Limited Fuel Resource Optimization (LERO)

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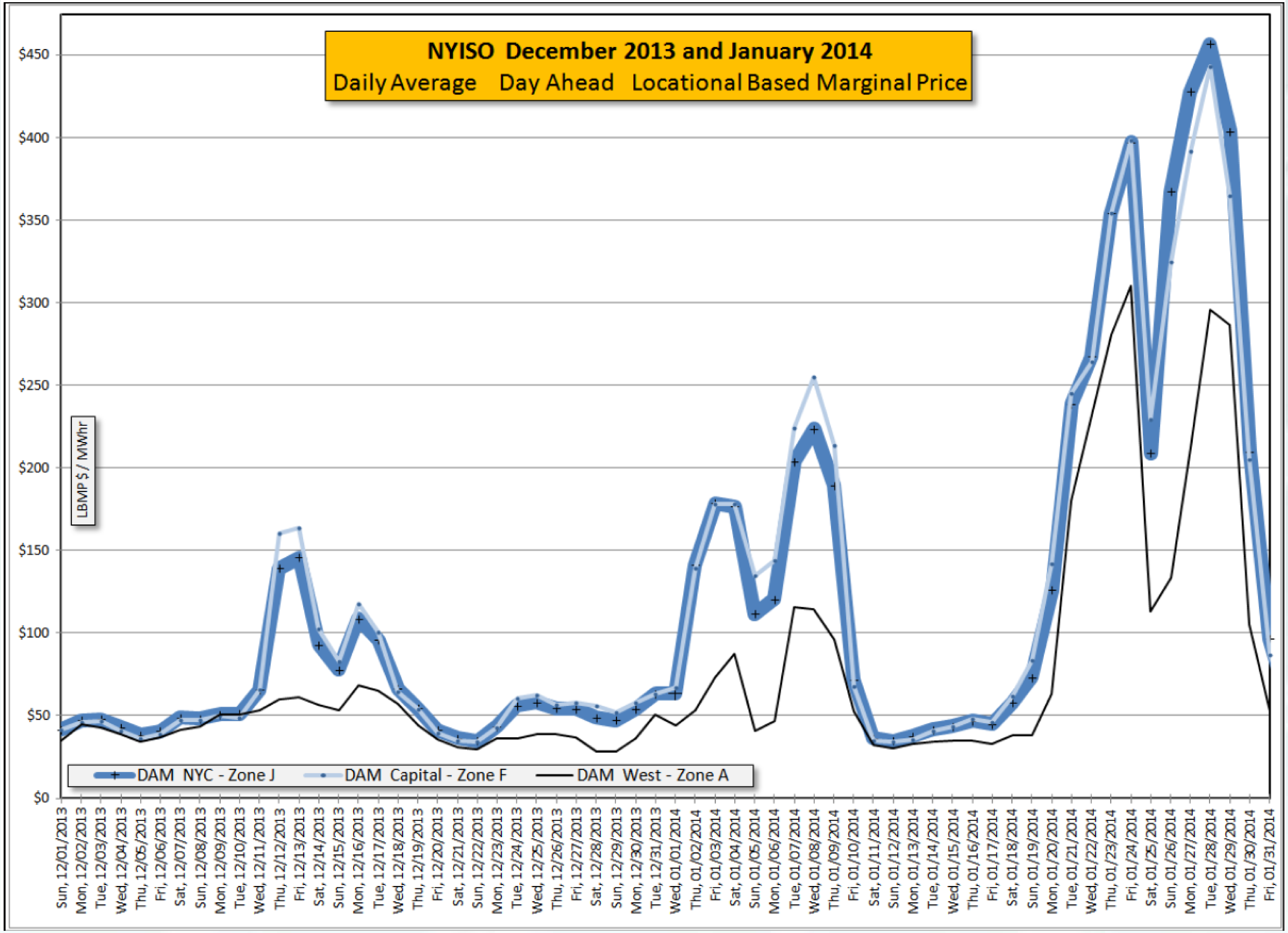
Background

- **The Polar vortex of winter 2013-2014 revealed some market efficiency problems when resources with limited fuel were not able to explicitly reflect their fuel supply with the standard bidding parameters available to them.**
  - ***Limited-fuel resources include pumped storage hydro, oil-fired generators, and gas-fired generators on critical winter days.***
- **The 2013, 2014 and 2015 *State of the Market Report for the New York ISO* recommended allowing suppliers to submit inter-temporal offers that better reflect fuel supply constraints in the Day-Ahead market.**


