Real-Time LMP and Impacts on Uplift

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Locational Marginal Price

LMP = System Energy Price + Transmission Congestion Cost + Cost of Marginal Losses

- What is included in the LMP?
  - System Energy Price
  - Transmission Congestion Cost(s)
  - Cost of Marginal Losses
  - Effect of Reserve Shortages

- What is not included in the LMP?
  - For resources not on the margin, any difference between the LMP and the resource's marginal cost where LMP < marginal cost
  - For manually dispatched units, any lost opportunity between LMP and the marginal cost of the resource’s dispatch point where LMP > marginal cost
  - Generator start up and no load costs
  - DR Shutdown cost

- There will always be at least one marginal resource
  - System Energy Resource
- Additional marginal resources for each binding transmission constraint
- In most cases, there are multiple marginal resources for a given time interval

Resources Eligible to Set Price

- Online generators dispatchable by PJM
- Dispatchable Transactions following PJM’s dispatch instructions
- Economic Demand Response
- Price Responsive Demand
- Emergency Demand Response
- Emergency Import Transactions
- Generation from emergency segments of units already on-line and operating in the real-time energy market

Resources Not Eligible to Set Price

- Manually dispatched generators
- Units that have the Fixed Gen flag selected in the Market Unit Hourly tab in Markets Gateway
- Must Run units
- Units that are in start up or shut down mode
- Units that are condensing

When is a Resource Marginal?

- A resource is marginal when it supplies the next MW of generation or demand reduction to meet load or control a transmission constraint
  - System conditions heavily influence where that next MW is needed from the supply stack
    - Weather
    - Interchange
    - Accuracy of the load forecast

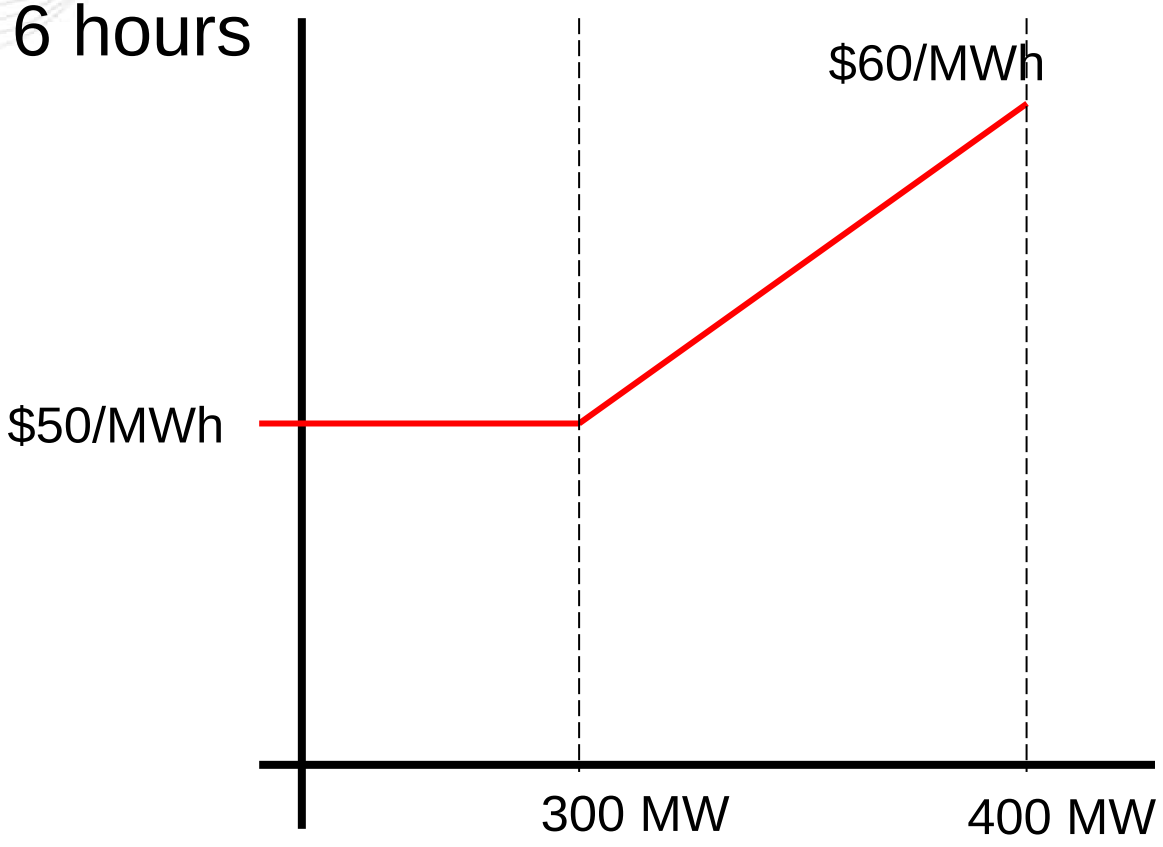
Why Wasn't My Resource Marginal?

- Artificial dispatchable range for Inflexible resources
  - CTs
  - Emergency Demand Response
- Generator runs to control a transmission constraint that never binds
- Imports have the ability to suppress the price when they are not needed

- Minimum Run Time
- Unit Setting LMP
  - Startup/No-Load Cost
- Multi-Unit Dispatch Example

Generator Information

- Name = Pebble Beach 1
- Start/Notification (Lead) Time = 6 hours
- Min Run Time = 4 hours
- Min = 300 MW
- Max = 400 MW
- Offer Price =
  - 300 MW @ $50/MWh
  - 400 MW @ $60/MWh
- Startup Cost = $10,000
- No-Load = $2,000/hr



Formulas

- LMP Credits = MW * LMP
- Offer Curve = price interpolated from offer Curve at MW point
- Offer Cost = area under offer curve at MW point
- Amortized Startup = Startup cost / run-time
  - $10,000 / 4hrs = $2,500/hr
- Total Cost = Offer Cost + Amortized Startup + No-Load
- Hourly Net = LMP Credits – Total Cost
  - Negative if running at a loss for the hour

HE	10	11	12	13	14	15
MW	0	400	400	300	300	0
LMP ($/MWh)	30	65	75	20	25	35
LMP Credits ($/MWh)	0	26,000	30,000	6,000	7,500	0
Offer Curve ($/MWh)	0	60	60	50	50	0
Offer Cost ($)	0	20,500	20,500	15,000	15,000	0
Amortized Startup ($)	0	2,500	2,500	2,500	2,500	0
No Load ($/hr)	0	2,000	2,000	2,000	2,000	0
Total Cost ($)	0	25,000	25,000	19,500	19,500	0
Hourly Net ($)	0	$1,000	$5,000	**($13,500)**	**($12,000)**	0

