Lost Opportunity Cost: Ancillary Services

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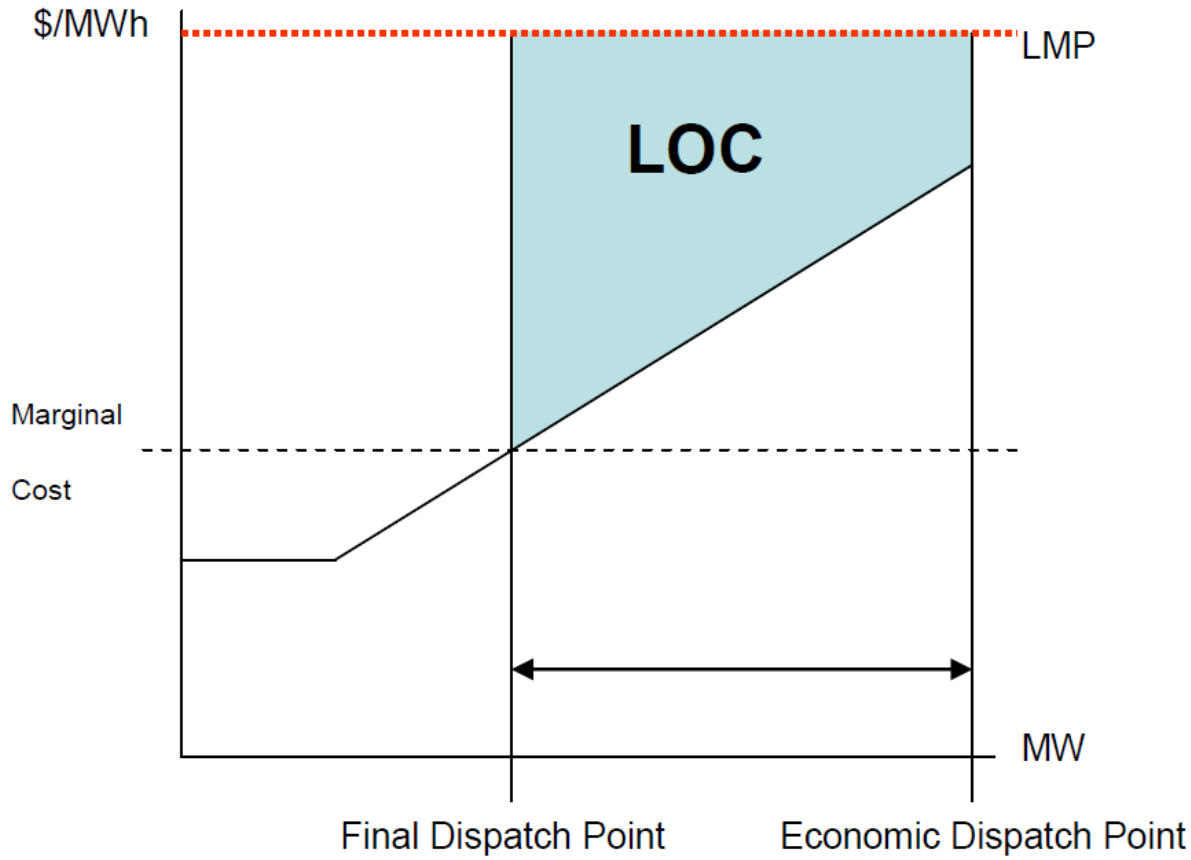
Energy & Ancillary Services

- Resources can participate in the PJM Energy Market through the Day Ahead, Real-Time and/or Ancillary Services market
- PJM jointly optimizes energy and reserves (synchronized and non-synchronized)
- Energy and reserve MWs are substitute products
  - MWs used to serve energy cannot simultaneously be used to provide reserves

Incentive Compatibility

- Generation resources forgo energy market revenues when providing MWs for reserves
- Energy and reserve payments must be incentive compatible with dispatch instructions
  - All payments must make the marginal reserve supplier indifferent between providing reserves and energy

Lost Opportunity Cost in Ancillary Services



Lost opportunity cost is the forgone energy revenues incurred by a generation resource that provides a PJM required ancillary service

Example: Synchronized Reserves

- Energy and Reserve MW and Prices are jointly determined
  - Objective: minimize total production costs subject to system conditions, resource operating parameters and reserve requirement constraint
- Energy assignments are merit ordered
  - Resources with the lowest $/MWh offers are assigned first
  - The marginal energy supplier sets the energy price
- Reserve assignments are merit ordered
  - Resources with the lowest lost opportunity costs are assigned first
  - The marginal reserve supplier sets the reserve price