NYISO December 2013 and January 2014
Daily Average Day Ahead Locational Based Marginal Price
LBMP $ / MWhr
$450
$400
$350
$300
$250
$200
$150
$100
$50
$0
DAM NYC - Zone J
DAM Capital - Zone F
DAM West - Zone A
Sun, 12/01/2013
Mon, 12/02/2013
Tue, 12/03/2013
Wed, 12/04/2013
Thu, 12/05/2013
Fri, 12/06/2013
Sat, 12/07/2013
Sun, 12/08/2013
Mon, 12/09/2013
Tue, 12/10/2013
Wed, 12/11/2013
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Sat, 01/25/2014
Sun, 01/26/2014
Mon, 01/27/2014
Tue, 01/28/2014
Wed, 01/29/2014
Thu, 01/30/2014
Fri, 01/31/2014

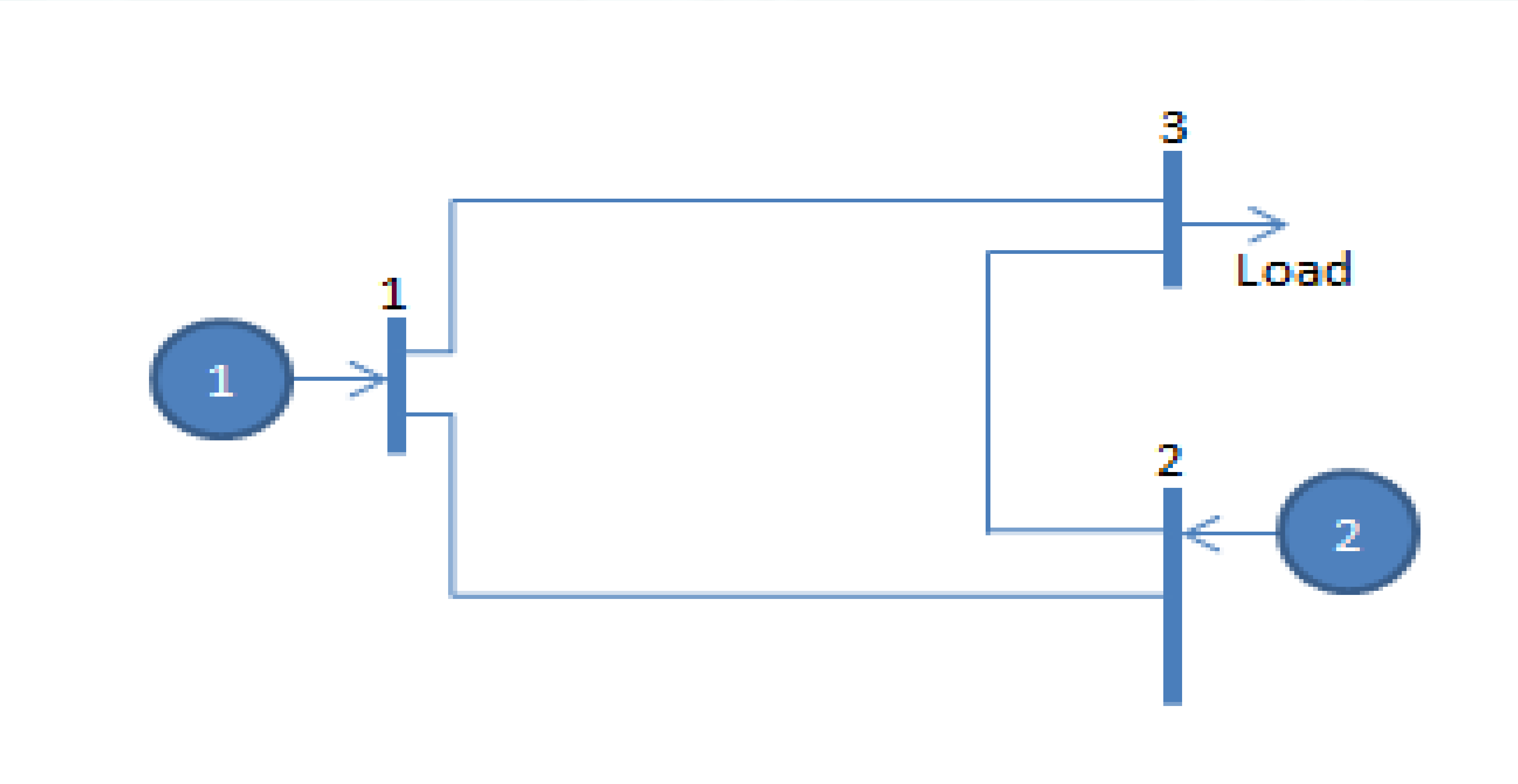
Background

- **In the NYISO's Day-Ahead market…**
  - ***Resources with limited fuel supply are not able to explicitly reflect in their offers the limited fuel supply available so as to maximize their expected revenues.***
  - ***Currently, a resource's fuel constraints is captured in its hourly offers.***
- **As a result, limited-fuel resources may not be most efficiently dispatched during the times when they are most needed.**
  - ***Security Constraint Unit Commitment (SCUC) may not be able to produce the most efficient solution over the day.***

Limited Fuel Resource Optimization (LERO)

- **Day-Ahead Market optimization**
- **LERO constraint targets**
  - ***Option 1: Total Energy Curve (TEC)***
    - **Total energy output is modeled as a constraint**