Example Details

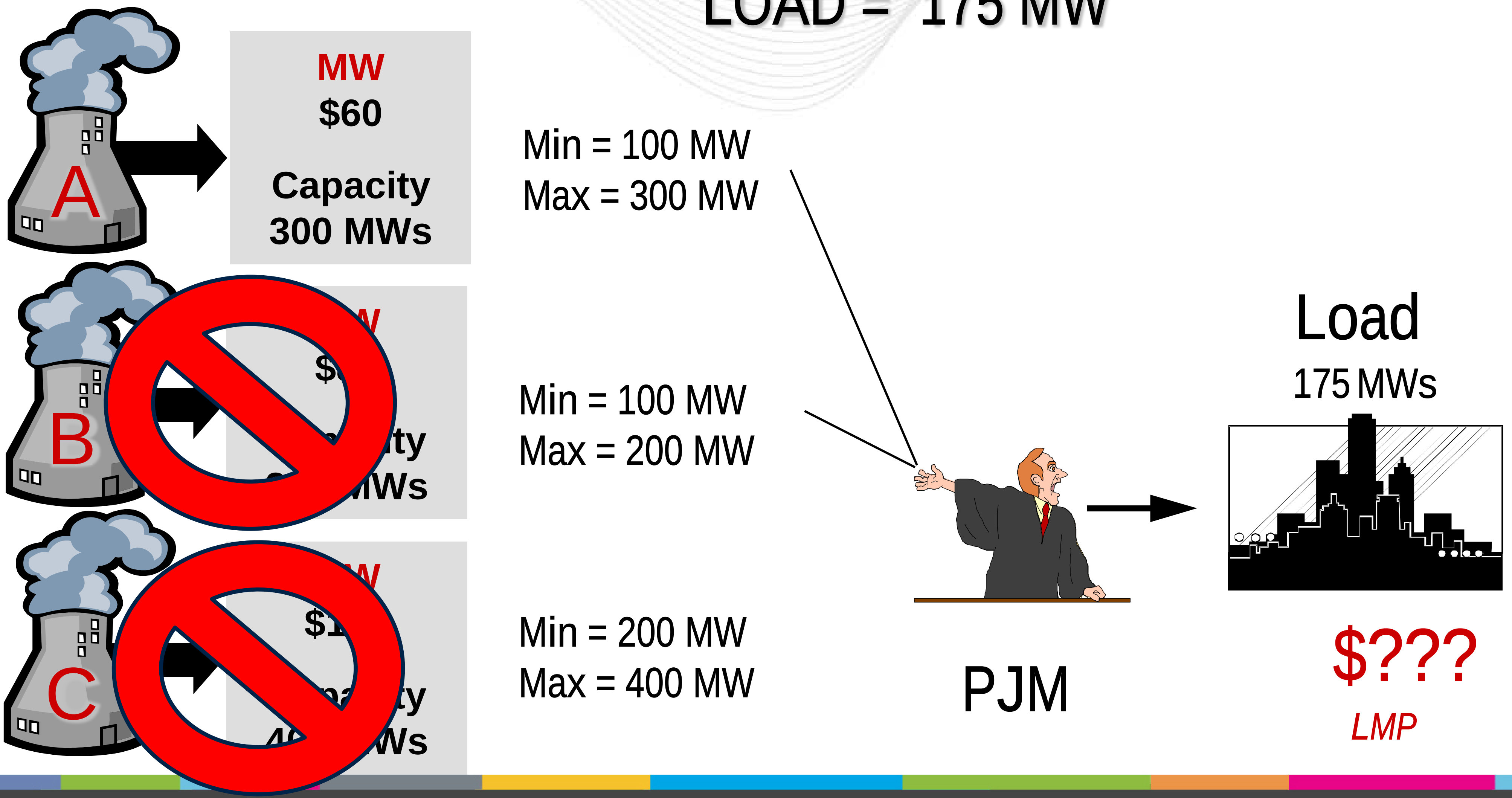
- Unit running in real-time at PJM direction
- No other credits accrued during operating day
- Unit following dispatch
- Unit operating at a loss for the day
  - Sum of “Hourly Net” row is **($19,500)**
  - Unit would be paid BOR in this case
- Allocation would depend on BORCA chart

HE	10	11	12	13	14	15
MW	0	320	330	390	310	0
LMP ($/MWh)	30	**52**	**53**	**59**	**51**	35
LMP Credits ($/MWh)	0	16,640	17,490	23,010	15,810	0
Offer Curve ($/MWh)	0	**52**	**53**	**59**	**51**	0
Offer Cost ($)	0	16,020	16,545	19,905	15,505	0
Amortized Startup ($)	0	2,500	2,500	2,500	2,500	0
No Load ($/hr)	0	2,000	2,000	2,000	2,000	0
Total Cost ($)	0	20,520	21,045	24,405	20,005	0
Hourly Net ($)	0	**($3,880)**	**($3,555)**	**($1,395)**	**($4,195)**	0

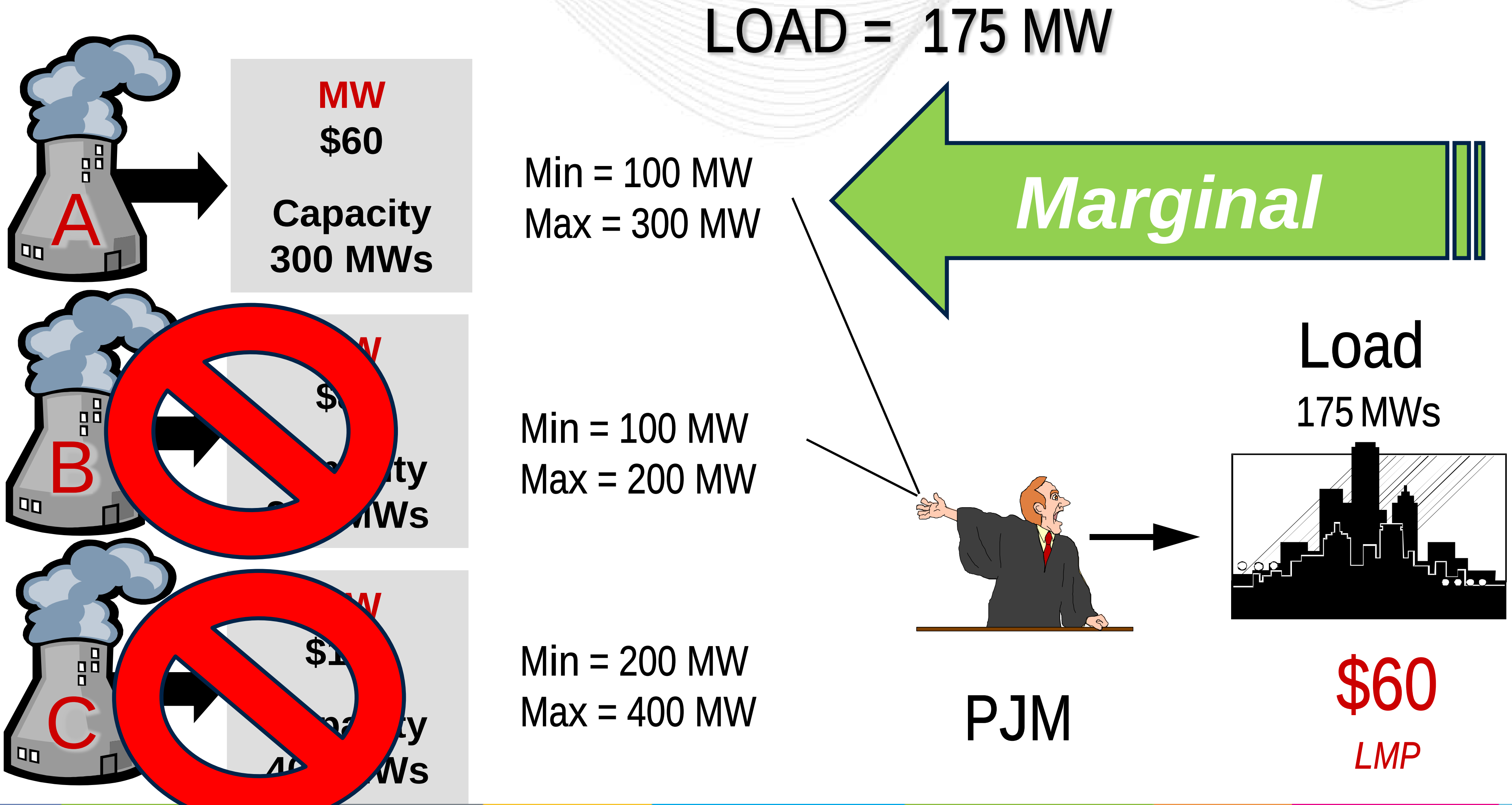
Example Details

- Unit running in real-time at PJM direction
- No other credits accrued during operating day
- Unit following dispatch
- Unit is marginal for its entire run period
  - LMP only covers marginal costs of the unit
  - Startup and no load require a make whole
  - Sum of “Hourly Net” row is **($13,025)**
  - Unit would be paid BOR in this case
- Allocation would depend on BORCA chart

