.A. 2013
China is expected to remain the major energy consumer in the forthcoming years, reducing the share of coal in the energy mix.

Primary energy demand forecast Gtoe, 2010-2035

Chinese primary energy demand forecast per fuel %, 2010-2035

What could alternative scenarios for the future evolution of the Chinese energy sector look like?
Agenda

Brief overview of the Chinese energy system

EDP’s 2050 Simulator for China

China's energy outlook: Three scenarios
China energy roadmap – drawn in Five-Year Plans (FYP) – already points to challenging objectives on efficiency, emissions and RES

Key energy and climate policy goals and indicators
China, 2006-2020

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY INTENSITY (% REDUCTION IN FIVE YEARS)</td>
<td>20%</td>
<td>19.1%</td>
<td>16%</td>
<td>NOT SET</td>
</tr>
<tr>
<td>CARBON INTENSITY (% REDUCTION IN FIVE YEARS)</td>
<td>NOT SET</td>
<td></td>
<td>17%</td>
<td>40-45% VS 2005</td>
</tr>
<tr>
<td>NEW ENERGY (% OF PRIMARY ENERGY)</td>
<td>10%</td>
<td>9.6%¹</td>
<td>11.4%</td>
<td>15%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GROWTH RATES</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIMARY ENERGY CONSUMPTION (ANNUAL GROWTH)</td>
<td>4%</td>
<td>6.3%</td>
<td>3.75-5%*</td>
<td>–</td>
</tr>
<tr>
<td>ELECTRICITY ENERGY CONSUMPTION (ANNUAL GROWTH)</td>
<td>–</td>
<td>11%</td>
<td>8.5%*</td>
<td>(5.5%)*</td>
</tr>
<tr>
<td>ELECTRICITY GENERATING CAPACITY (ANNUAL GROWTH)</td>
<td>8.4%²,³</td>
<td>13.2%¹</td>
<td>8.5%*</td>
<td>(5.6%)*</td>
</tr>
<tr>
<td>GDP (ANNUAL GROWTH)</td>
<td>7.5%</td>
<td>10.6%</td>
<td>7%</td>
<td>–</td>
</tr>
</tbody>
</table>

¹ Asterisked numbers indicate estimates made by government that are not formal targets. Bold numbers are new targets.
The 2050 simulator allows users to view the energy sector's evolution given their forecast about future technology adoption and consumption behaviors.
By answering 32 questions about energy prices, demand and supply evolution, and GHG emissions, the user defines an energy path.

- **Prices**
- **Energy Demand**
- **Generation or Capacity**
- **CO₂ Emissions**

32 questions divided into 4 groups

Multiple choice answers:
1. Business as Usual scenario
2. Minor transformations required
3. Medium transformations necessary
4. Scenario involving major transformations (without breaking the laws of physics!)
The simulator allows for immediate visualization of the path impacts along several dimensions in graph or numeric format.

2050 Outputs
Outputs also include energy flows and performance data

**Energy flows output**
Sankey graphs

- Primary energies
- Transformation into power
- Final energy by sectors

**Performance output**
Emissions vs. Cost

*Your pathway*

*Most cost-efficient pathways*
The simulator's objective function is to (1) minimize greenhouse gas emissions, (2) at the lowest cost, and (3) at the lowest difficulty level.
What will China's future energy sector look like in the decades to come?

www.2050china.edp.pt
Agenda

Brief overview of the Chinese energy system

EDP’s 2050 Simulator for China

China's energy outlook: Three scenarios
## Common assumptions across all scenarios

