Single Period Integer Relaxation Examples

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Dispatch Run

- Make no modifications to resource parameters

- Determine desired dispatch points
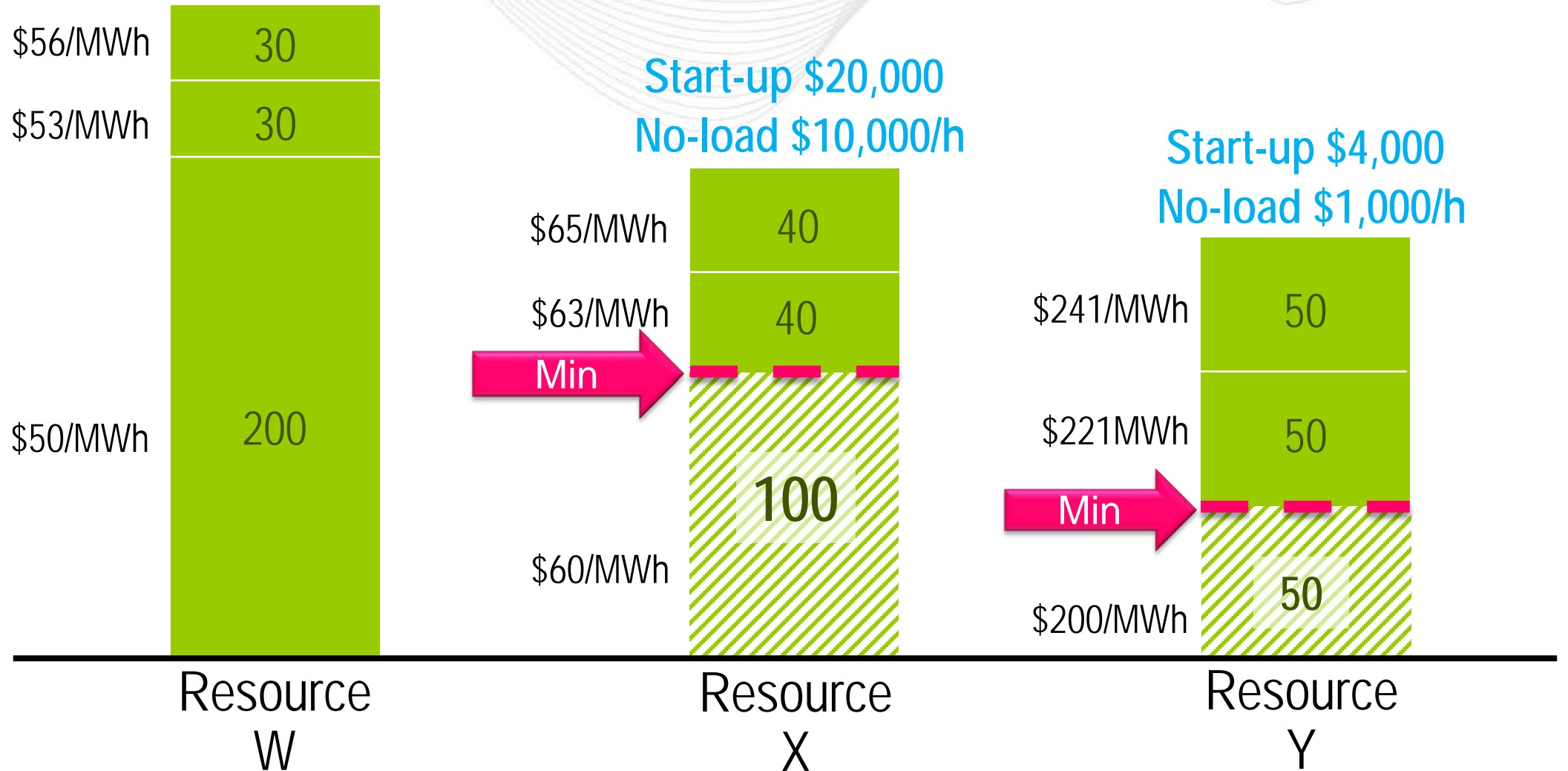
- Do not calculate prices