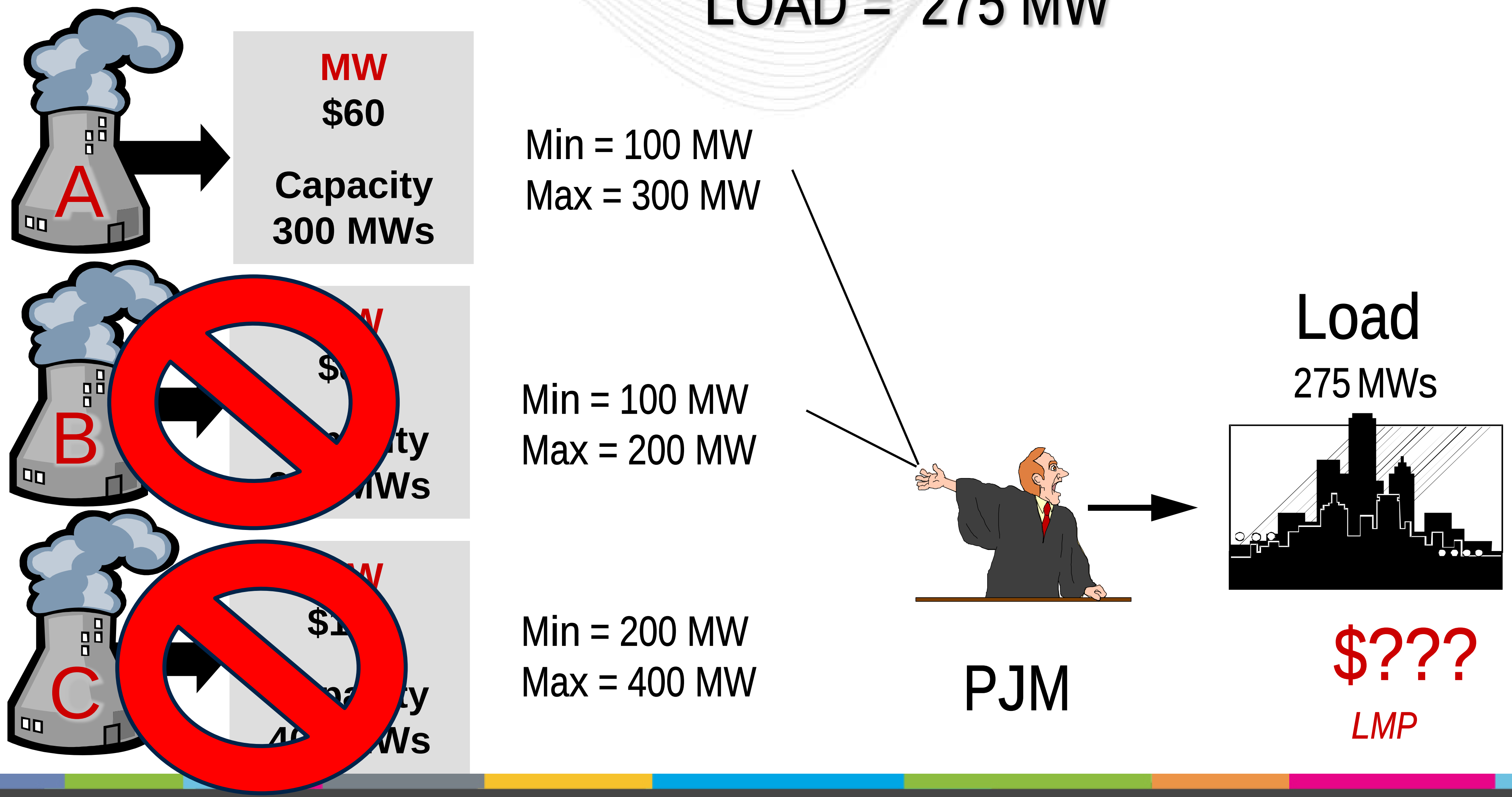
LOAD = 175 MW


A
MW
$60
Capacity
300 MWs
B
C
Min = 100 MW
Max = 300 MW
Min = 100 MW
Max = 200 MW
Min = 200 MW
Max = 400 MW
PJM
Load
175 MWs
$???
LMP