Example: Merit Ordered Lost Opportunity Cost

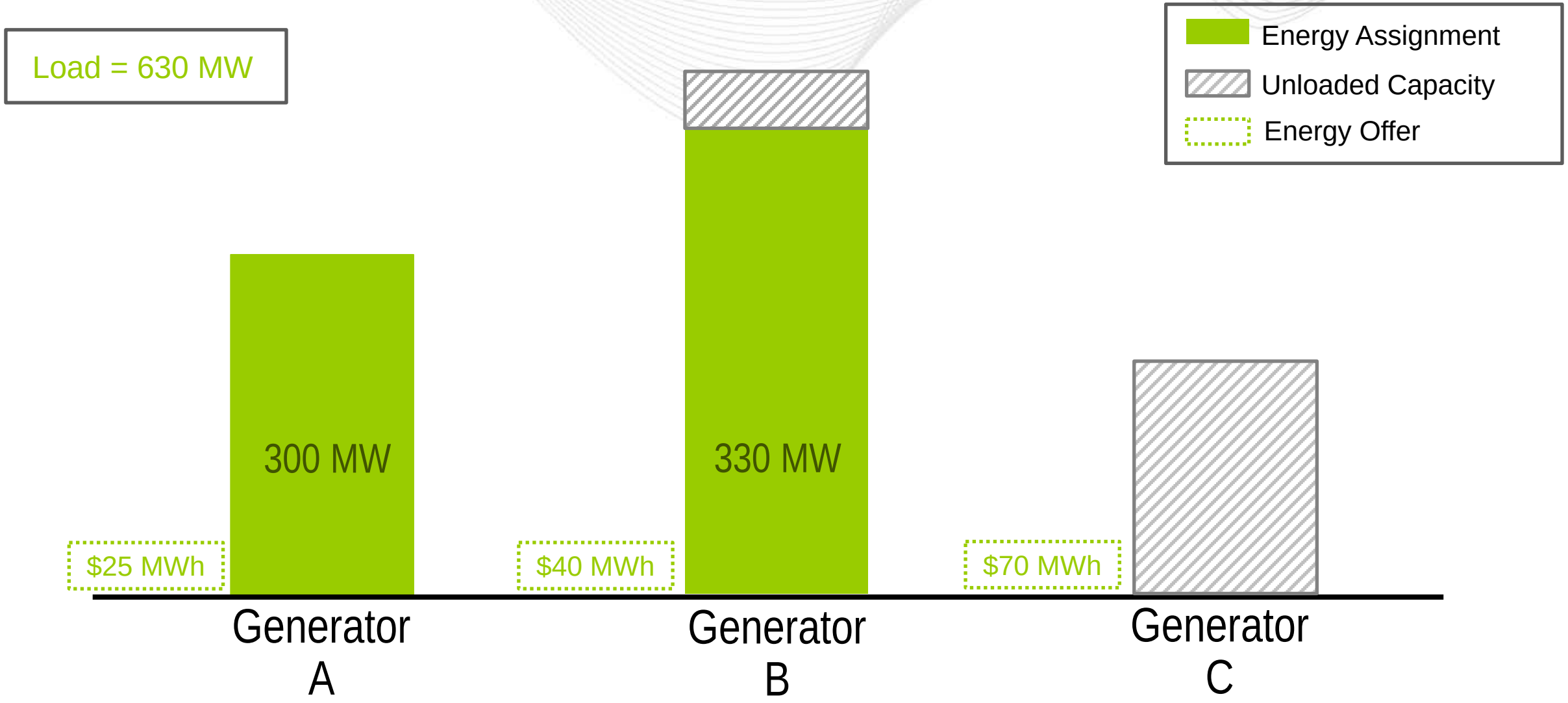
- Lost Opportunity Cost = LMP – Marginal Cost
- Holding LMP constant, lost opportunity cost decreases as marginal cost increases
- The most expensive resources for energy will have the lowest lost opportunity cost
  - Merit ordered reserve assignment dictates that these resources will be assigned first in the reserve market

Example: Generator Offers

Generator	Energy Offer ($/MWh)	Generator Capacity (MW)	Reserve Capability (MW)
A	$25	300	80
B	$40	400	100
C	$70	200	120