Pricing Run

- Modify resource parameters

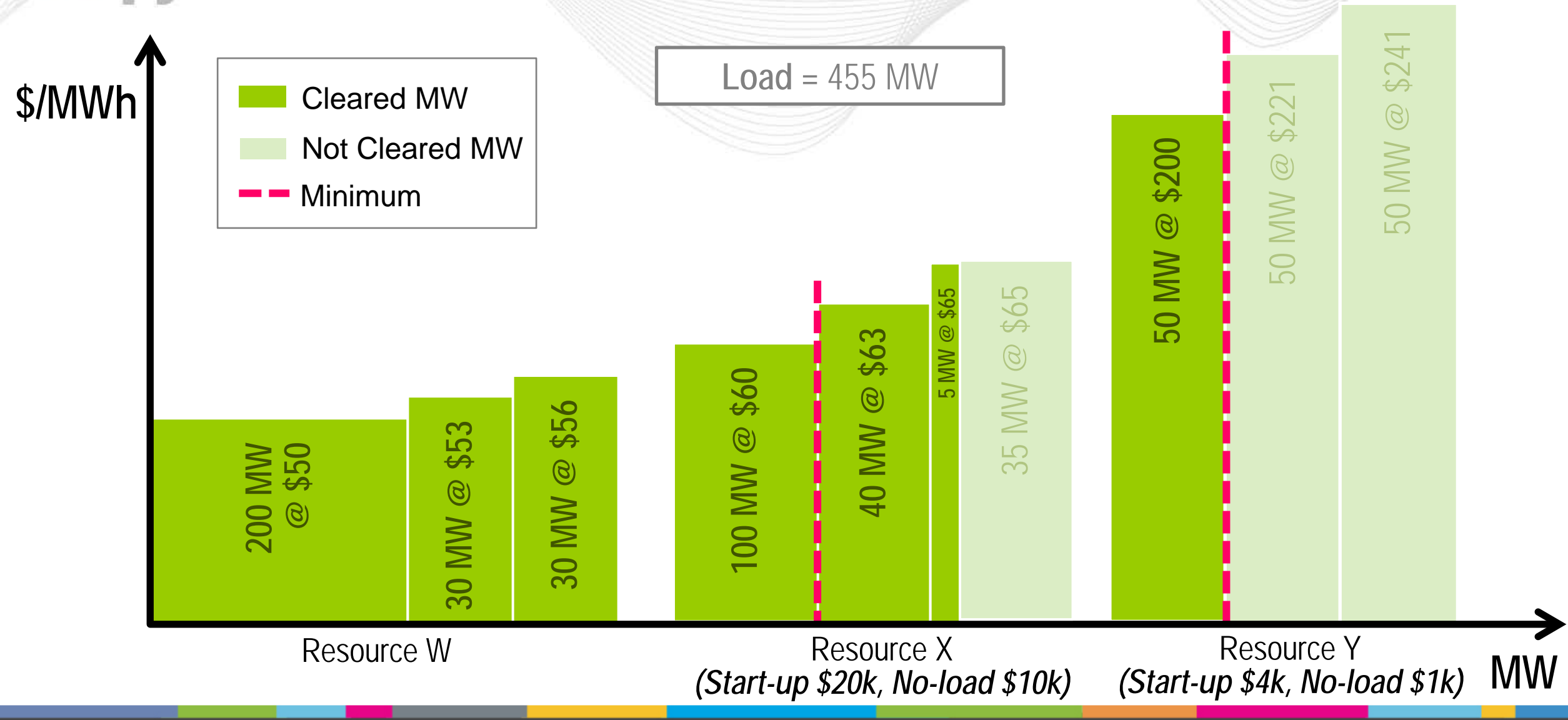- Calculate prices

Example #1

- Load equals 455 MW

- Fixed costs (start-up and no-load) are considered in setting the price.

- Assume all resources are eligible for integer relaxation treatment

- **Note:** Offline resources **do not** participate in pricing

Example #1: Offer Blocks (MW) & Fixed Costs

Any resource that is "committed" must run at least at its minimum

Resource W:
- $56/MWh — 30
- $53/MWh — 30
- $50/MWh — 200

Resource X:
Start-up $20,000
No-load $10,000/h
- $65/MWh — 40
- $63/MWh — 40
- Min
- $60/MWh — 100

Resource Y:
Start-up $4,000
No-load $1,000/h
- $241/MWh — 50
- $221MWh — 50
- Min
- $200/MWh — 50

Resource W   Resource X   Resource Y

The Commitment and Dispatch Run: Example #1

Load = 455 MW

$/MWh

- Cleared MW
- Not Cleared MW
- Minimum

Resource W

200 MW @ $50
30 MW @ $53
30 MW @ $56

Resource X
(Start-up $20k, No-load $10k)

100 MW @ $60
40 MW @ $63
5 MW @ $65
35 MW @ $65

Resource Y
(Start-up $4k, No-load $1k)

50 MW @ $200
50 MW @ $221
50 MW @ $241

MW

- Allow resources to be partially committed for pricing calculations:

  – Equivalently, resources are allowed to be fully dispatchable between 0 and their economic maximums.

- Start-up and No-load costs of X and Y are considered in setting the price.

  – Equivalently, the bid blocks of Resources X and Y can be modified to incorporate the proportional start-up and no-load costs.