Economic Dispatch and LMP

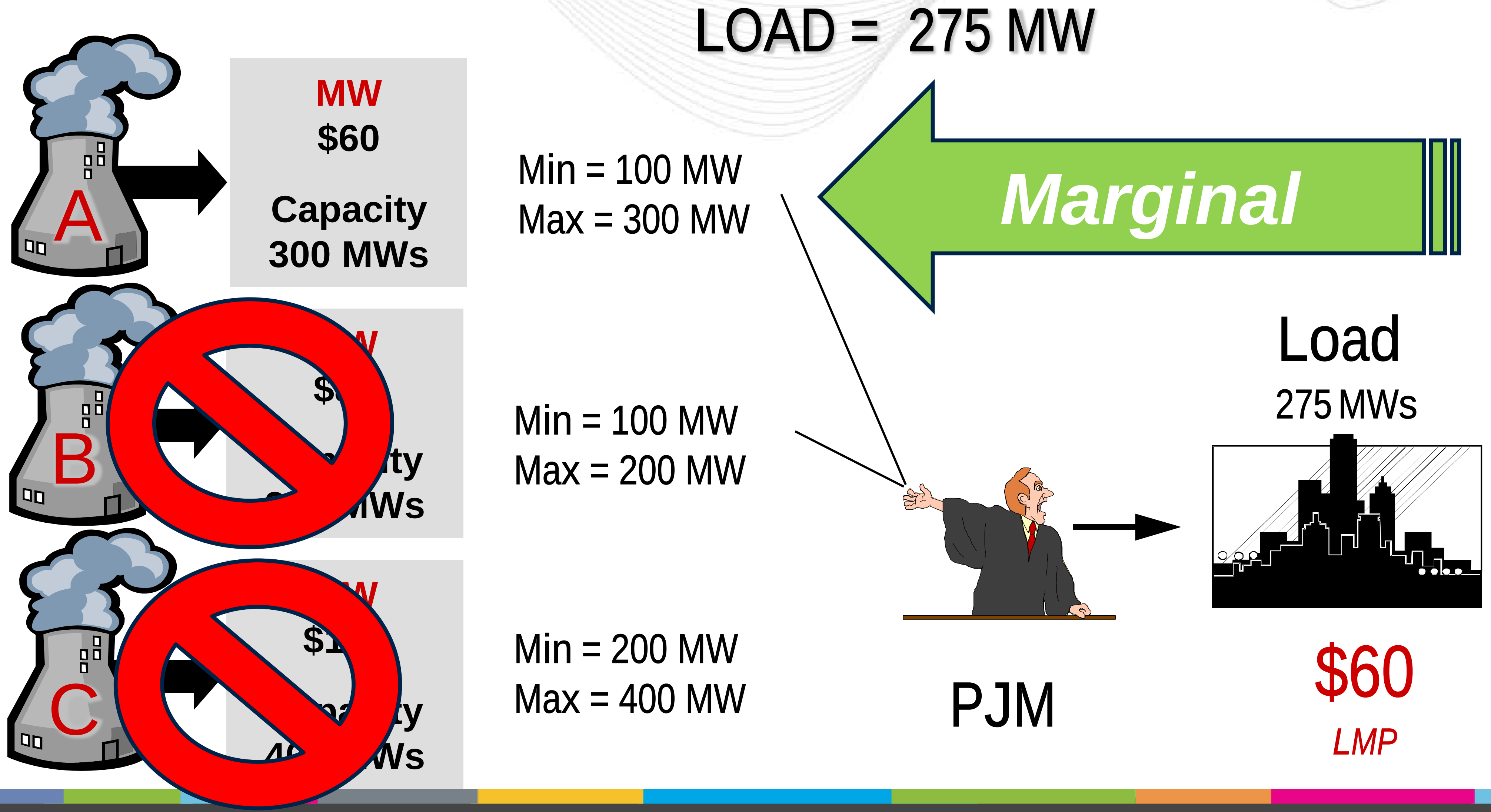


LOAD = 275 MW

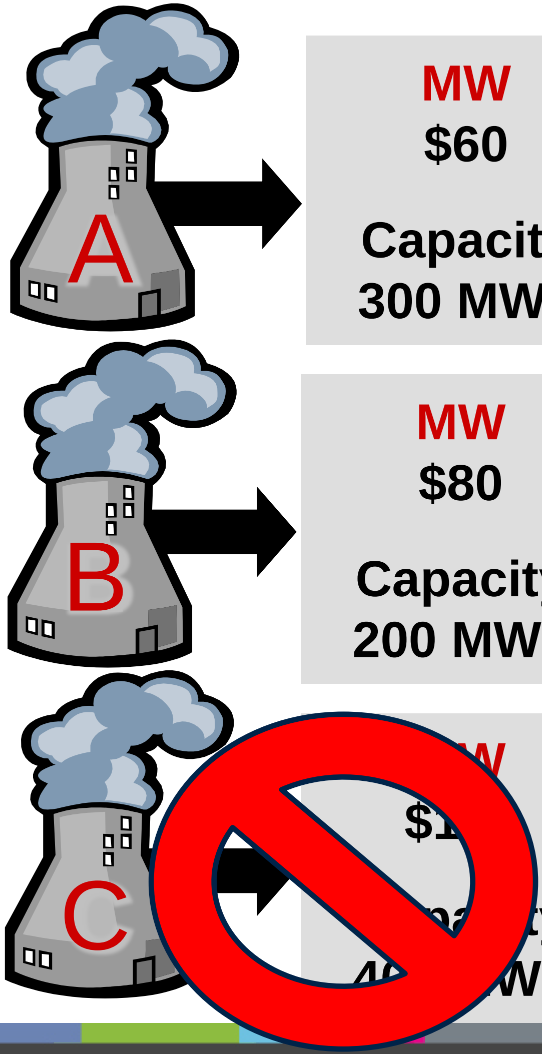


MW
$60
Capacity
300 MWs
A
B
C
Min = 100 MW
Max = 300 MW
Min = 100 MW
Max = 200 MW
Min = 200 MW
Max = 400 MW
PJM
Load
275 MWs
$???
LMP

Economic Dispatch and LMP



LOAD = 350 MW



MW
$60

**Capacity
300 MWs**

Min = 100 MW
Max = 300 MW
MW = ?

MW
$80

**Capacity
200 MWs**

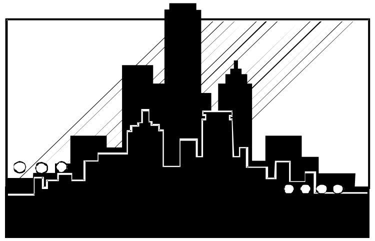
Min = 100 MW
Max = 200 MW
MW = ?

$1

Min = 200 MW
Max = 400 MW

PJM

Load
350 MWs



$???
LMP

LOAD = 350 MW

A

MW
$60

Capacity
300 MWs

Min = 100 MW
Max = 300 MW
MW = 250 MW

B

MW
$80

Capacity
200 MWs

Min = 100 MW
Max = 200 MW
MW = 100 MW

C

Min = 200 MW
Max = 400 MW

Marginal

Load
350 MWs

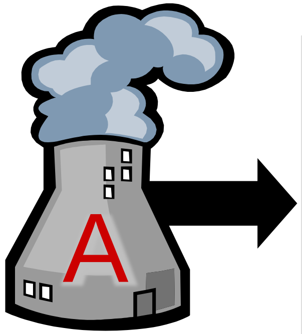
PJM

$ 60
LMP

Explanation

- Generators A and B must be running to meet a load level of 350 MW
- Generator A must be reduced to accommodate the 100 MW min of Generator B
- Because Generator A has 50 MW of room left, and is the cheapest option to service the next MW, **Generator A is marginal**

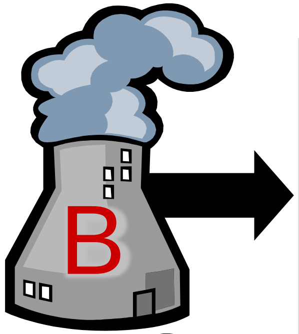
LOAD = 550 MW



MW
$60

Capacity 300 MWs

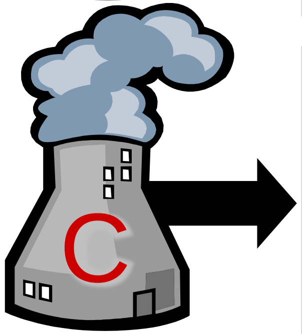
Min = 100 MW
Max = 300 MW
MW = ?



MW
$80

Capacity 200 MWs

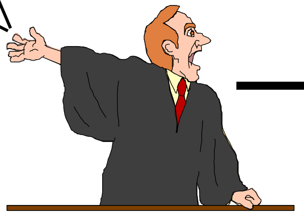
Min = 100 MW
Max = 200 MW
MW = ?



MW
$100

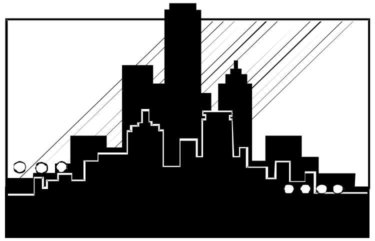
Capacity 400 MWs

Min = 200 MW
Max = 400 MW
MW = ?



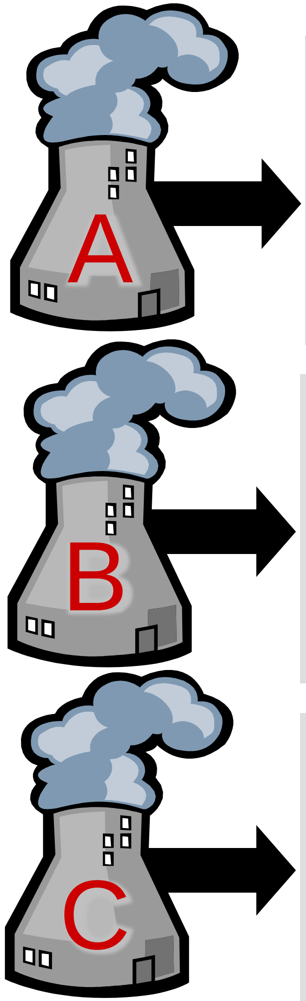
PJM

Load
550 MWs



$???
LMP

LOAD = 550 MW



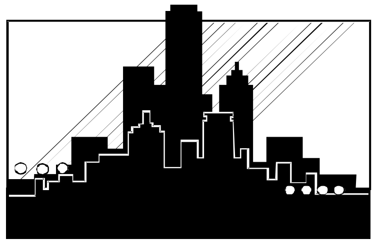
A	**MW** **$60** **Capacity 300 MWs**	Min = 100 MW Max = 300 MW *MW = 250*
B	**MW** **$80** **Capacity 200 MWs**	Min = 100 MW Max = 200 MW *MW = 100*
C	**MW** **$100** **Capacity 400 MWs**	Min = 200 MW Max = 400 MW *MW = 200*

