Global 2050 Calculator: Assessment of Primary and Secondary Energy Supply

Technical workshop on Fossil fuels and Electricity Generation Technologies

23rd - 24th April, 2014
Gurgaon, India
Content of Presentation – Day 1

► Session-1: Model Overview & Primary Energy supply
  • Model overview & structure of electricity and fossil fuel sectors
  • Pathways of FF extraction efficiency
  • Pathways of FF refining efficiency

► Session-2: Fossil fuel based power generation
  ▪ Pathways of split between coal, oil and NG based generation
  ▪ Pathways of efficiency of coal, oil and NG based power generation
  ▪ Pathway of carbon capture & storage (CCS)
Session-1
Model Overview &
Primary Energy supply
Session 1-1

Model Overview
Principles of the Global 2050 Calculator

The Global 2050 Calculator is a simple excel based accounting tool for energy and corresponding emissions which is based only on engineering principle of technology development and adoption and does not contain any constraint in the system during technology deployment.

As a matter of fact this tool provides enormous flexibility to the policy and decision makers at all levels to fit their respective surrounding environments in a diversified information platform which can further help them to take informed decisions.
Technology Mapping

Electricity & Fossil Fuel

Electricity

Clean Power
- Solar
- Wind
- Hydro
- Marine
- Nuclear
- Geothermal
- Storage

Fossil
- Coal
  - Ultra super critical (USC) & USC + CCS
  - Super critical (SC) & SC + CCS
  - Sub-critical (Sub-C) & Sub-C + CCS
- Oil
  - Efficient liquid technology (ELT) & ELT + CCS
  - Inefficient liquid technology (IELT) & IELT + CCS
- Gas
  - Open cycle gas turbine (OCGT) & OCGT + CCS
  - Combined cycle gas turbine (CCGT) & CCGT + CCS

Fuel Production

Coal mine
- Oil well
- NG gas extraction

Coal washeries
- Oil refinery
- NG gas liquefaction

Hydrogen
- SMR
- Coal gasification
- Electrolysis
- Sabatier process
Electricity & Fossil Structure of the Global 2050 Calculator

Indicative flow diagram of the energy system considered in the calculator
Structure of the Spread Sheets and Linkages

- Different levels of energy systems converted into excel sheets in the model work book.

- Users get choices to determine the level of activities under each selected technology which are made user defined in the tool.

- User has options to select levels from 1 energy supply sector (electricity generation) and from 4 different energy demand sectors (transport/buildings/manufacturing/land-food).

- Users get choices to select output units as well.

- Model endogenously determines the total energy demand from each demand sector and then determines the total supply required.
Basic assumptions of electricity supply sector in the model

- Demand = Supply
- Demand meets in a priority order of renewables, nuclear and fossil fuels
- Primary objective of the supply mix is to reduce GHG emissions
- Electricity flows freely from one part to another part of the world - existence of global power grid
- No source of energy is intermittent ..all are firm power
Model has FOUR different levels of selection of activities
Level-1: Very pessimistic situation in the future in terms of deploying technology capable of reducing GHG emissions at a global scale.
Level -2: Cautiously optimistic situation in the future in terms of deploying low emission technology at a global scale.
Level -3: Optimistic situation in the future in terms of deploying low emissions technology at a global scale.
Level -4: Very optimistic situation in the future in terms of deploying low emissions technology at a global scale.
# User input choices in the electricity sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Lever</th>
<th>User defined Level</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electricity generation</strong></td>
<td>Coal/oil/gas split</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Fossil fuel efficiency</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Carbon capture and storage</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Nuclear</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Wind</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Hydroelectric</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Marine</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Solar</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Geothermal</td>
<td>1.1</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Storage and demand shifting</td>
<td>1.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Section 1-2
Primary energy extraction efficiency
Global Coal Extraction

**Level-4:** The coal extraction efficiency is 80% in 2011 which improves to 95% in 2050.

**Level-1:** The efficiency remains constant at 80% till 2050.
Global Oil Extraction

**Level-4:** The oil extraction efficiency is 93% in 2011 which improves to 98% in 2050.

**Level-1:** The efficiency remains constant at 93% till 2050.
Natural Gas Extraction Efficiency Levels

Global Gas Extraction

**Level-4:** The gas extraction efficiency is 70% in 2011 which improves to 90% in 2050.

**Level-1:** The efficiency remains constant at 70% till 2050.
Section 1-3
Primary energy refining efficiency
Global Coal Washery

**Level-4:** The coal washery efficiency is 95% in 2011 which improves to 97% in 2050.

**Level-1:** The efficiency remains constant at 95% till 2050.
Global Oil Refinery

**Level-4:** The oil refinery efficiency is 93% in 2011 which improves to 96% in 2050.

**Level-1:** The efficiency remains constant at 93% till 2050.
Natural Gas Processing Efficiency Levels

Global Gas Processing

**Level-4:** The gas processing efficiency is 98% in 2011 which improves to 98% in 2050.

**Level-1:** The efficiency remains constant at 98% till 2050.
Section 2

Fossil fuel based power generation
Section 2-1

Future pathway of split between coal, oil and NG based generation
Fossil fuels proportional split

Methodology

► Regional/country reserve and resource allocation. Historical and future estimates were mapped.

► Regional/country level production and consumption trends were recorded.

► Studied production and generation technologies deployed and under development globally.

► Analyzed variables which drive primary energy demand like industry, transport, etc.

► Analyzed variables which have a bearing on secondary energy like capacity factor, efficiency, demand load, etc.
Assumptions

1. Coal based power generation will dominate if no additional measures are taken due to its easy and abundant availability at low cost.