- For example, under integer relaxation with a single offer block, in the pricing run the total offer cost of dispatching a resource is:

$$Total\ Offer\ Cost = \ Incremental\ Energy\ Cost \times Dispatch +$$

$$Startup\ Cost \times Commitment\ Status +$$

$$Noload\ Cost \times Commitment\ Status$$

Where:

$$Commitment\ Status = \frac{Dispatch}{Economic\ Maximum}$$
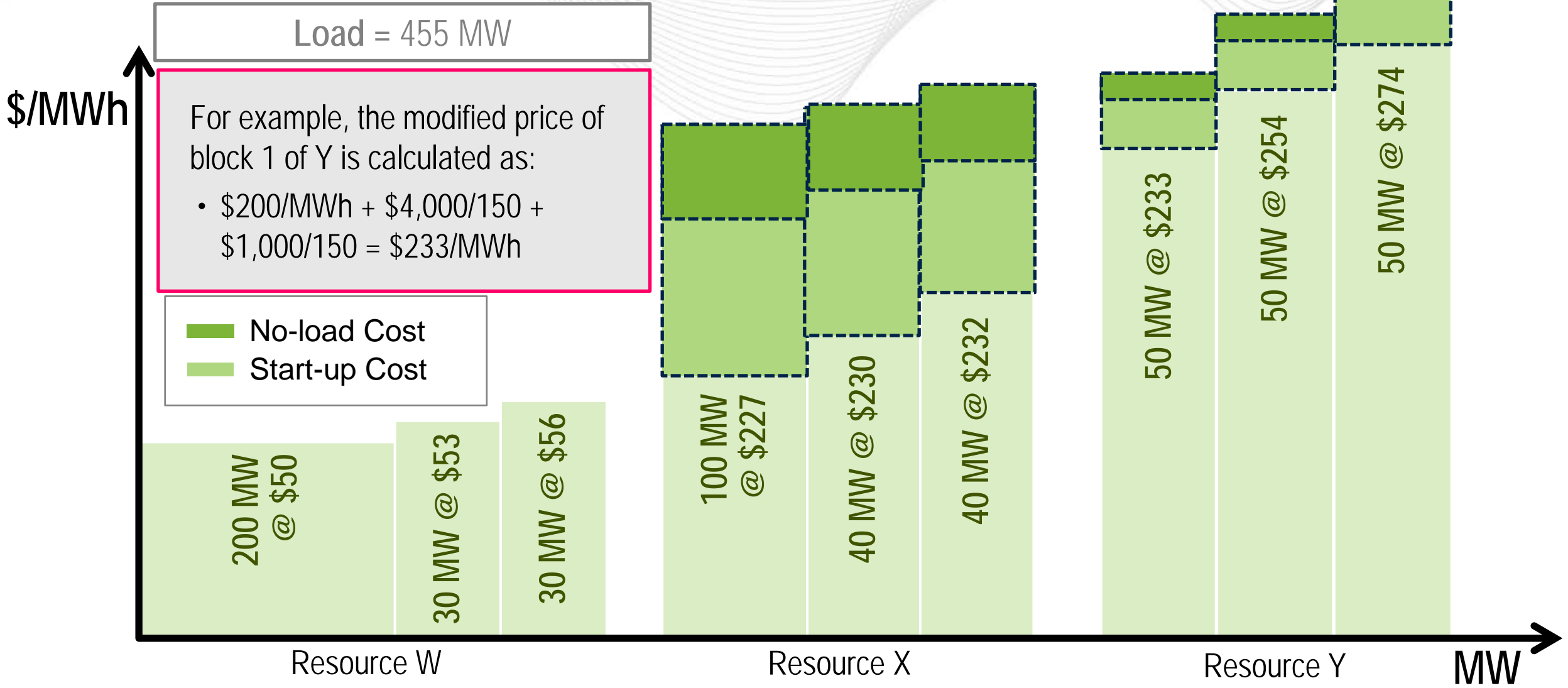
- As a result, the total offer cost of dispatching a resource in the pricing run can be rewritten as:

$$Total\ Offer\ Costs = \boxed{Incremental\ Energy\ Cost} \times Dispatch +$$

$$\boxed{\frac{Startup\ Cost}{Economic\ Maximum}} \times Dispatch +$$

$$\boxed{\frac{Noload\ Cost}{Economic\ Maximum}} \times Dispatch$$
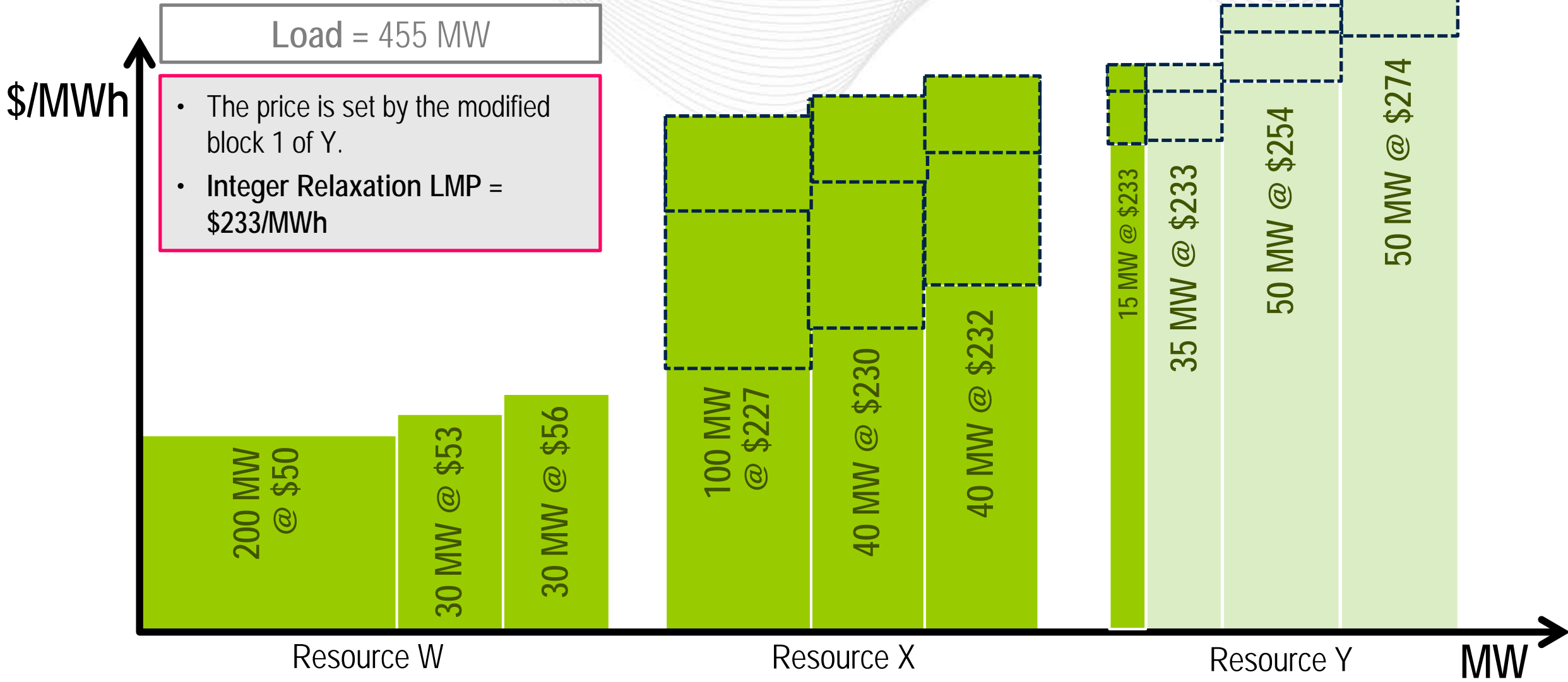
- A resource's equivalent offer is equal to the sum of all three components in the boxes above.

Pricing Run Equivalent Offers for Example #1

Load = 455 MW

For example, the modified price of block 1 of Y is calculated as:
- $200/MWh + $4,000/150 + $1,000/150 = $233/MWh

No-load Cost
Start-up Cost

Resource W
- 200 MW @ $50
- 30 MW @ $53
- 30 MW @ $56

Resource X
- 100 MW @ $227
- 40 MW @ $230
- 40 MW @ $232

Resource Y
- 50 MW @ $233
- 50 MW @ $254
- 50 MW @ $274

$/MWh

Load = 455 MW

- The price is set by the modified block 1 of Y.
- **Integer Relaxation LMP = $233/MWh**

200 MW @ $50

30 MW @ $53

30 MW @ $56

100 MW @ $227

40 MW @ $230

40 MW @ $232

15 MW @ $233

35 MW @ $233

50 MW @ $254

50 MW @ $274

Resource W

Resource X

Resource Y

MW

- The integer relaxation LMP is set by the first block of Resource Y, which includes its start-up and no-load costs in the price

- The dispatch MWs for all resources come from the dispatch run where Resource X and Y incur their full start-up and no-load costs

- Resource Y **will** need a make-whole payments since it is only recovering part of its start-up and no-load costs through the price since it is not being dispatched at its economic maximum