Marginal

PJM

Load

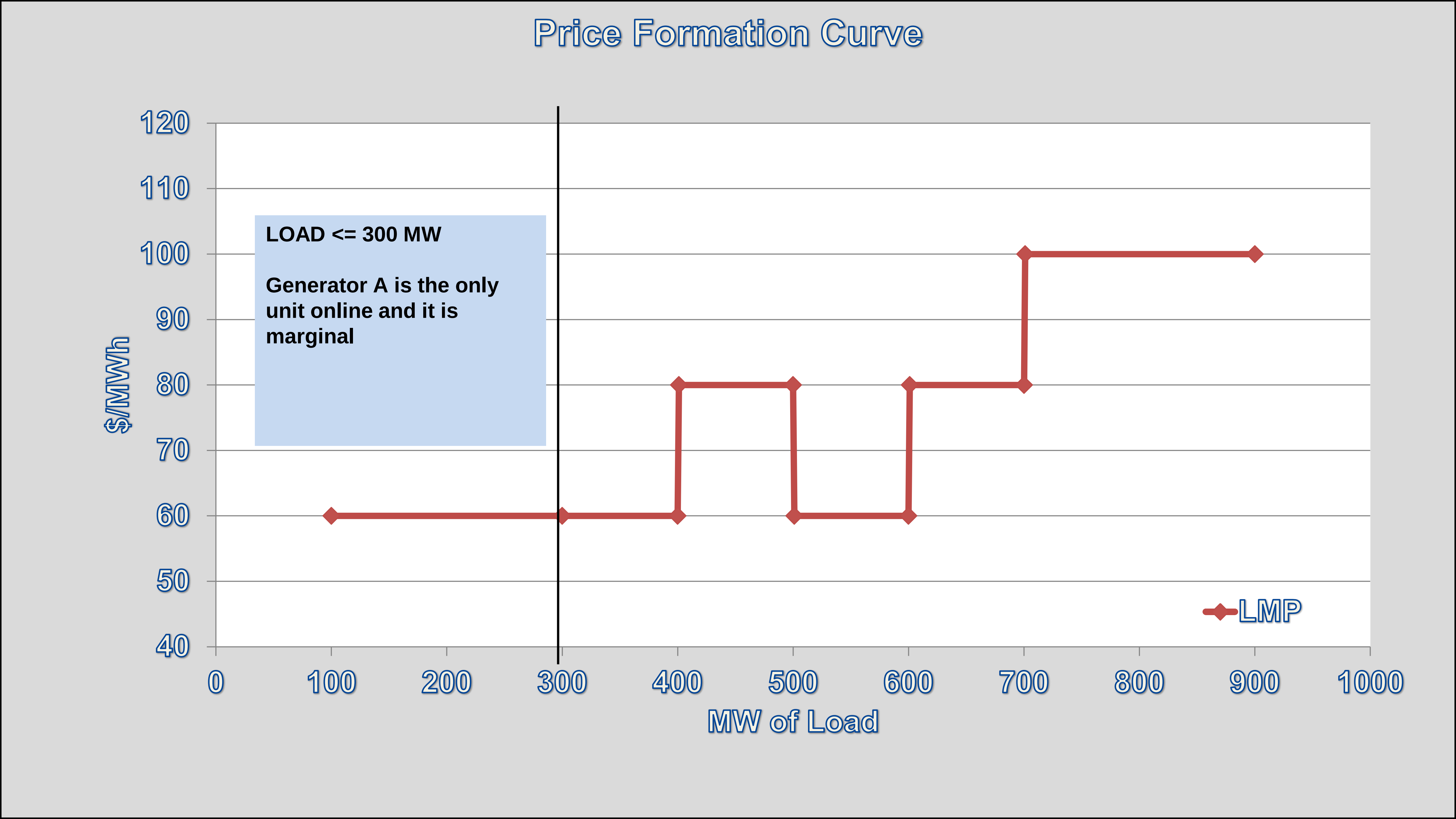
350 MWs

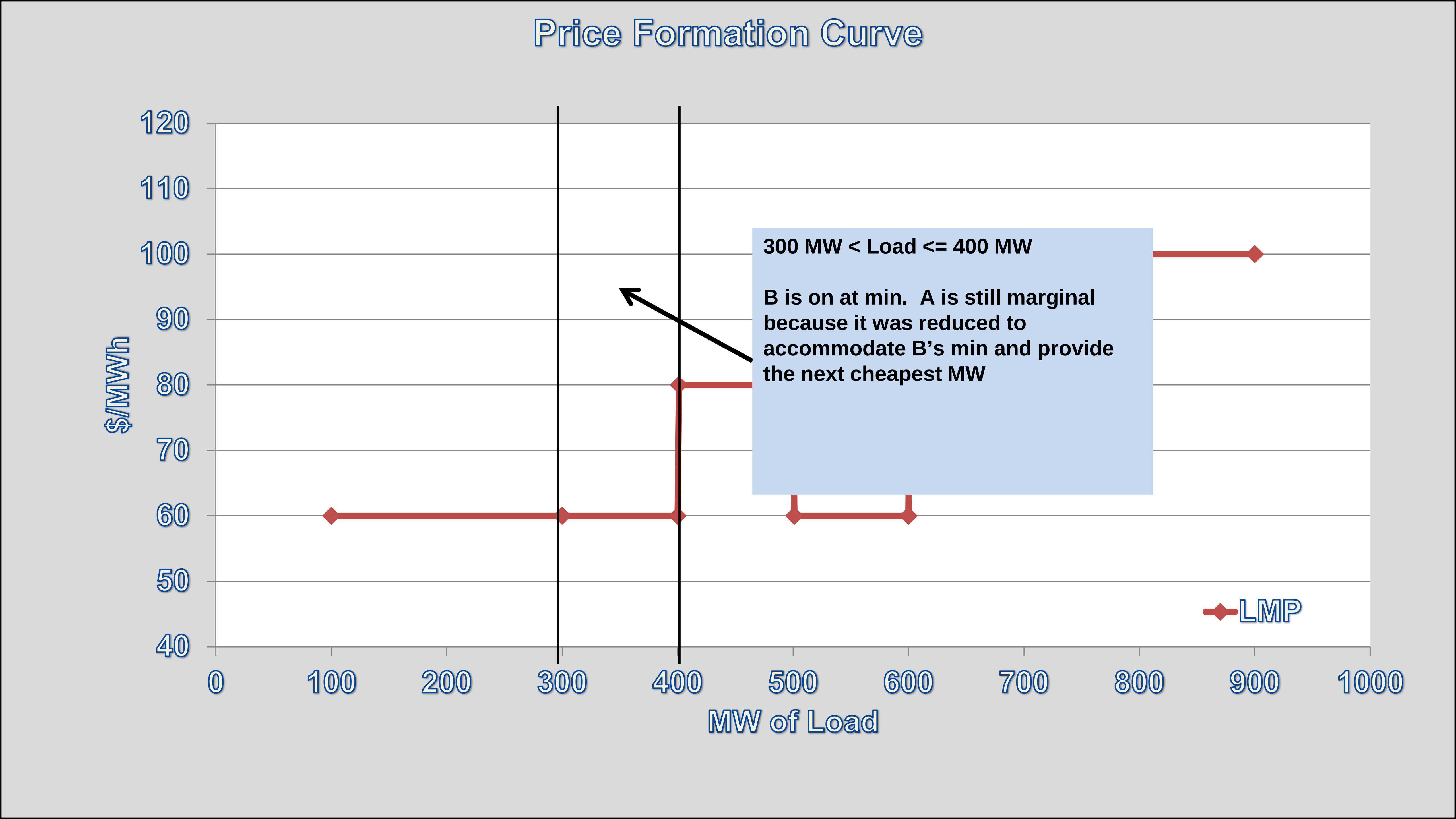


$ 60

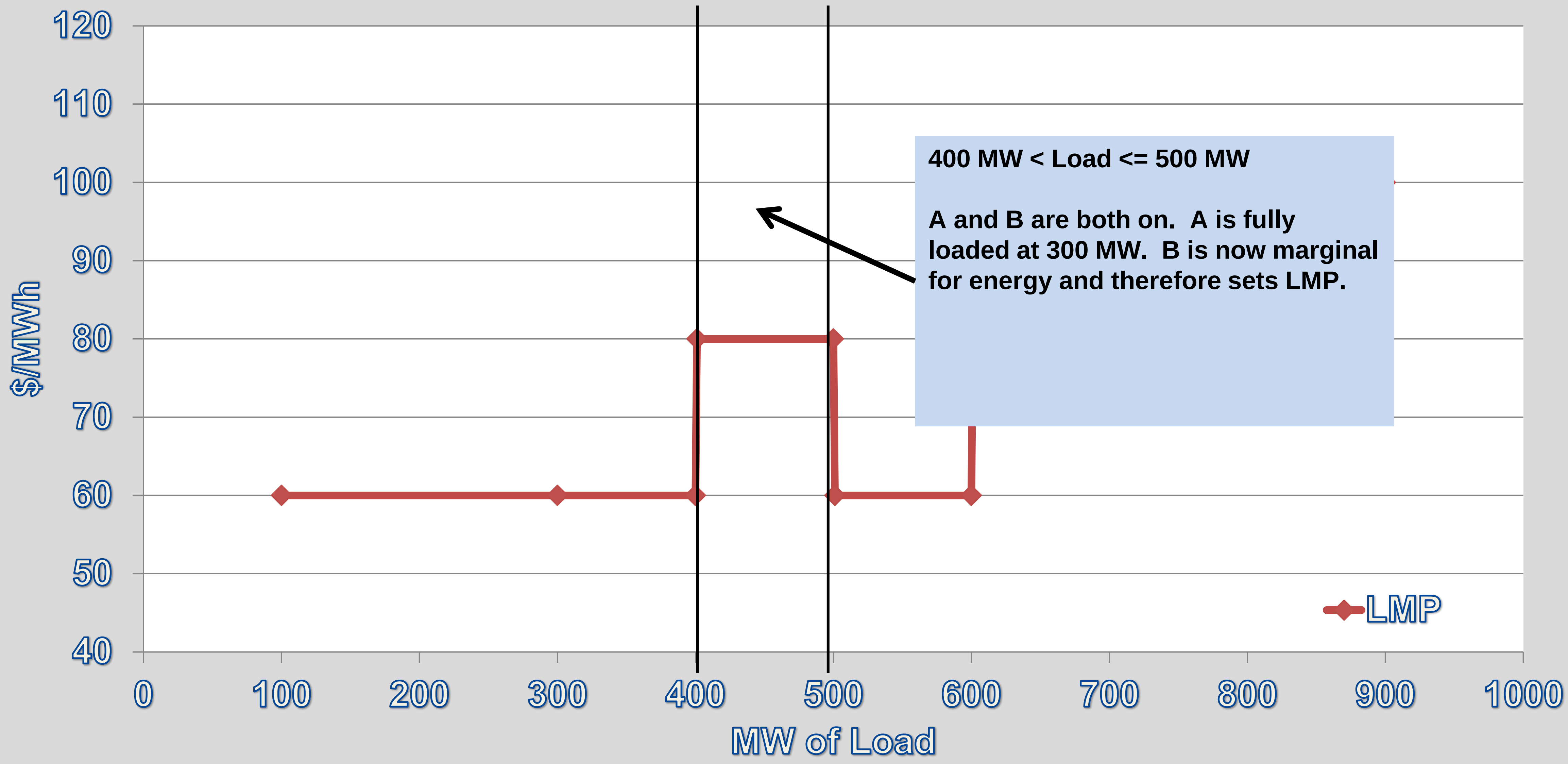
LMP

- All generators must be running to meet a load level of 550 MW
- Generators A and B must be reduced to accommodate the 200 MW min of Generator C
