# Economics for Wholesale Electricity Markets

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# Costs of Different Plants

Module 3

# 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

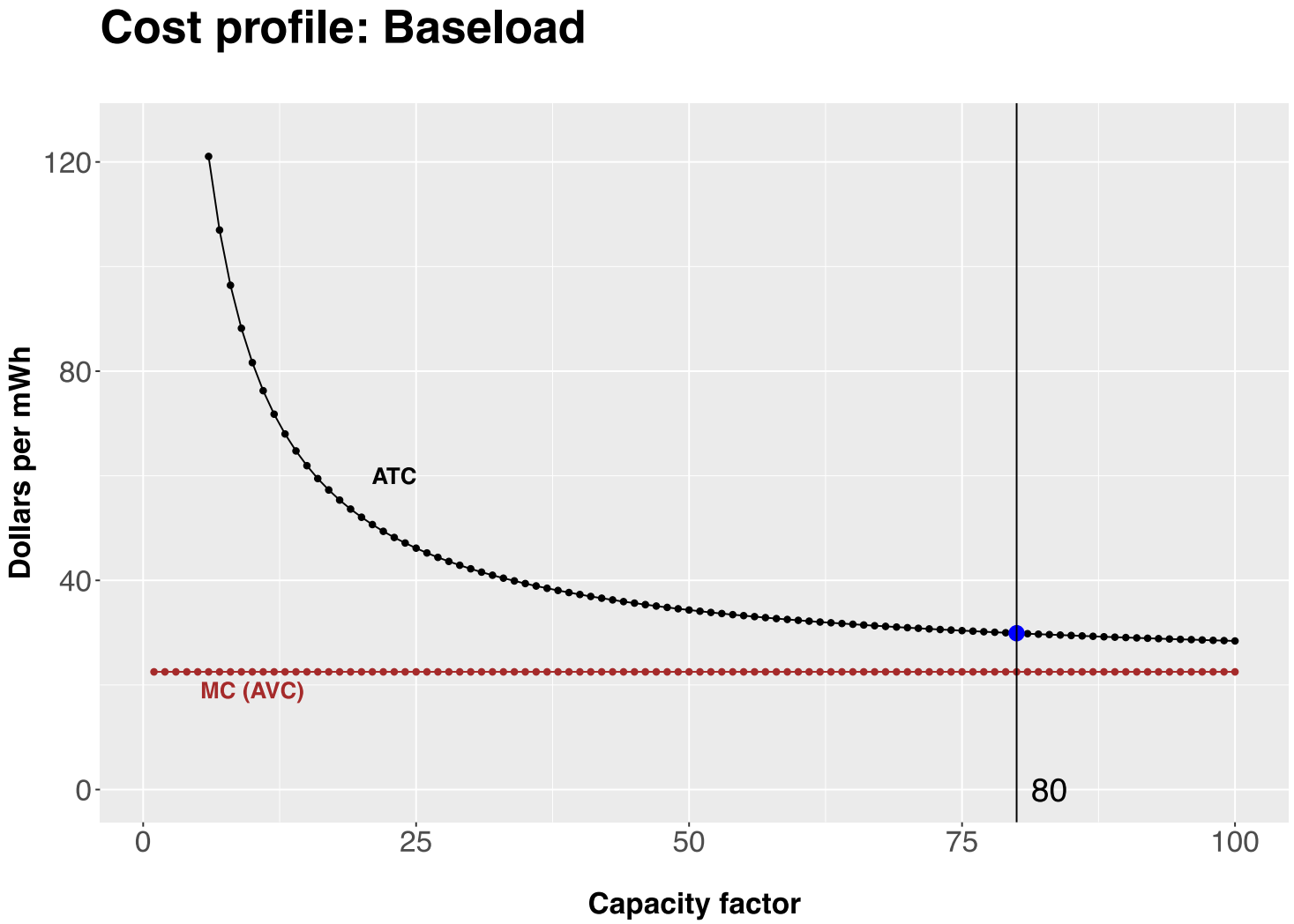
# Common elements

- 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