The **Integer Relaxation LMP** is calculated at **$233/MWh.**

Asset	Commit.	Dispatch (MW)	EcoMax (MW)	Total Offer Cost ($)	Payment ($)	MWP ($)	LOC ($)
W	On	260	260	13,270	60,580	0	0
X	On	145	180	38,845	33,785	5,060	820
Y	On	50	150	15,000	11,650	3,350	0

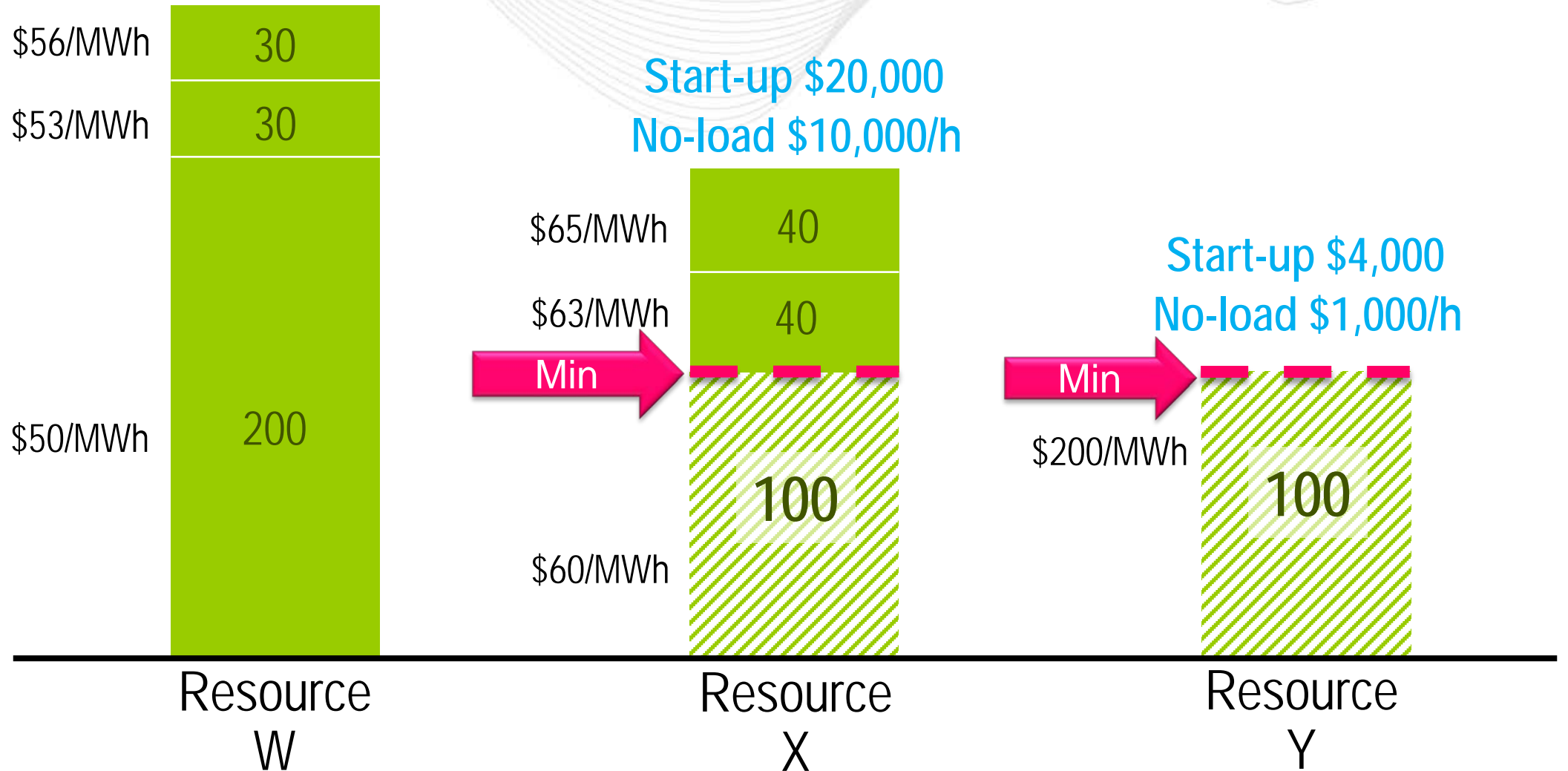*Both X and Y receive a make-whole payment to make them whole to their total offer cost.*

X receives a LOC payment since it would want to produce at its economic maximum at a $233/MWh clearing pricing since it would make a profit of $820.