- Because Generator A has 50 MW of room left, and is the cheapest option to service the next MW, **Generator A is marginal**

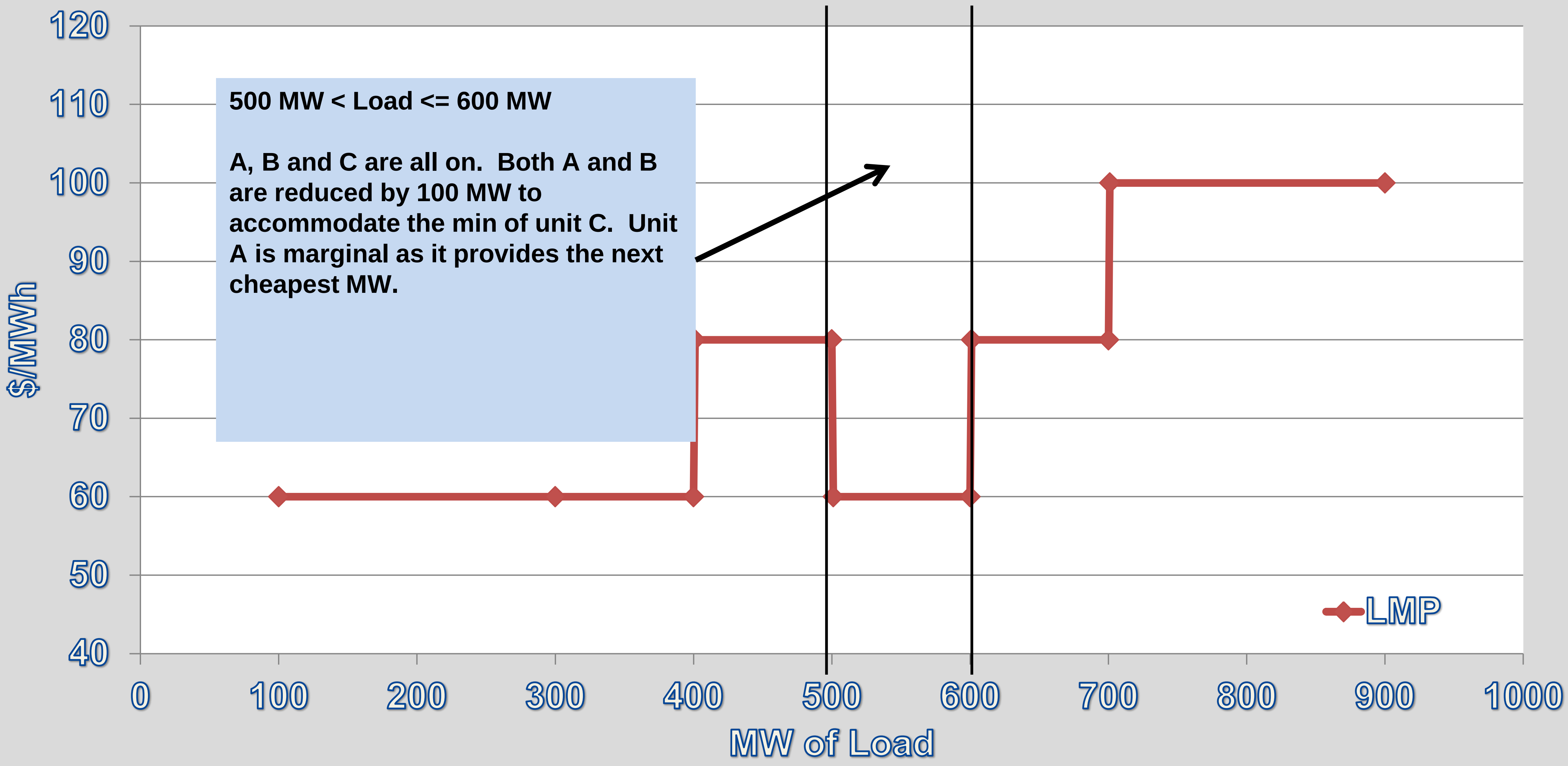

Price Formation Curve
LOAD <= 300 MW
Generator A is the only unit online and it is marginal
$/MWh
120
110
100
90
80
70
60
50
40
0
100
200
300
400
500
600
700
800
900
1000
MW of Load
LMP