### Common assumptions for all simulated scenarios (answers from 1 to 4)

<table>
<thead>
<tr>
<th>Category</th>
<th>Assumption Details</th>
</tr>
</thead>
</table>
| **Prices**             | • IEA long term oil price scenario: 130 $_{10}/bbl (2)  
                       • IEA long term oil coal scenario: 110 $_{10}/ton (2)  
                       • IEA long term natural gas scenario: 11 $_{10}/Mbtu (2)  
                       • Long term CO₂ base case scenario: 50 €_{10}/ton (2) |
| **Population**         | • Current Chinese population by 2050: 1350 Million (3)                                                                |
| **GDP/capita**         | • Double current Chinese GDP/Capita by 2050: 10 k$/capita (4)                                                          |
| **Energy intensity**   | • Current Residential Chinese energy intensity level by 2050: 260 toe/kcapita (3)  
                       • Current Services, agr. & fish Chinese energy intensity level by 2050: 25 toe/M$ (2)  
                       • Double current Chinese vehicles penetration level by 2050: 400 vehicles/kcapita (3) |
| **Power imports**      | • No power imports by 2050 (1)                                                                                         |
| **CO₂ mitigation**     | • No thermal power plants with CCS (1)  
                       • No industrial plants with CCS (1)  
                       • No emissions reduction due to geosequestration (1)               |
<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Rationale</th>
<th>EDP’s 2050 Simulator answers (different from 1)</th>
</tr>
</thead>
</table>
| King Coal            | • Business as Usual  
                        • Coal keeps its leading high market share  
                        • Low energy efficiency levels                                      | • N.a.                                                              |
| Shale Gas            | • China discovers Shale Gas  
                        • Power system shifts from Coal to Gas  
                        • Low energy efficiency levels                                       | • Transports fuel switching: 75% road and non-road transports from oil to biofuels and natural gas (4)  
                        |                                                                      | • Power generation: gas accounts for 2,000 GW (4)                      |
| RES & Electrification| • Focus on electrification and energy efficiency  
                        • Clean power generation (Nuclear and Renewables)                     | • Industry: 40% current intensity level to 50 toe/M$ (3)  
                        |                                                                      | • Demand electrification:  
                        |                                                                      | • Residential, services and industry electrification (3)  
                        |                                                                      | • Transports: 50% road and 30% non-road electrification (3)  
                        |                                                                      | • Power generation: focus on nuclear and RES (3)                  |
These 3 scenarios imply very different energy mixes...

Share of primary energy demand evolution by fuels
%

© Copyright EDP – Energias de Portugal, S.A. 2013
...leading to substantially different GHG emissions

GHG emission evolution
GTonCO$_{2eq}$ 2000-2050

2050 GHG emissions vs. 2005
%, 2050

- King Coal: 1,080 (225%)
- Shale Gas: 788 (165%)
- RES & Elect: 382 (80%)

Source: IEA, World Energy Outlook 2012
Note: As benchmark, according to IEA, current carbon intensity for US = 400 and for EU = 240 (2011)

© Copyright EDP – Energias de Portugal, S.A. 2013
The higher energy efficiency level of the RES & Electrification scenario has a huge impact on energy consumption...

Final energy demand by sectors
Mtoe, 2050

- Losses & autocons.
- Residential
- Services, agr. & fish
- Industry
- Transport

<table>
<thead>
<tr>
<th>Sector</th>
<th>King Coal</th>
<th>Shale Gas</th>
<th>RES &amp; Elect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary energy demand</td>
<td>4.691</td>
<td>4.305</td>
<td>2.749</td>
</tr>
<tr>
<td>Final energy demand</td>
<td>2.955</td>
<td>2.962</td>
<td>1.842</td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>-38%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Higher efficiency of CCGT vs. Coal-fired reduces primary energy demand

Energy efficiency may reduce significantly final energy demand

Note: As benchmark, according to IEA, current energy intensity for US = 170 and for EU = 110 (2011)
...which, even with higher levels of electrification, leads to similar needs of power generation than that of the King Coal and Shale Gas scenarios.
Although the RES & Elect scenario has higher unit costs of energy and seems to be more difficult to implement, it leads to lower total energy costs.

### Difficulty level (of implementation) %, 2000-2050

- King Coal: 7%
- Shale Gas: 19%
- RES & Elect: 40%

### Total cost of energy B$/\text{year}, 2050

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total Cost</th>
<th>Unit Cost of Energy by 2050 [$/\text{MWh}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>King Coal</td>
<td>2.191</td>
<td>64</td>
</tr>
<tr>
<td>Shale Gas</td>
<td>2.183</td>
<td>63</td>
</tr>
<tr>
<td>RES &amp; Elect</td>
<td>1.600</td>
<td>75</td>
</tr>
</tbody>
</table>

-27% decrease in total cost compared to King Coal.
If China increases its GDP/Cap by 2050 to current US values, primary energy demand would increase by 3.4x to 16 Gtoe.

**Primary energy vs. GDP/capita**
Mtoe, 2050

10 k$/capita: Current China x2 → 4.691
20 k$/capita: Current US / 2 → 8.510
30 k$/capita: Current EU → 12.328
40 k$/capita: Current US → 16.147

**Primary energy vs. Industry energy intensity**
Mtoe, 2050

20 toe/M$: Current US → 2.059
50 toe/M$: 40% current China → 2.848
90 toe/M$: 75% current China → 3.902
120 toe/M$: Current China → 4.691

**Final energy vs. Road transport penetration**
Mtoe, 2050

200 Vehicles/kcap: Current China → 9% 2.706
400 Vehicles/kcap: Current China x2 → 17% 2.955
500 Vehicles/kcap: EU → 20% 3.080
700 Vehicles/kcap: US → 26% 3.330

© Copyright EDP – Energias de Portugal, S.A. 2013
Shale Gas