LOC = (Integer Relaxation LMP * EcoMax) - Incremental energy offer – Start-up Cost – No Load Cost
= ($233*180 MW) – (($60*100 MW)+($63*40 MW)+($65*40 MW)) – $20,000 – $10,000) = $820
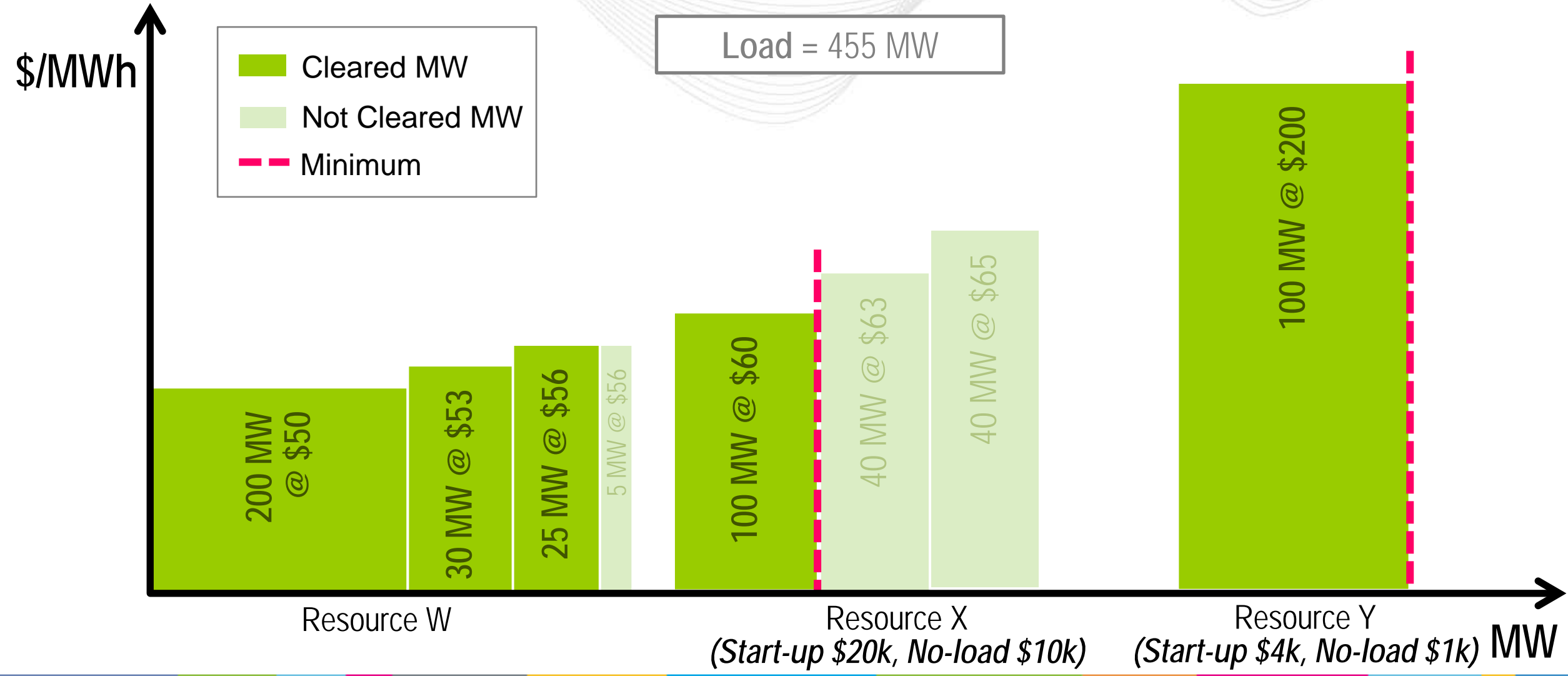
Example #2

- Load equals 455 MW

- Fixed costs (start-up and no-load) are considered in setting the price.

- Assume all resources are eligible for integer relaxation treatment

- **Note:** Offline resources **do not** participate in pricing

Example #2: Offer Blocks (MW) & Fixed Costs

Any resource that is "committed" must run at least at its minimum

Resource W:
- $56/MWh — 30
- $53/MWh — 30
- $50/MWh — 200

Resource X:
Start-up $20,000
No-load $10,000/h
- $65/MWh — 40
- $63/MWh — 40
- Min
- $60/MWh — 100

Resource Y:
Start-up $4,000
No-load $1,000/h
- Min
- $200/MWh — 100

The Commitment and Dispatch Run: Example #2

Load = 455 MW

Legend:
- Cleared MW
- Not Cleared MW
- Minimum

$/MWh (y-axis)
MW (x-axis)

Resource W:
- 200 MW @ $50
- 30 MW @ $53
- 25 MW @ $56
- 5 MW @ $56

Resource X (Start-up $20k, No-load $10k):
- 100 MW @ $60
- 40 MW @ $63
- 40 MW @ $65