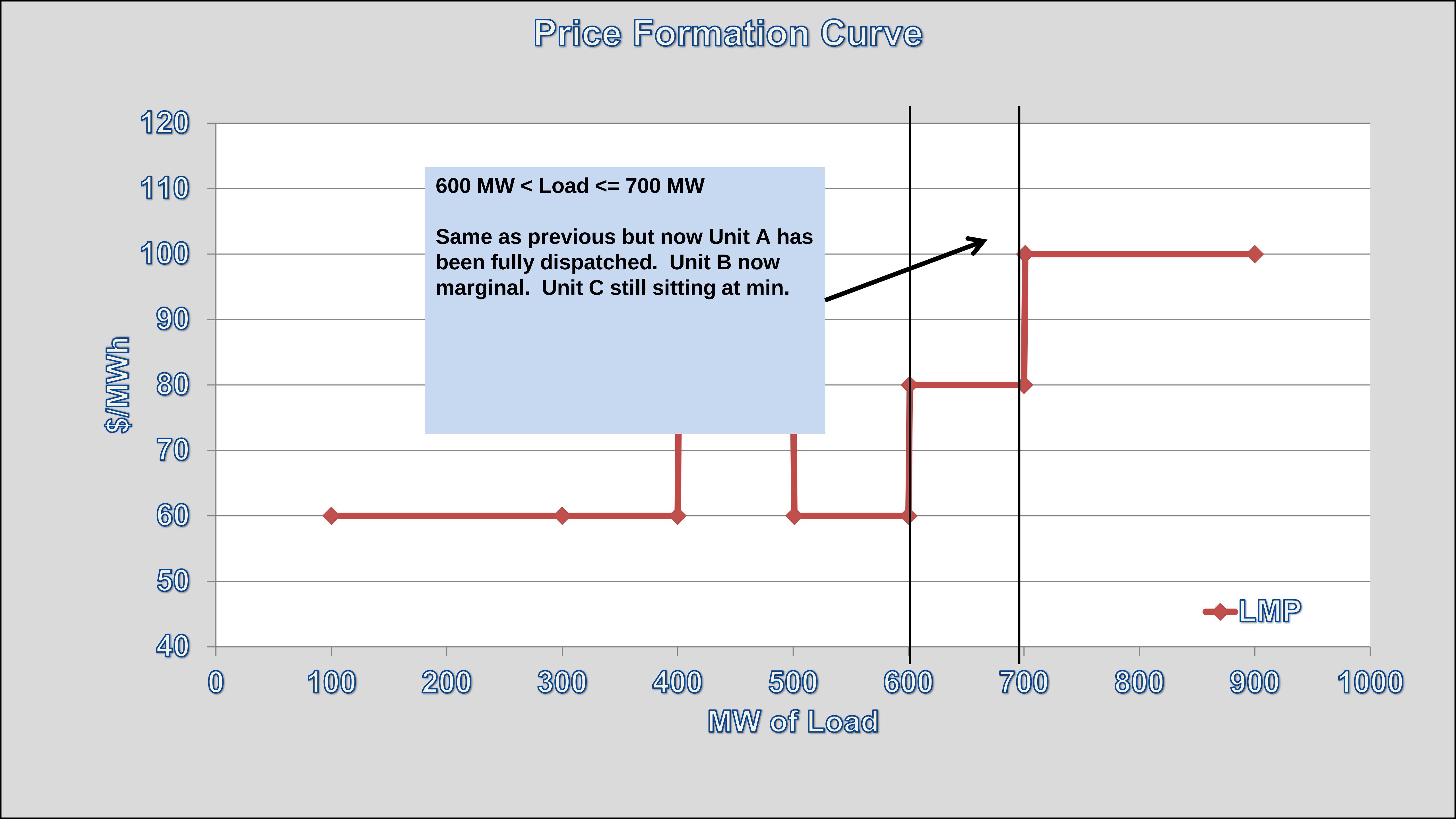

Price Formation Curve
$/MWh
120
110
100
90
80
70
60
50
40
0
100
200
300
400
500
600
700
800
900
1000
MW of Load
300 MW < Load <= 400 MW
B is on at min. A is still marginal because it was reduced to accommodate B's min and provide the next cheapest MW
LMP