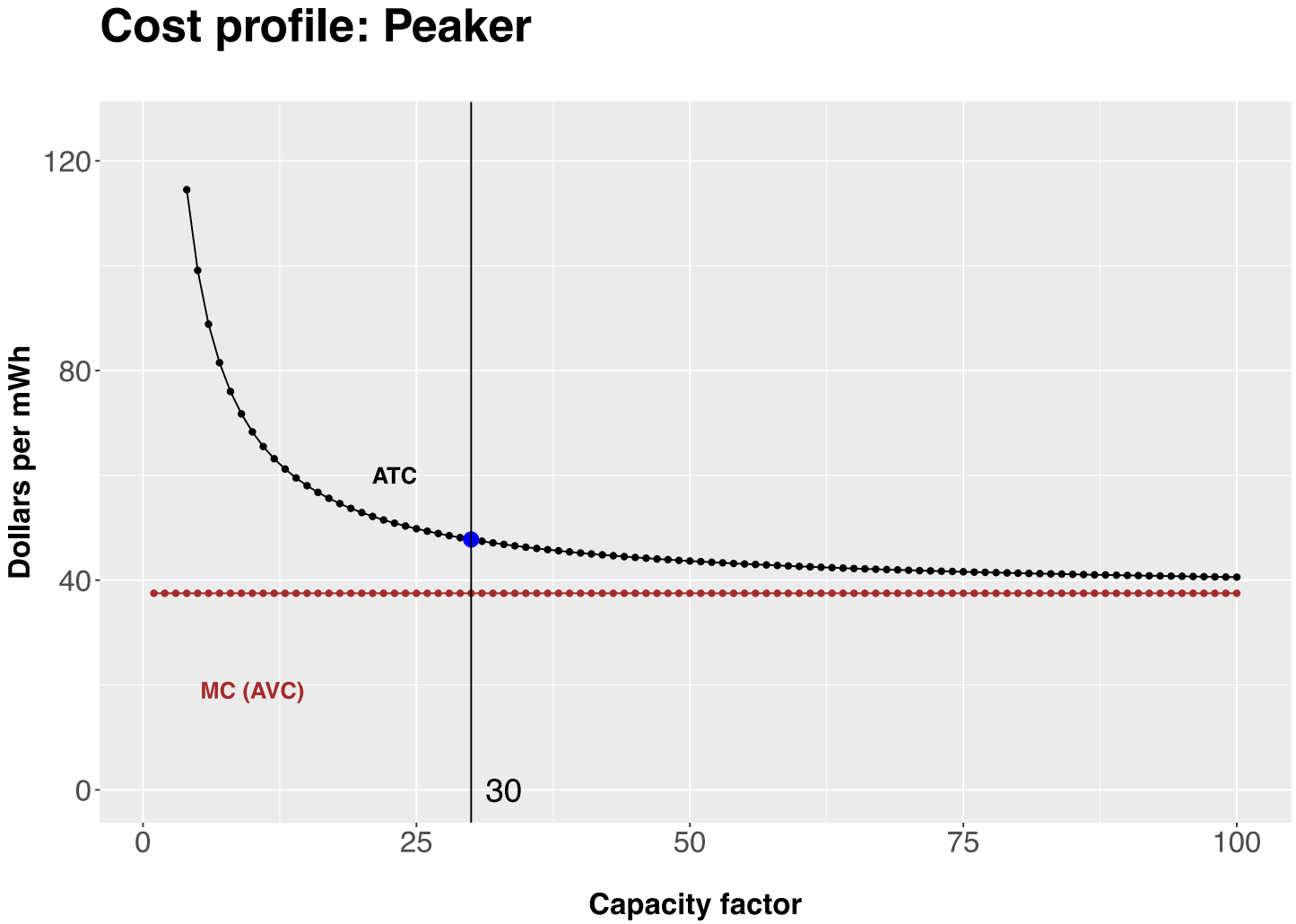
# Plant 1: Big fossil



# 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

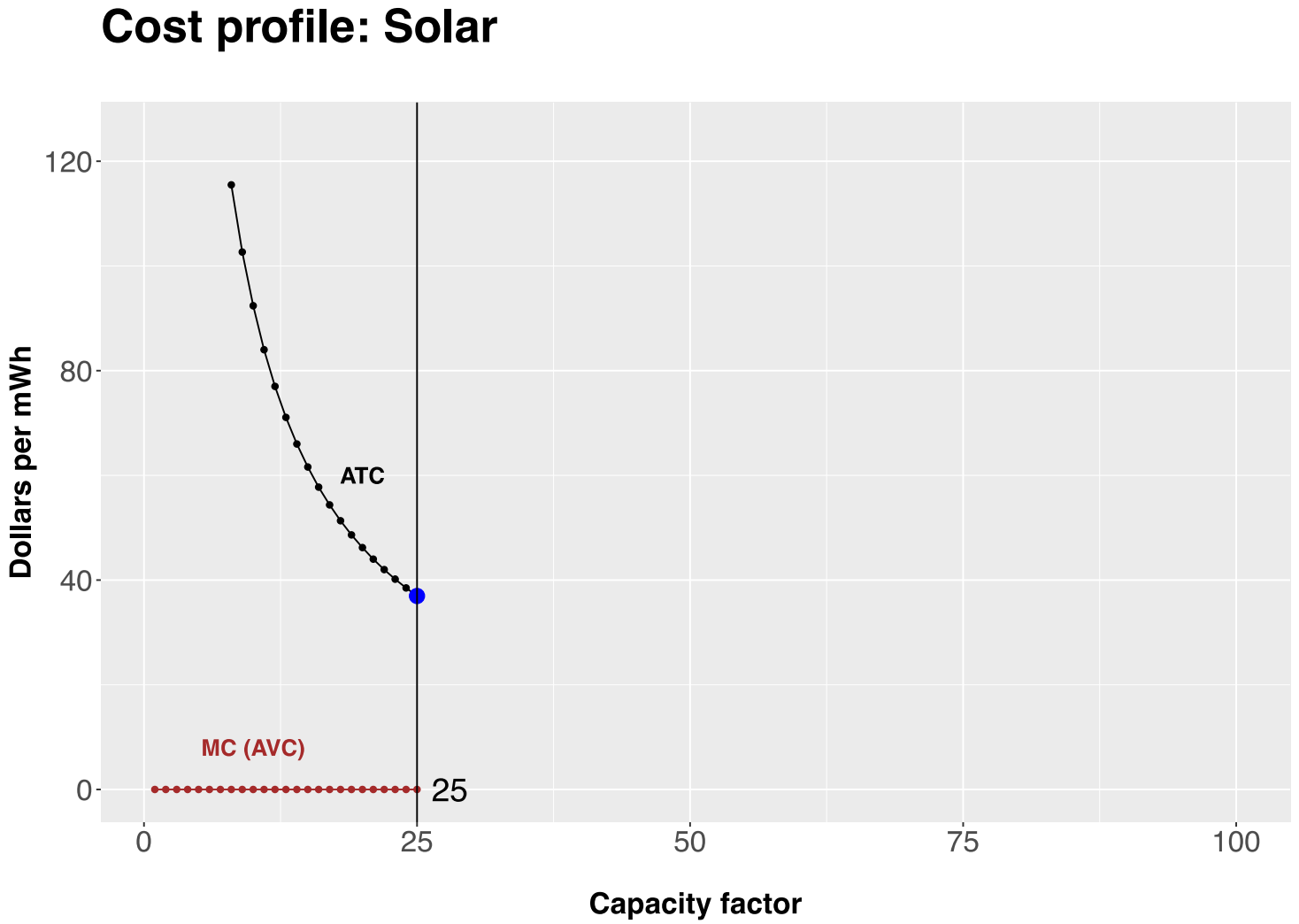