    - **Require fuel to energy conversion to capture limited fuel input volume**
  - ***Option 2: Fuel Cost & Efficiency Curve (FEC)***
    - **Explicitly impose fuel input constraint**
    - **Fully capture unit efficiency**
  - ***The two options are not mutually exclusive***

Three-Bus Examples



- **Three bus model (two generator buses and a load bus)**
- **Scheduling horizon is two hours**
- **One unit (Gen 1) bidding with a fuel constraint**

Option 1: Total Energy Curve Bidding (TEC)

- **This design allows the Market Participant to submit an inter-temporal offer for a day or for a subset of hours during the day:**
  - ***Hourly three-part bids for a generator or each generator in a portfolio***
  - ***A cost curve reflecting total energy capability in the timeframe (MWh) and the cost to produce that energy ($/MWh) for the generator or portfolio***

Option 1: TEC Problem Formulation

Prevailing objective function costs:

$$Min \sum_{i}\sum_{t}(C_{i,t}^{0} \times u_{i,t}) + \sum_{t}\sum_{i}\sum_{b}(C_{b,i,t} \times P_{b,i,t}) + \sum_{j}\sum_{be}(CE_{be,j} \times E_{be,j}) \quad (1)$$

Energy balance constraint:

$$\sum_{i}\sum_{b} P_{b,i,t} = Load_t \quad (2)$$

Generator constraint:

$$P_{b,i}^{min} \times u_{i,t} \leq P_{b,i,t} \leq P_{b,i}^{max} \times u_{i,t} \quad (3)$$

$$P_{i,t} = \sum_{b} P_{b,i,t} \quad (4)$$

Total energy constraint:

$$0 \leq E_{be,j} \leq E_{b,j}^{max} \quad (5)$$

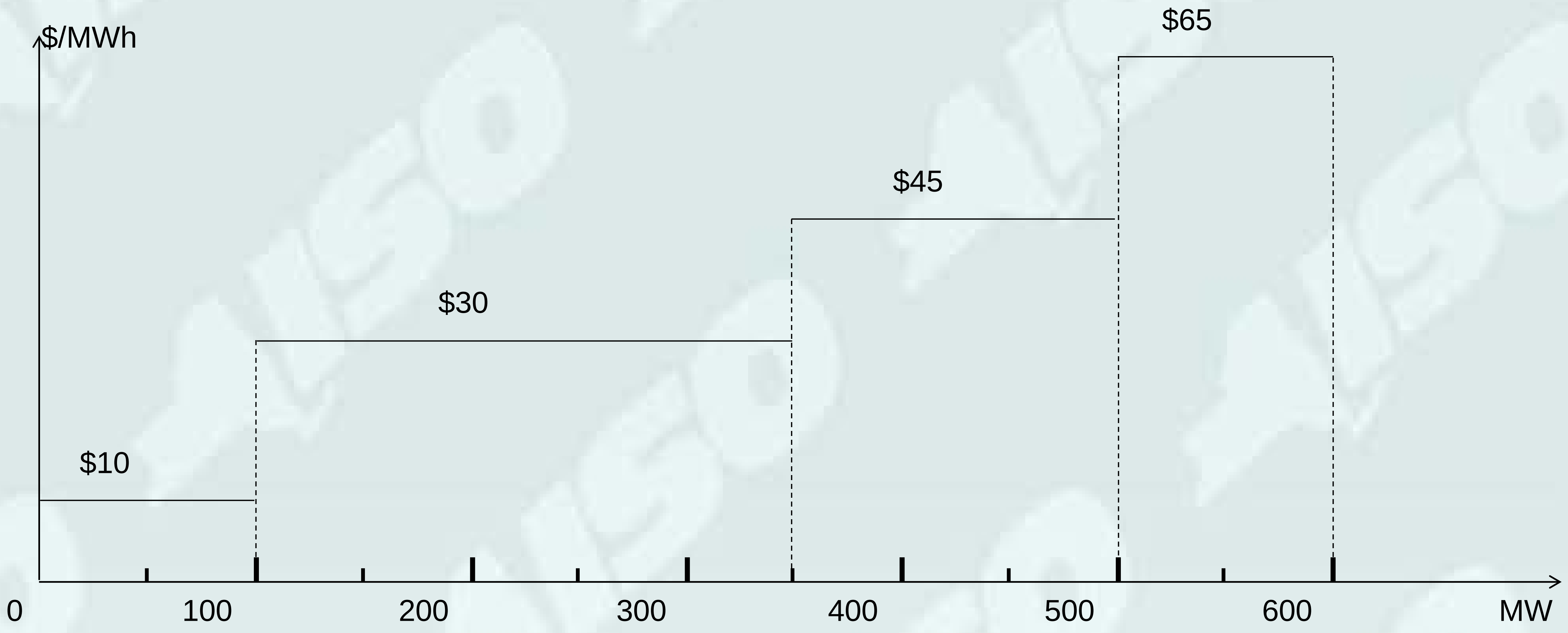
$$\sum_{t}\sum_{i \in C_j} P_{i,t} = \sum_{be} E_{be,j} \quad (6)$$

Operational flow order constraint:

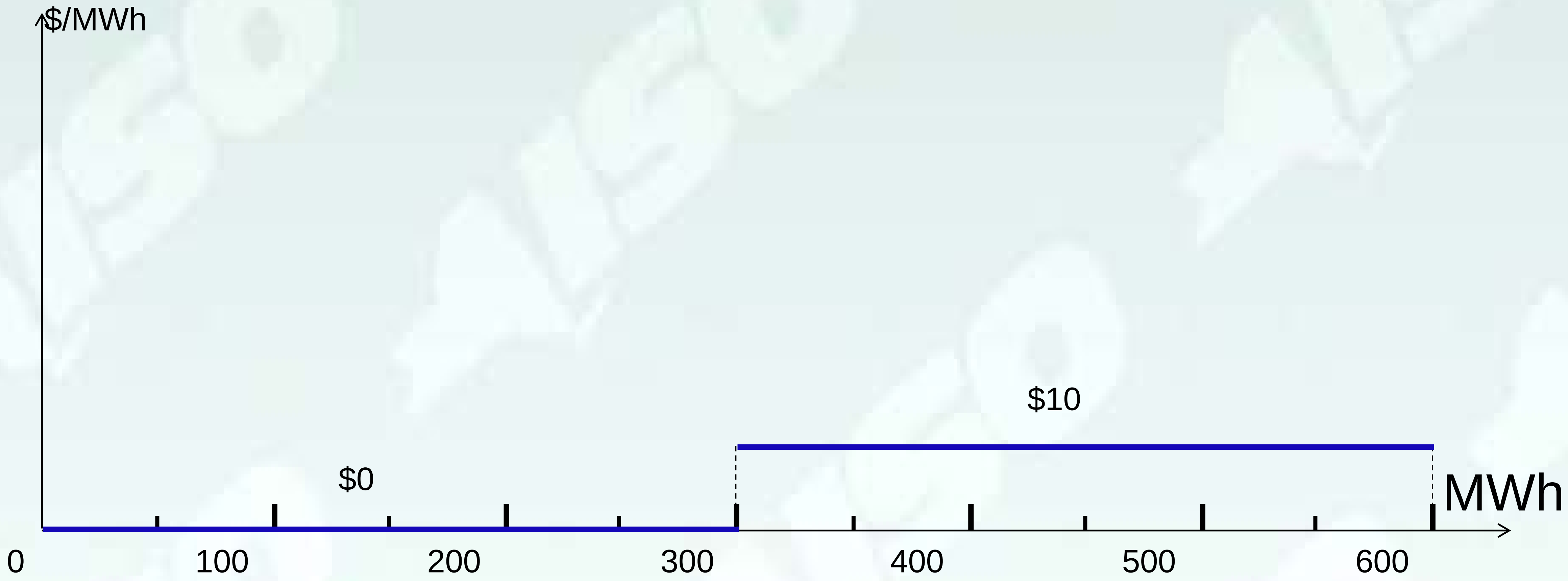
$$-(1-u_{i,t}) \times UOL_{i,t} \leq P_{i,t} - P_{i,t-1} \leq (1-u_{i,t-1}) \times UOL_{i,t}, i \in C_j \quad (7)$$