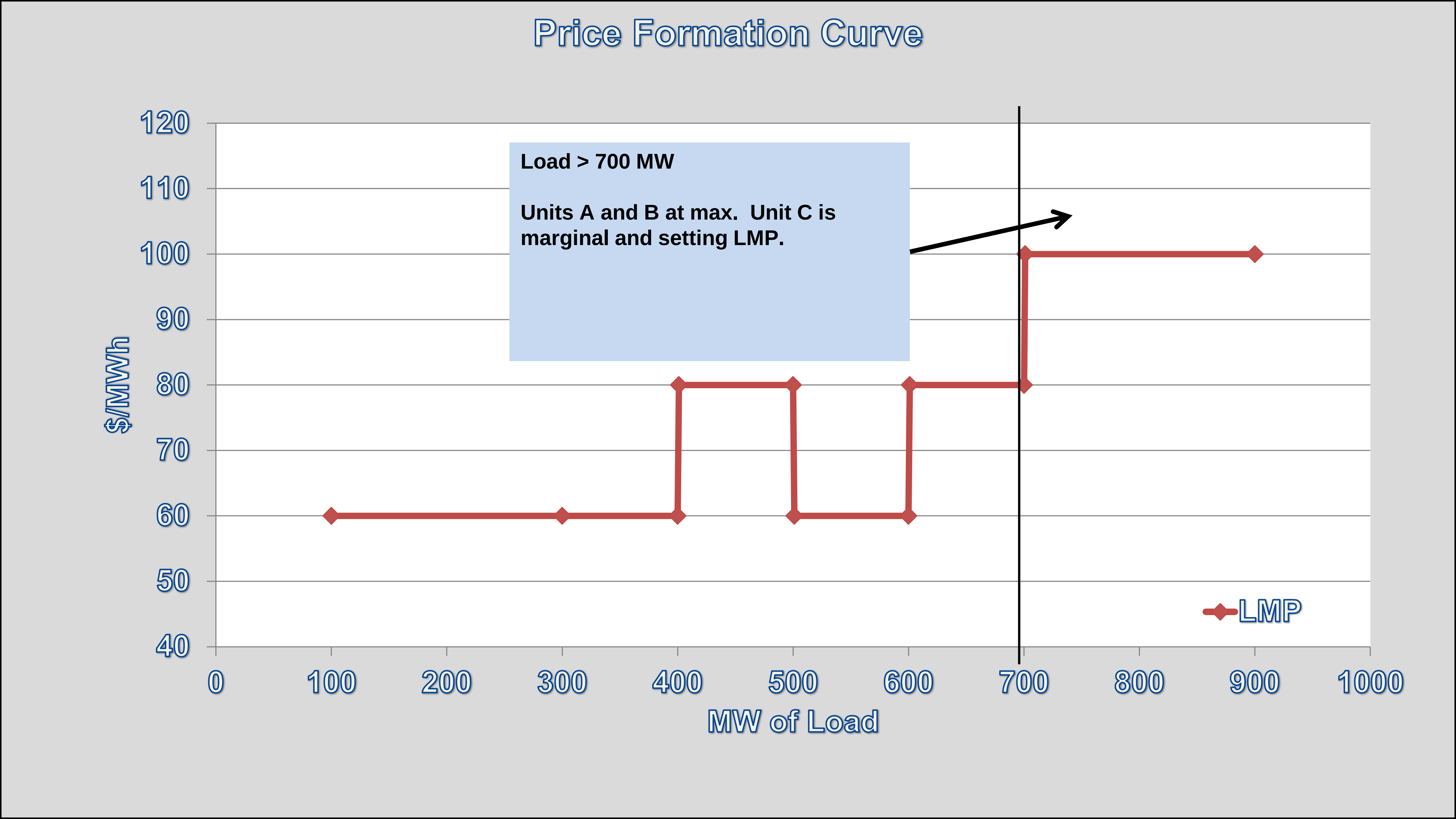
Price Formation Curve



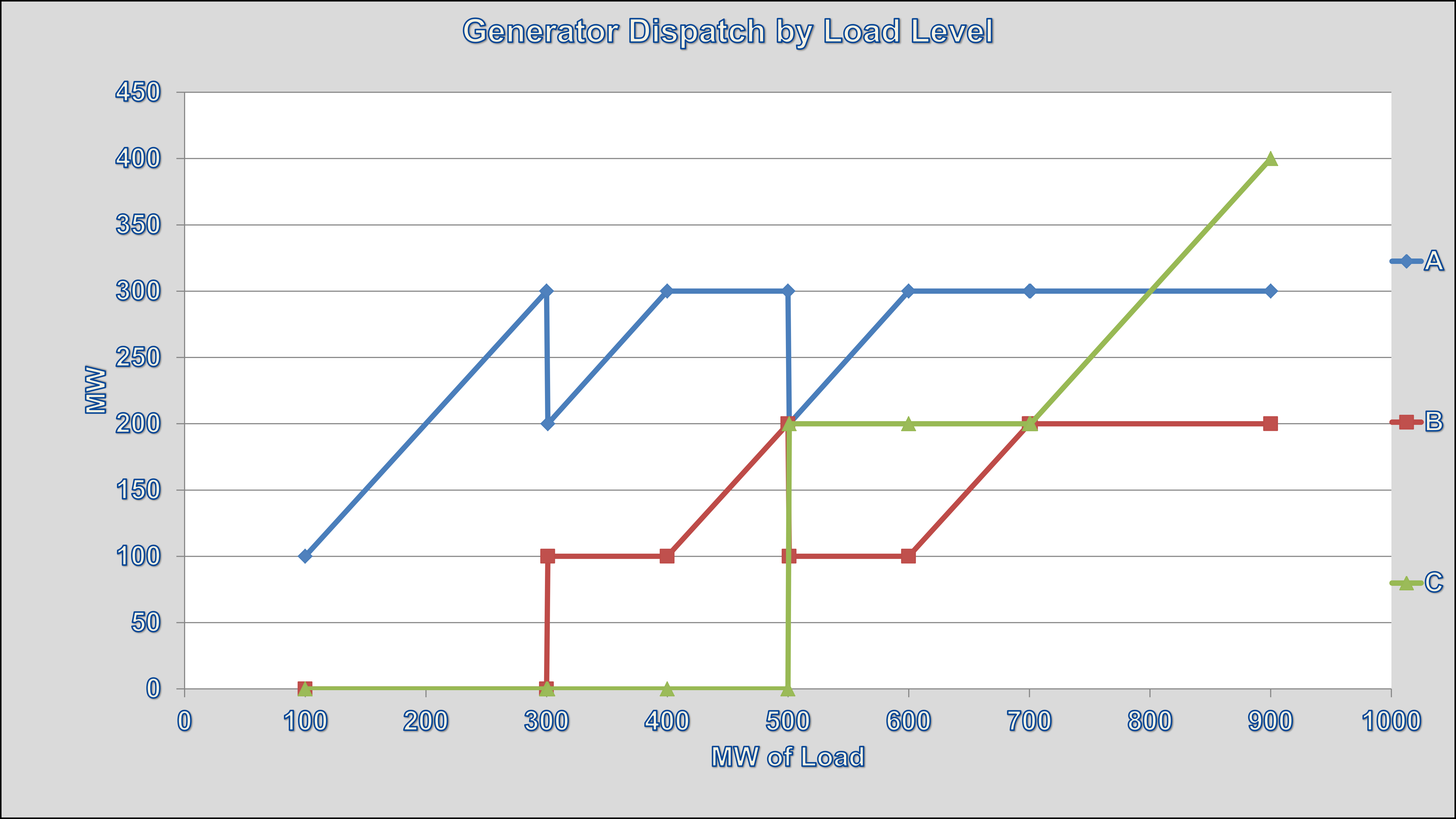
Price Formation Curve



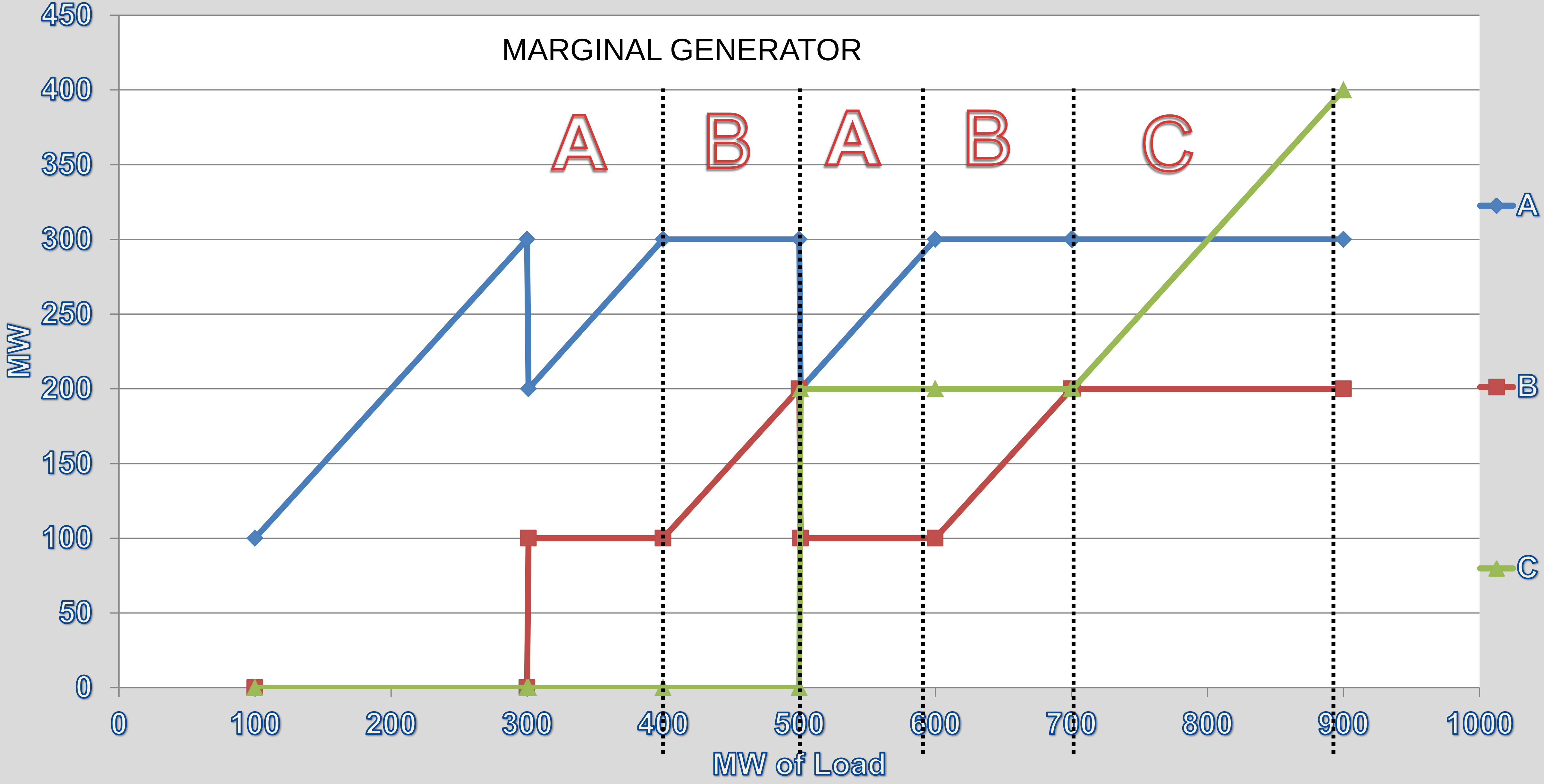

Price Formation Curve
600 MW < Load <= 700 MW
Same as previous but now Unit A has been fully dispatched. Unit B now marginal. Unit C still sitting at min.
120
110
100
90
80
70
60
50
40
$/MWh
0
100
200
300
400
500
600
700
800
900
1000
MW of Load
LMP


Price Formation Curve
Load > 700 MW
Units A and B at max. Unit C is marginal and setting LMP.
$/MWh
120
110
100
90
80
70
60
50
40
0
100
200
300
400
500
600
700
800
900
1000
MW of Load
LMP

- Not always the most expensive unit online
- This would send the wrong signal to the generator being dispatched for the next MW
- Can bounce around depending on unit parameters
- Follows the non-zero sloped curve in the next slides (unit being dispatched up)


Generator Dispatch by Load Level
MW
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
1000
MW of Load
A
B
C

Generator Dispatch by Load Level



“Price Formation” Docket

Order 831

Offer cap level and offer validation

Order 825

Sub-hourly settlement and transient shortage pricing

Uplift Allocation NOPR

Fast Start Pricing NOPR