Costs of Different Plants
Generators have different cost profiles

- Capital cost for an incremental plant
  - What is the efficient scale for a new plant?
- Heat rate, which determines variable costs
- O&M: fixed and variable
- Marginal cost
- Efficient duty cycle
  - What is an efficient average capacity factor?
  - Can the plant adjust output rapidly or should it run at a steady output?
  - What are the minimum and maximum efficient output rates?
Different kinds of plants

• Fossil fuel central station: baseload
• Hydro: run of river or dispatchable
• Renewable: run when available
• Peaker: run at high demand
• Backup generators (private, does not feed grid): high capital cost per KW of capacity, high variable costs [behind the meter generally]
• Coming up: distributed solar with battery backup
Fossil fuel baseload

• Coal, NGCC, Nuclear
• High initial capital costs:
  • The minimum efficient scale is quite large
• Low variable cost (low heat rate)
• High expected capacity factor
• Dispatchable: we can choose when to run them
• Some can adjust faster than others
  • Coal and nuclear are slow, NGCC pretty quick
Peaking units

- Combustion turbines, diesel generators, (batteries?)
- Low initial capital cost
  - Efficient scale is small
- High variable cost
  - The heat rate is high, so variable costs are high
- Usually, low expected capacity factor, say 30% or less
- Adjust very quickly to follow load
Hydro

• Very high initial capital cost; very low O&M costs
• Zero variable cost
  • But there is an opportunity cost of using water now
  • It may be more valuable later
• Capacity factor variable
  • Some can ramp up and down to follow load
  • Some are “run-of-river”
• A kind of energy storage
Non-hydro renewables

• Initial capital cost varies according to scale
  • Minimum efficient scale can be quite low
• Very low O&M cost
• Zero variable and marginal cost
• Low and somewhat unpredictable capacity factor
• Use when available
  • Not dispatchable – can’t be called upon to follow load
  • You don’t choose when it is available
  • But may be able to match some loads, ex. Irrigation
  • Cheap batteries will make a big difference
Backup generators
(captive generating capacity)

• High capital cost per kW of capacity
• Very high variable costs
• Very low capacity factor
• Behind the meter
  • Not part of grid capacity
• Approx. 50 GW of capacity in India
Demand scheduling: a kind of capacity

- Some demand may be adjusted to available supply
  - Irrigation, EVs, storage, etc.
- Involuntary load shedding or
- Demand reduction:
  - Contracts with customers to reduce load
  - Voluntary load shedding at a price
- Low capital cost
- Marginal cost varies a lot, but there may be large reserves at relatively low cost
Storage: the next big thing

• Storage is a kind of supply
  • But may be in the form of short term demand reduction
  • Daily balancing
• Can be large scale or small
• Can follow load (up to a point)
• Costs are falling rapidly
• Can substitute for transmission infrastructure
Distributed renewables with batteries

- Costs are falling very fast
- Can provide some grid services
  - May be used to lower costs of service
- But can result in mass defections from the grid
  - Puts a limit on what tariffs can be charged
  - Those who pay high tariffs are in a better position to self finance
Four examples

- A large, baseload fossil fuel power station
- A small peaker plant, say a combustion turbine or diesel generator
- A solar project
- Load reduction
  - Load shedding, demand reduction or private “behind-the-meter” generation
Common elements

• Market interest rate is 7% annually
• Term of loan is 30 years (360 months)
• A month is assumed to have 720 hours
• Fossil fuel cost is $2.50 per million Btu
• For combustion plants, the heat rate is assumed constant for any capacity factor
• Each type of plant has a preferred capacity factor
Plant 1: Big fossil

- We will use our earlier example:
  - Plant: 500 mW capacity
  - “Overnight” cost: $320,000,000
    - Fixed monthly payment: $2,129,000
  - Heat rate: 9 million Btu/MWh
  - Preferred capacity factor: 80%
  - Marginal cost is the fuel cost per MWh: $22.50
  - Each 1% of capacity generates 3,600 MWh of electricity
  - LCOE (long run average total cost): $29.90
Plant 1: Big fossil

Cost profile: Baseload

![Graph showing cost profile and ATC and MC (AVC)]
Plant 2: Fast peaker

- Plant: 15 MW capacity
- “Overnight” cost: $5,000,000
  - Fixed monthly payment: $33,265
- Heat rate: 15 million Btu/MWh
- Preferred capacity factor: 30%
- Marginal cost is the fuel cost per MWh: $37.50
- Each 1% of capacity generates 108 MWh of electricity
- LCOE (long run average total cost): $47.90
Plant 2: Fast peaker

Cost profile: Peaker

Dollars per mWh

Capacity factor
Plant 3: Standard solar

- Plant: 100 MW capacity
- “Overnight” cost: $100,000,000
  - Fixed monthly payment: $665,302
- Heat rate: 0 million Btu/MWh <- no fuel required
- Preferred capacity factor: 25%
- Marginal cost is the fuel cost per MWh: $0
- Each 1% of capacity generates 720 MWh of electricity
- LCOE (long run average total cost): $37.0
Plant 3: Standard solar

Cost profile: Solar

Dollars per mWh versus Capacity factor

ATC
MC (AVC)

0
25
50
75
100
Plant 4: Demand response

• Demand response is a special kind of plant
  • We will assume zero capital cost (for simplicity)
  • Example: large consumers running backup generators
  • There is just a flat fee per MWh reduced: $80/MWh
• While load shedding does not have an explicit price, we assume that it is costly to discoms
  • Customer unhappiness
  • Political feedback
Different Marginal costs

Marginal cost of different options

- **Demand reduction**
- **Baseload**
- **Peaker**
- **Solar**

Dollars per mWh vs. Capacity factor
Different average costs and LCOE

Average total costs and LCOE

- Baseload
- Peaker
- Solar

Dollars per mWh vs. Capacity factor
Three plants compared

Average total cost and marginal cost

<table>
<thead>
<tr>
<th>Baseload</th>
<th>Peaker</th>
<th>Solar</th>
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- **Dollars per mWh**

- **Capacity factor**

- X-axis: Capacity factor
- Y-axis: Dollars per mWh
Putting it all together

• Now, we have the marginal and long-run average costs for four different ways of addressing electricity demand

• The next picture shows the cost of 100 MWh increments from each of our plant types (including demand reduction)
Another view of all four options

Marginal cost and LCOE of capacity

MegaWatts

Marginal cost

Solar  Baseload  Peaker  Demand reduction