# Plant 2: Fast peaker



# 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

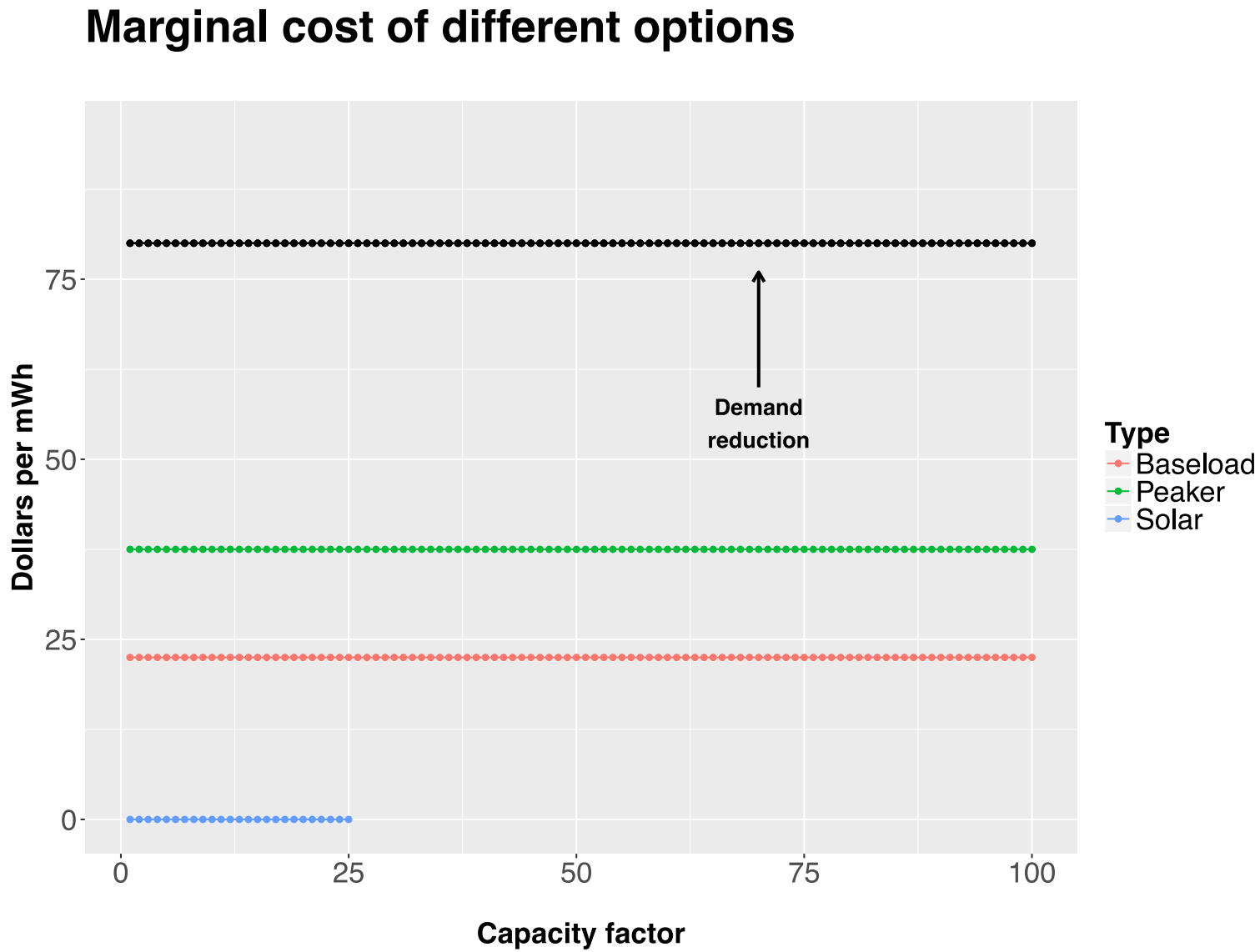
# Plant 3: Standard solar