Resource Y (Start-up $4k, No-load $1k):
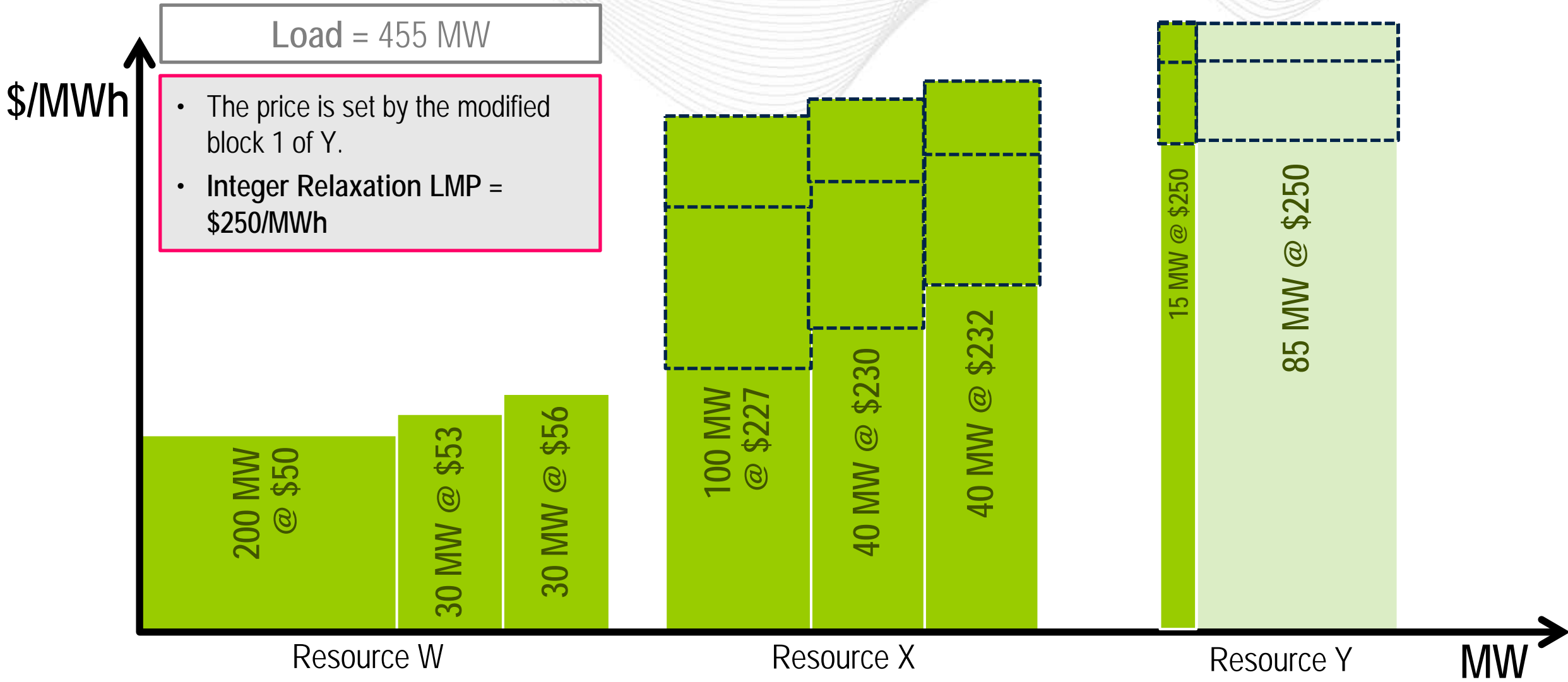- 100 MW @ $200

- Allow resources to be partially committed for pricing calculations:

  – Equivalently, resources are allowed to be fully dispatchable between 0 and their economic maximums.

- Start-up and No-load costs of X and Y are considered in setting the price.

  – Equivalently, the bid blocks of Resources X and Y can be modified to incorporate the proportional start-up and no-load costs.

