Capital Stock intensive planning for the Indian electricity sector

Karthik Bhat, Petra Ochensberger, Udo Bachhiesl, Heinz Stigler

Institut für Elektrizitätswirtschaft und Energieinnovation/TU Graz

16.02.2017
Contents

- Motivation and Objective
- Indian Electricity System
- ATLANTIS_India
- Capital Stock
- Capital Stock intensive planning
- Scenario definition
- Results
- Conclusions
Motivation and Objective

**Motivation:**
- India’s energy transition towards carbon free energy
- Long term sustainability
- Smart investments
- Losing the coal dependency

**Objectives:**
- To calculate the capital stock of the current Indian power plant fleet
- To evaluate specific technology types
The Indian Electricity System

- Huge: Area and Capacity
- 5 power regions
- 330 GW of installed capacity
- 890 TWh of annual electricity consumption
- 145400 circuit kilometers of transmission lines
- 58.76% coal capacity
- 18% renewable
- 14% hydro
The Indian Electricity System

- 1990 – 2006: Large capacities of coal fired power plants added without check

- Cheap availability of domestic and imported coal

- Electricity generation from coal: ~70%

- Major CO2 emissions source

- Use of super critical and ultra supercritical boilers
Challenges for the Energy transition

• High demand growth rate
• Huge dependency on coal
• Nuclear power: Standstill
• $\text{CO}_2$ emissions: Paris agreement, 30% reduction in intensity
• Transmission and Distribution losses
• Large scale renewable energy technology: Expensive a.t.m.
• Energy efficiency targets
Atlantis_India

- Reference to the model ATLANTIS, IEE, TU graz
- Unique techno economic model developed at the IEE
- Over 3000 nodes covering India, Bangladesh, Bhutan, Nepal and Sri Lanka
- More than 6000 transmission lines with physical restrictions
- Over 3750 power plants (smaller PPs aggregated)
- Node-specific demand model
- Additional demand model for e-mobility and other factors
- Economic market model: Copper plate, Zonal Pricing and Redispatch
- Emulation of real-like scenarios
Automatic Capacity extensions

- There is a scarcity of installed capacity ~10%
- Due to the highly increasing demand growth rates
- Results in a demand-supply gap
- In-built function to cover gap in capacity
- Gas CCGT power plants of specific capacity is added
- The model checks for demand covering, and then makes the addition
- 20-50 MW of capacity for each power plant added
Capital Stock in Energy Economics

- Total amount of a company/ firm’s capital
- Can be economically termed as the ’Wealth’ of an energy system
- ‘Anlage Vermögen’
- Represents the invested capital
- Considers the economic and technical lifetimes of the assets
- Normally used for asset evaluation: Historical cost concept
- Historical cost concept: does not consider replacement values over time
- Leads to an under-evaluation of long term assets
- Highlights preservation of long lasting assets over nominal capital
- Information on investments of each power plant: very difficult to obtain
Gross Capital Stock

- Based on only the replacement values of power plants
- No depreciation is included
- Better measure of asset value than historical acquisition values
- Forms the basis for the net capital stock calculations
Net Capital Stock

- Replacement values for power plants with consideration of depreciation over the life time of the power plant
- Depreciation: decrease in the worth of an asset due to ageing
- Gives an actual and fair measure of the value of the system’s invested capital
- Technical life times and economic life times
- Book keeping: normally with economic life time
- High capital intensity and high technical lifetimes: greater worth
### Technical and Economic lifetimes

<table>
<thead>
<tr>
<th>Power Plant Type</th>
<th>Economical Life Time</th>
<th>Technical Life Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Lignite</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>Gas CCGT</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>Bituminous Coal</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Nuclear BWR</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Nuclear CANDU</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Nuclear Thorium</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Oil</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>PV</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Pumped Storage</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Dam Hydro</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Run of the River Hydro</td>
<td>75</td>
<td>100</td>
</tr>
<tr>
<td>Wind Onshore</td>
<td>25</td>
<td>30</td>
</tr>
</tbody>
</table>

When a power plant has a specific shut down date other than the end of its technical/ economical useful life, the shut down date is considered
Capital Stock intensive planning