2. Oil use tends to increase under L1 scenario due to its ready to use, low cost proven technology available across the world.

3. To increase gas based generation, world needs certain policy push and extra initiatives.

4. In Level -4 we assume new gas reserves are available at low cost (shale gas pitched in), gas transport facilities improved (LNG facilities and pipelines commissioned)
Proportional split of hydrocarbons stations (solid/liquid/gas)
Proportional split of hydrocarbons stations (solid/liquid/gas)

Level-3

Level-4

Coal
Oil
Gas

Confidential – All rights reserved – Ernst & Young 2013
1. What do you think about our level 4 on FF supply mix inclined more towards NG based generation by 2050?

2. What do you think shale gas can influence the mix in future?

2. What is your opinion on making supply mix coal free by 2050?
Future pathway of efficiency improvement in coal, oil and NG based generation
Historic trend of coal-fired power plant efficiency

Historic trend of coal-fired power plant efficiency

World Energy Council, 2013
Historic trend of gas-fired power plant efficiency

Historic trend of gas-fired power plant efficiency

World Energy Council, 2013
Historic trend of steam conditions in thermal power plants
Historic trend of efficiency improvement in thermal power generation in Japan

- Measures for improving generation efficiency
  - Improve steam conditions
  - Enlarge plant scale

- Designed Thermal Efficiency (% gross efficiency, LHV basis)
  - Sub-Critical (Drum-Type)
  - Super Critical (SC)
  - Ultra Super Critical (USC)

- Key projects:
  - Takasago (260 MW x 2 units)
  - Takehara No. 1 (250 MW)
  - Takehara No. 3 (700 MW)
  - Matsushima (500 MW x 2 units)
  - Ishikawa (156 MW x 2 units)
  - Matsuura No. 1 (1,000 MW)
  - Matsuura No. 2 (1,000 MW)
  - Tachibanawan (1,050 MW x 2 units)
  - Isogo New No. 1 (600 MW)
  - Isogo New No. 2 (500 MW)

- Timeline:
  - 1965
  - 1970
  - 1975
  - 1980
  - 1985
  - 1990
  - 1995
  - 2000
  - 2005
  - 2010

- Trend in coal-fired power generation capacity per unit
Assumptions of pathways of coal based power plant split

1. For Level-1 we assume situation did not improve in terms of improving thermal efficiency and moving more towards super critical or ultra supercritical.. Case of India where efficiency declined.

2. Level-4 is considering the growth rate of Japan thermal efficiency improvement
## Technology Split for Coal Based Generation (Level-4)

<table>
<thead>
<tr>
<th>Technology</th>
<th>2011</th>
<th>2050</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra Super critical</td>
<td>8%</td>
<td>23%</td>
<td>2.74% CAGR</td>
</tr>
<tr>
<td>Super Critical</td>
<td>17%</td>
<td>32%</td>
<td>1.63% CAGR</td>
</tr>
<tr>
<td>Sub-Critical</td>
<td>75%</td>
<td>45%</td>
<td>-1.30% CAGR</td>
</tr>
</tbody>
</table>

## Technology Split for Oil Based Generation (Level-4)

<table>
<thead>
<tr>
<th>Technology</th>
<th>2011</th>
<th>2050</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Fuel Efficient Plant</td>
<td>30%</td>
<td>71%</td>
<td>2.23% CAGR</td>
</tr>
<tr>
<td>Liquid Fuel Inefficient Plant</td>
<td>70%</td>
<td>29%</td>
<td>-2.23% CAGR</td>
</tr>
</tbody>
</table>

## Technology Split for Gas Based Generation (Level-4)

<table>
<thead>
<tr>
<th>Technology</th>
<th>2011</th>
<th>2050</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Cycle Gas Turbine</td>
<td>35%</td>
<td>7%</td>
<td>-4.04% CAGR</td>
</tr>
<tr>
<td>Combined Cycle Gas Turbine</td>
<td>65%</td>
<td>93%</td>
<td>0.92% CAGR</td>
</tr>
</tbody>
</table>
Split of Coal Based Power Generations

Level-1

Level-4
Split of Liquid Fuel Based Power Generation

Level-1

Level-4
Split of Gas Based Power Generation

Level-1

Level-4
1. What do you think about our level 4 on thermal efficiency improvement target adopted following Japanese example by 2050?

2. Can world follow the Japanese case in terms of converting to super critical stations?

2. What is your opinion about CCGT adoption at a global scale following Japanese example?
Section 2-3
Carbon Capture & Storage
Growth assumptions for estimating potential of CCS

► Worldwide, 120 GW of electrical storage and nearly 0 GW (pilots or very small scale) of carbon capture storage (CCS) was online in 2011.

► Built rate of levels for CCS

**Level-4:** In 2050 there is 3700 GW equivalent of installed CCS capacity. The average built up rate is more than 100% (42.2 GW/year) till 2020, 12.79% (88.7GW/year) till 2030, whereas 6.96% (121.6GW/year) till 2040 and 4.07% (121.7GW/year) up till 2050.

**Level-1:** It initially builds at a high rate from 0 GW in 2011 to 16 GW till 2020 and then remains stagnant till 2050.
Levels for Carbon Capture & Storage (GW)

Initial deployment of CCS is considered mostly in OECD countries and developing nations would largely contribute around 2025.
Questions to experts on CCS

1. Do you think our Level -4 built rates are achievable / reasonable / undermined?

2. What is your opinion on world can achieve by 2050 closest possible range?
Thank You