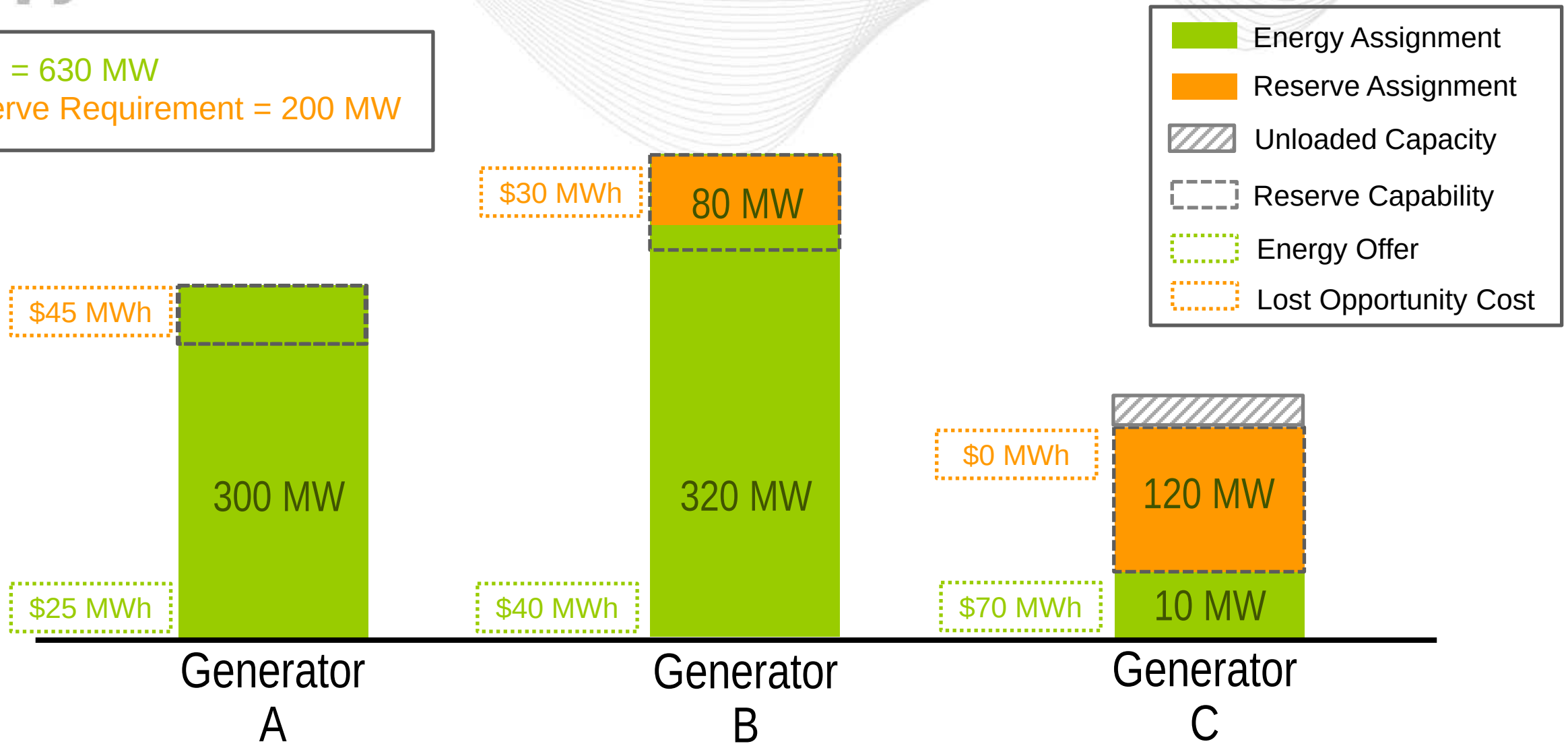
For simplicity, assume that reserve bids are zero