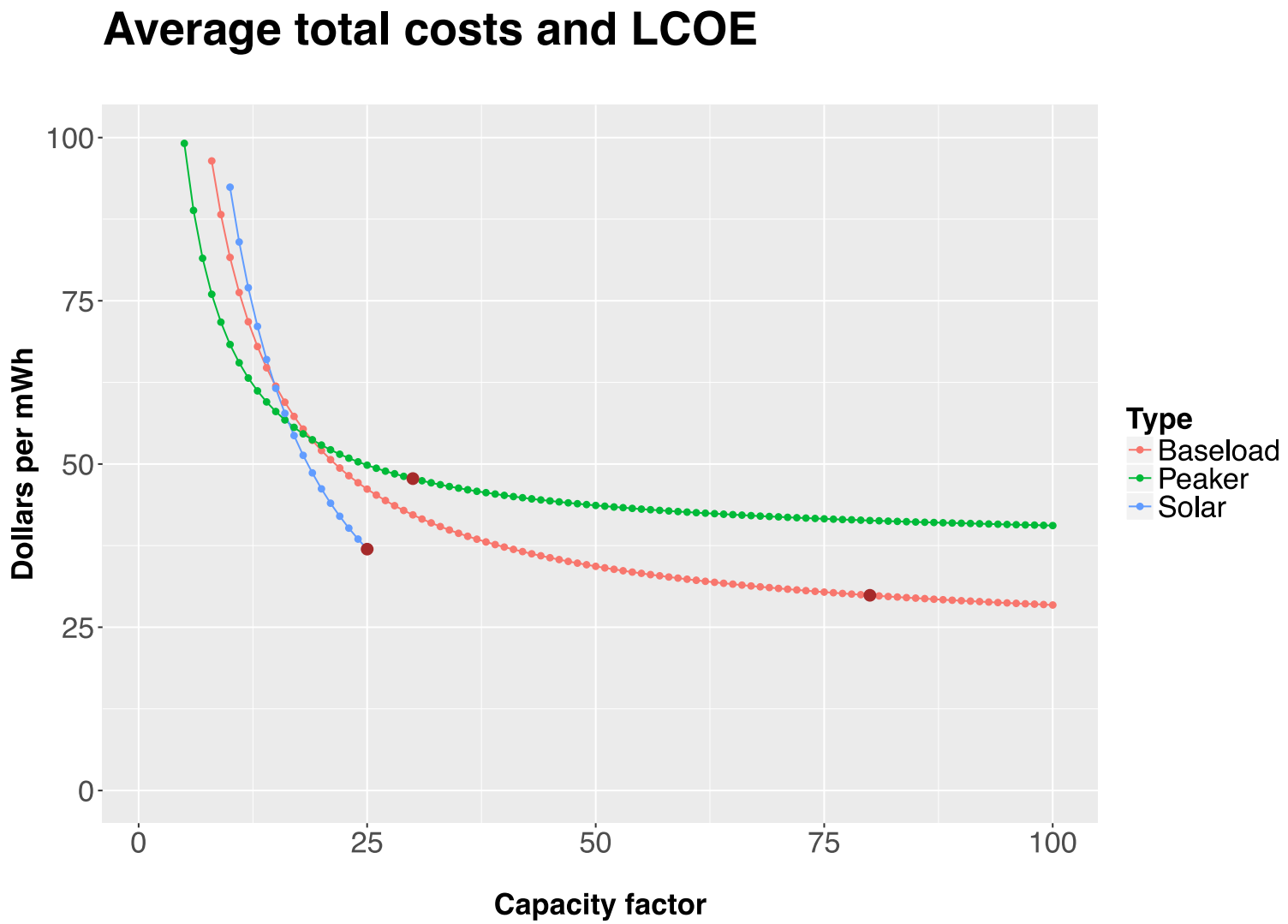
# Plant 4: Demand response

- 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

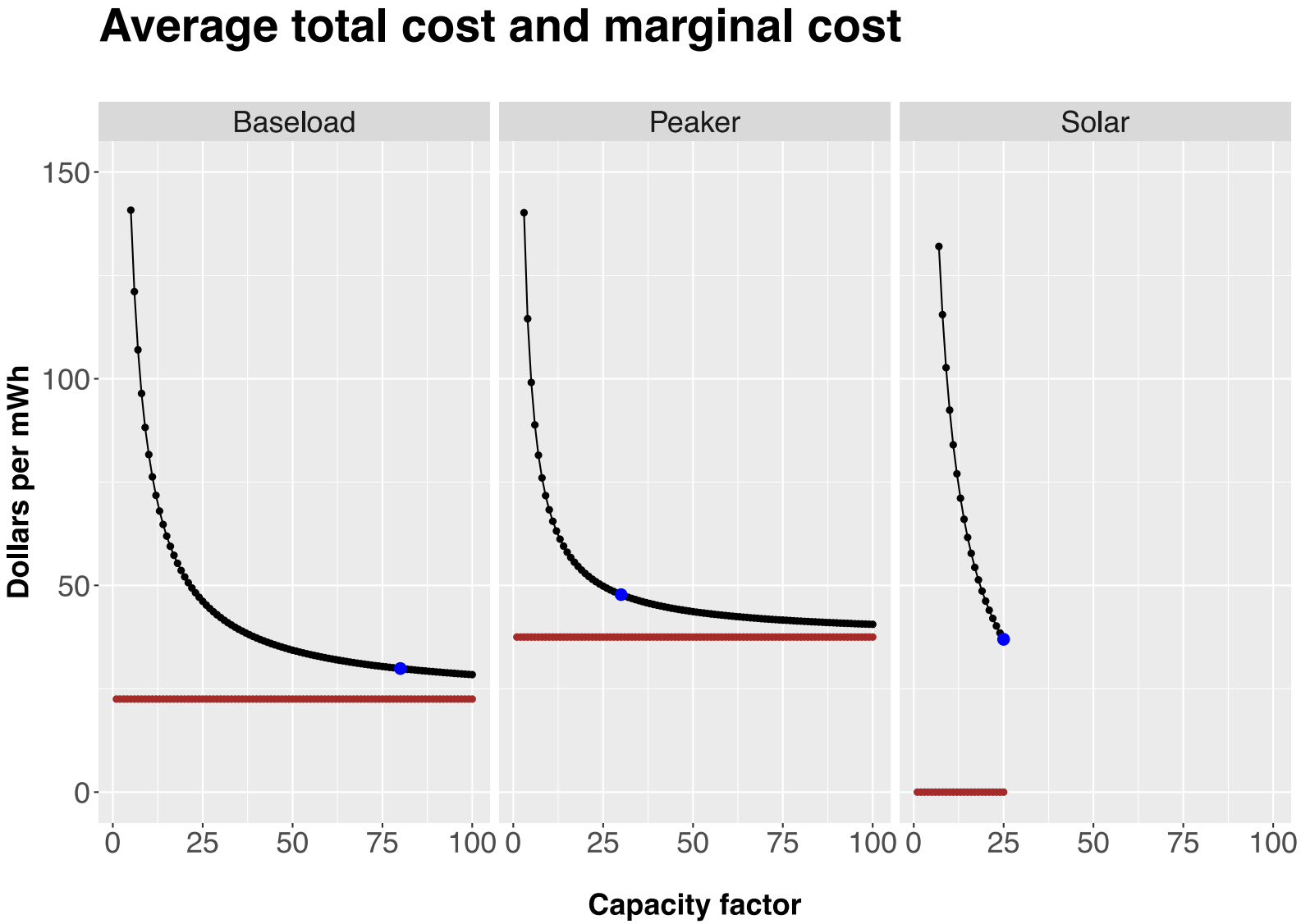
# Different Marginal costs



# Different average costs and LCOE



# Three plants compared



# 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