Southern Region power plant fleet age, 2030

- Coal
- Run-of-River Hydro
- Dam Hydro
- Pumped storage hydro
- Photovoltaik
- Wind
- Nuclear
- Gas

Years

Installed Capacity (MW)

0-5  6-10  11-15  16-20  21-25  26-30  31-35  36-40  41-45  46-50  51-55  56-60  61-65  66-70  71-75  76-80  81-85  86-90  91-95  96-100  101-105
Capital stock intensive planning

- Focus on Net Capital Stock of the futuristic fleet
- Building more hydro power plant capacity than VRE
- VREs are capital intensive and have shorter life times
- Hydro power plants: Capital intensive and large life times
- Also nuclear power: Capital intensive and relatively larger life times
- Considering Financial challenges
  - Focus on smaller run of river hydro investments
  - Improve nuclear capacity
  - Investments in neighbouring countries with high hydro potential
Historical acquisition values vs Replacement values, (All Regions)

Value of power plant fleet (Net Capital Stock)

Replacement values

Historical Acquisition Values

Karthik Subramanya Bhat, Institut für Elektrizitätswirtschaft und Energieinnovation/TU Graz
16.02.2018
Increase: Gross and Net capital stock in % (all regions)
Results: Gross Capital Stock Regions
Results: Net Capital Stock Regions

Karthik Subramanya Bhat, Institut für Elektrizitätswirtschaft und Energieinnovation/TU Graz
16.02.2018
Results: By technology types, NR

**GROSS CAPITAL STOCK (Bil. EURO)**

- Wind (Offshore)
- Wind (Onshore)
- Speicher
- Solar/PV
- Sonstige
- Pumpspeicher
- Schiefer
- Öl
- Nuklear
- Laufwasser
- Gas
- Kohle
- Biomasse

**NET CAPITAL STOCK (Bil. EURO)**

- Wind (Offshore)
- Wind (Onshore)
- Speicher
- Solar/PV
- Pumpspeicher
- Sonstige
- Schiefer
- Öl
- Nuklear
- Laufwasser
- Gas
- Kohle
- Biomasse
Results: By technology types, SR

GROSS CAPITAL STOCK (Bil. EURO)

- Wind (Offshore)
- Wind (Onshore)
- Speicher
- Solar/PV
- Sonstige
- Pumpspeicher
- Schiefer
- Öl
- Nuklear

NET CAPITAL STOCK (Bil. EURO)

- Wind (Offshore)
- Wind (Onshore)
- Speicher
- Solar/PV
- Sonstige
- Pumpspeicher
- Schiefer
- Öl
Depreciation values

2006
- Wind: 0.4%
- Wasser: 75.0%
- Solar/PV: 13.7%
- Sonstige: 9.6%
- Öl: 0.2%
- Biomasse: 1.0%

2040
- Wind: 17.6%
- Wasser: 75.5%
- Solar/PV: 0.8%
- Sonstige: 3.0%
- Öl: 1.8%
- Biomasse: 1.3%
- Gas: 0.1%
- Kohle: 9.6%
Investment over the years

Net Investments

Millionen [EUR]

RES
Konventionelle

Karthik Subramanya Bhat, Institut für Elektrizitätswirtschaft und Energieinnovation/TU Graz
16.02.2018
Power plant age 2050

Graph showing the age distribution of power plants in 2050, with a breakdown of energy generation by technology.
Best Case Scenarios

- **Renewable transition**
  - Nuclear + Hydro
  - Hydro + Renewables

- **Traditional Market**
  - Coal + Gas

- **Liberalized Market**
  - Coal + Hydro

- **BAU - Coal Traditional**
Conclusions

- Transition towards carbon free energy: Possible goal
- Focus on technologies with high capital and large lifetimes
- Increase of hydro power capacity and nuclear capacity
- Longer life times: Inter-generational benefits from investments
- Small run of river hydro power plants must be encouraged
- Blind investments in PV and Wind: Shorter lifetimes, could lead to asset stranding
- Avoid short term visions: think long term sustainability
Danke für Ihre Aufmerksamkeit!