Example: Energy Assignments – No Reserve Constraint



Energy & Reserve Assignments w/Reserve Constraint

Load = 630 MW
Reserve Requirement = 200 MW



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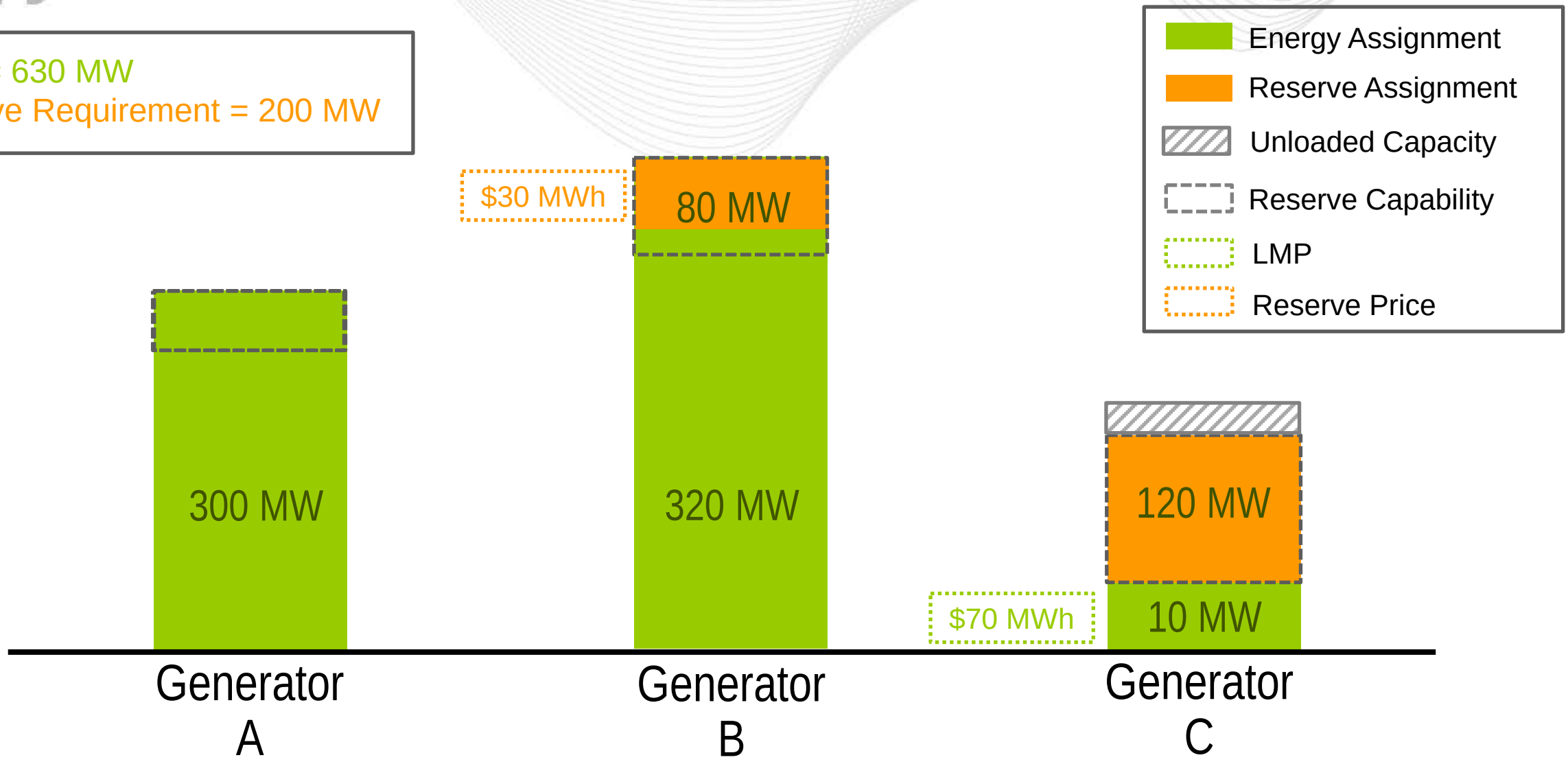


Example: Lost Opportunity Cost is Incentive Compatible

Generator B Offer and Assignments	
Energy Price (LMP)	$70
Reserve Price (LOC)	$30
Energy Offer	$40
Reserve Offer	$0
Generator Capacity	400 MW
Assigned Energy	320 MW
Assigned Reserve	80 MW

Energy Market Net Revenues at Economic Dispatch Point

LMP	MW	Offer	Revenues	Costs	Net Revenues
$70	400	$40	$28,000	$16,000	$12,000

Energy Market Net Revenues at Final Dispatch Point

LMP	MW	Offer	Revenues	Costs	Net Revenues
$70	320	$40	$22,400	$12,800	$9,600

Forgone energy net revenues to provide reserves: $2,400

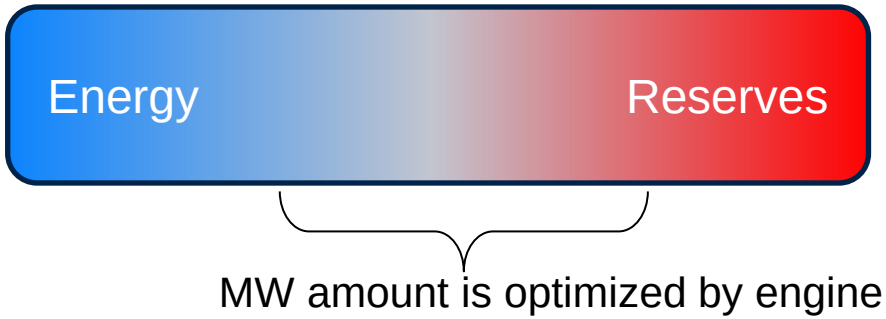
Reserve Market Net Revenues

LOC	MW	Offer	Revenues	Costs	Net Revenues
$30	80	$0	$2,400	$0	$2,400

Reserve market net revenues are exactly equal to the forgone energy market net revenues - thus the marginal reserve supplier is neutral between supplying reserves or energy

Unit vs. Demand Resource Offers

- Unit
  - Energy and reserve optimized by market clearing engine
  - LOC for revenue foregone in the energy market



- Demand Resource
  - Energy and reserve MW allocation specified by participant
  - **No LOC because no product substitution**