Some stylized facts

- Greater GDP $\leftrightarrow$ more energy consumption.
- Greater GDP per capita $\leftrightarrow$ more energy consumption per capita.
- As countries get richer, energy intensity declines because economy transitions: agricultural $\rightarrow$ industrial $\rightarrow$ services.

Energy demand by income

Rapid liquid fuel demand growth in emerging economies led by China has been a key driver of the crude oil price since the early 2000s.

Energy poverty

- $\sim$1.4 billion with no access to electricity
  - IEA base case: $\sim$1.2 billion in 2030
- $\sim$2.7 billion relying on traditional biomass
  - IEA base case: $\sim$2.8 billion in 2030
- 28% electrification, 80% biomass in Sub-Saharan Africa (excluding South Africa)
- South Asia is the second biggest challenge
Implications of energy poverty

- Economic poverty
- Increased illiteracy
- Decreased life expectancy
  - Water-borne diseases
  - Indoor air pollution
- Environmental degradation
  - Deforestation
  - Pollution (e.g., diesel generators)

Income and electricity access

Income and access to modern fuels

Premature deaths

What can be done?

- Electrification
  - Central generation for urban areas (more efficient and reliable)
  - Distributed generation for rural areas (more fitting for wind, solar, mini hydro)
- Modern fuels indoors
  - Cleaner burning stoves for biomass or coal
  - Switching to gaseous fuels (e.g., LPG)

Energy realities we can’t wish away

- Alternatives are far away from the scale needed to replace conventional fuels.
- They are more expensive than conventional technologies.
- Integration problems (e.g., intermittency, scalability limits, inability to communicate with existing infrastructure, impact on other fuels).
Gürcan Gülen, Ph.D.

**CEE Model (cents/kWh)**

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>$/kW</th>
<th>O&amp;M ($/kwh)</th>
<th>fuel (MMBtu)</th>
<th>O&amp;M ($/MMBtu)</th>
<th>loan Interest</th>
<th>loan period</th>
<th>PLF</th>
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<tbody>
<tr>
<td>Coal</td>
<td>9.0</td>
<td>7.2</td>
<td>10.2</td>
<td>12.3</td>
<td>9%</td>
<td>15</td>
<td>35.1</td>
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<tr>
<td>Natural gas</td>
<td>1.00</td>
<td>0.006</td>
<td>5.0</td>
<td>12%</td>
<td>10</td>
<td>85%</td>
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<tr>
<td>Nuclear</td>
<td>5.35</td>
<td>0.013</td>
<td>7.0</td>
<td>8%</td>
<td>15</td>
<td>90%</td>
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</tr>
<tr>
<td>Wind</td>
<td>2.43</td>
<td>0.009</td>
<td>1.0</td>
<td>8%</td>
<td>15</td>
<td>35%</td>
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<tr>
<td>Solar (CSP)</td>
<td>4.59</td>
<td>0.030</td>
<td>1.0</td>
<td>0%</td>
<td>15</td>
<td>24%</td>
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Capital and O&M costs are based on EIA's Nov 2010 report: [http://www.eia.gov/oiaf/beck_plantcosts/index.html](http://www.eia.gov/oiaf/beck_plantcosts/index.html)

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**Energy content & efficiency**

- Coal: 24-30 MJ/kg and 35-45% conversion efficiency
- Natural gas (methane): ~55 MJ/kg and 55-60% conversion efficiency (CC)
- Natural uranium: ~560 MJ/kg
- Reactor-grade uranium: ~3,700 MJ/kg and 30-35% conversion efficiency

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**Change is Slow & Difficult**

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal</th>
<th>Oil</th>
<th>Gas</th>
<th>Nuclear</th>
<th>Gas</th>
<th>Hydro</th>
<th>Other renewables</th>
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<tbody>
<tr>
<td>2008</td>
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<td></td>
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<tr>
<td>2035</td>
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