Pricing Run Equivalent Offers for Example #2
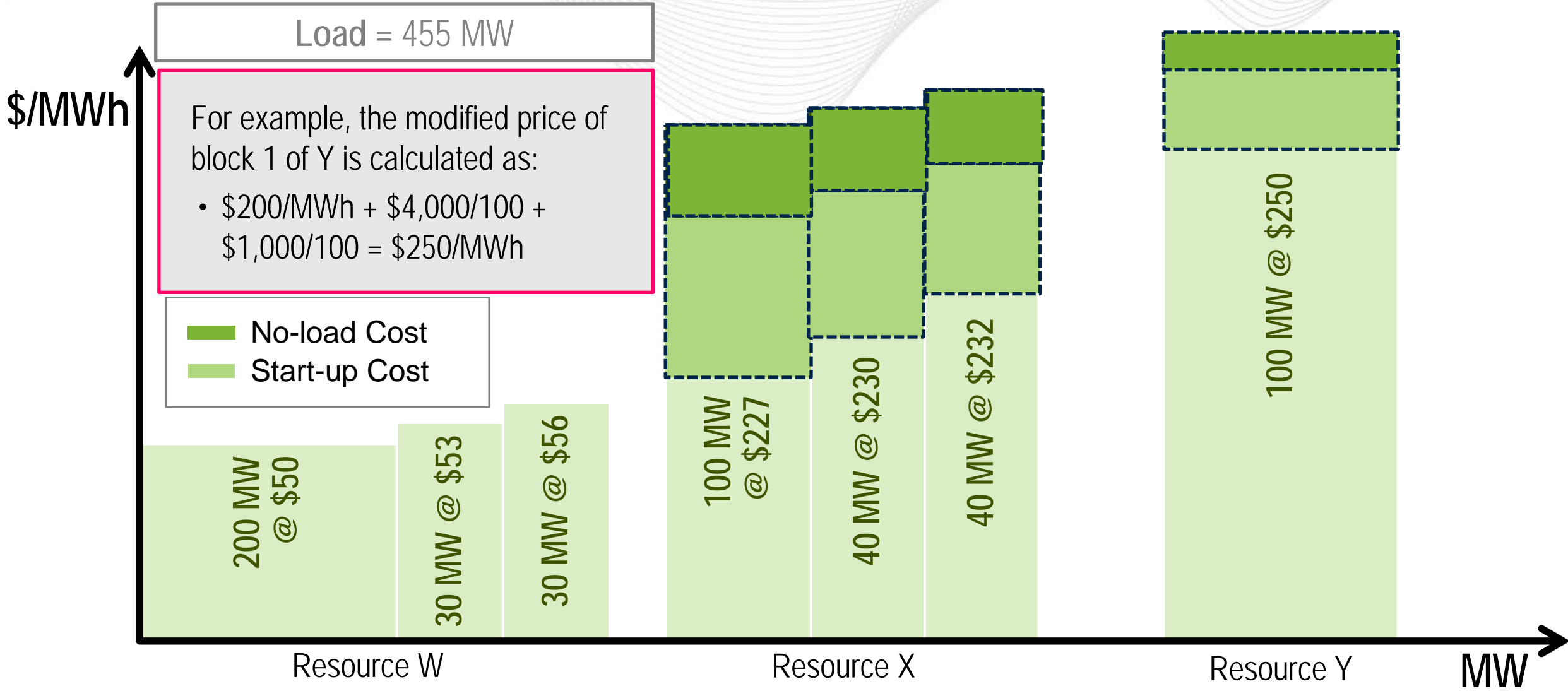
Load = 455 MW

For example, the modified price of block 1 of Y is calculated as:
- $200/MWh + $4,000/100 + $1,000/100 = $250/MWh

No-load Cost
Start-up Cost

200 MW @ $50
30 MW @ $53
30 MW @ $56

100 MW @ $227
40 MW @ $230
40 MW @ $232

100 MW @ $250

Resource W   Resource X   Resource Y

MW

$/MWh

$/MWh

Load = 455 MW

- The price is set by the modified block 1 of Y.
- **Integer Relaxation LMP = $250/MWh**

200 MW @ $50

30 MW @ $53

30 MW @ $56

100 MW @ $227

40 MW @ $230

40 MW @ $232

15 MW @ $250

85 MW @ $250

Resource W

Resource X

Resource Y

MW

- The integer relaxation LMP is set by the first block of Resource Y, which includes its start-up and no-load costs in the price

- The dispatch MWs for all resources come from the dispatch run where Resource X and Y incur their full start-up and no-load costs

- Resource Y **will not** need a make-whole payment since it is being dispatched to its economic maximum in the dispatch run and is recovering its entire start-up and no-load costs through the price

The **Integer Relaxation LMP** is calculated at **$250/MWh.**

Asset	Commit.	Dispatch (MW)	EcoMax (MW)	Total Offer Cost ($)	Payment ($)	MWP ($)	LOC ($)
W	On	255	260	12,990	63,750	0	970
X	On	100	180	36,000	25,000	11,000	3,880
Y	On	100	100	25,000	25,000	0	0

Resource X receives a make-whole payment to make it whole to its total offer cost.

In addition, Resource W and X receive a LOC payment since at Resource W's and X's offer prices of $50-$56/MWh and $60–$65/MWh, they would want to produce at their economic maximums at a $250/MWh clearing pricing since they would make a profit of $970 and $3,880, respectively.