TEC Example

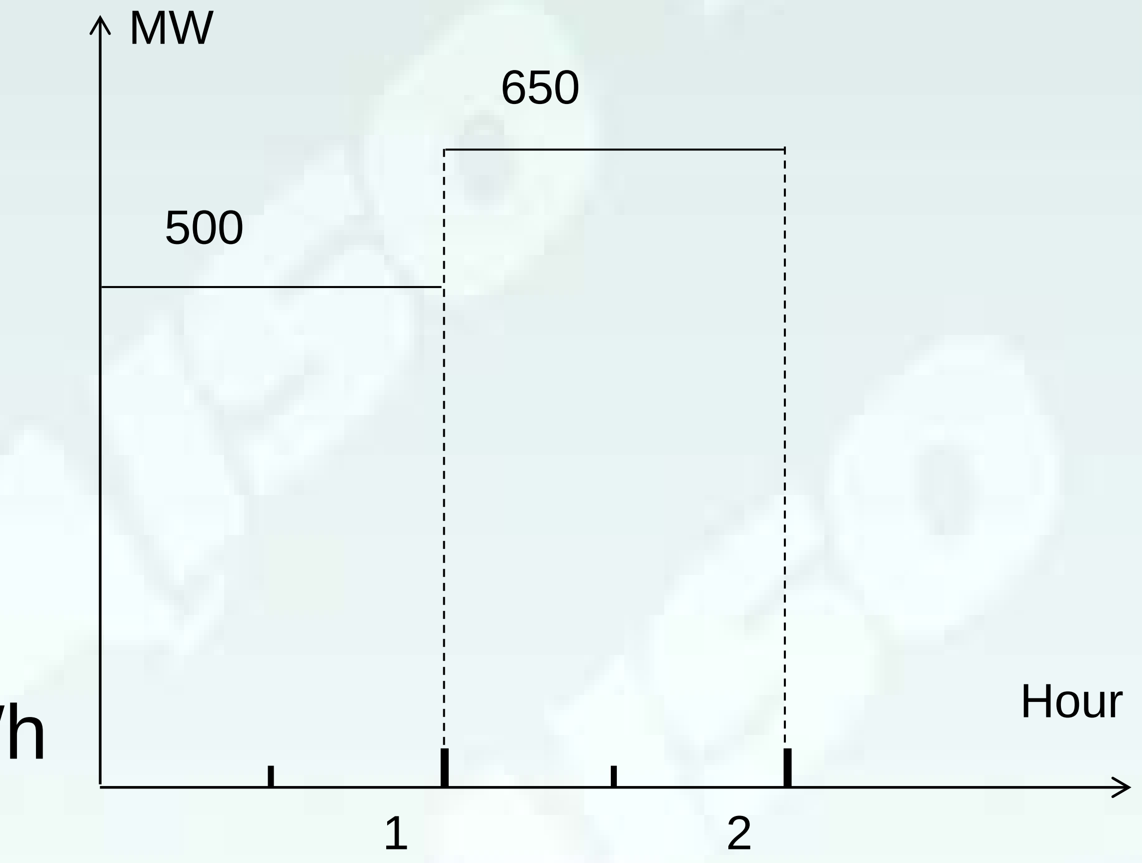
GEN 1 (LERO)



GEN 2

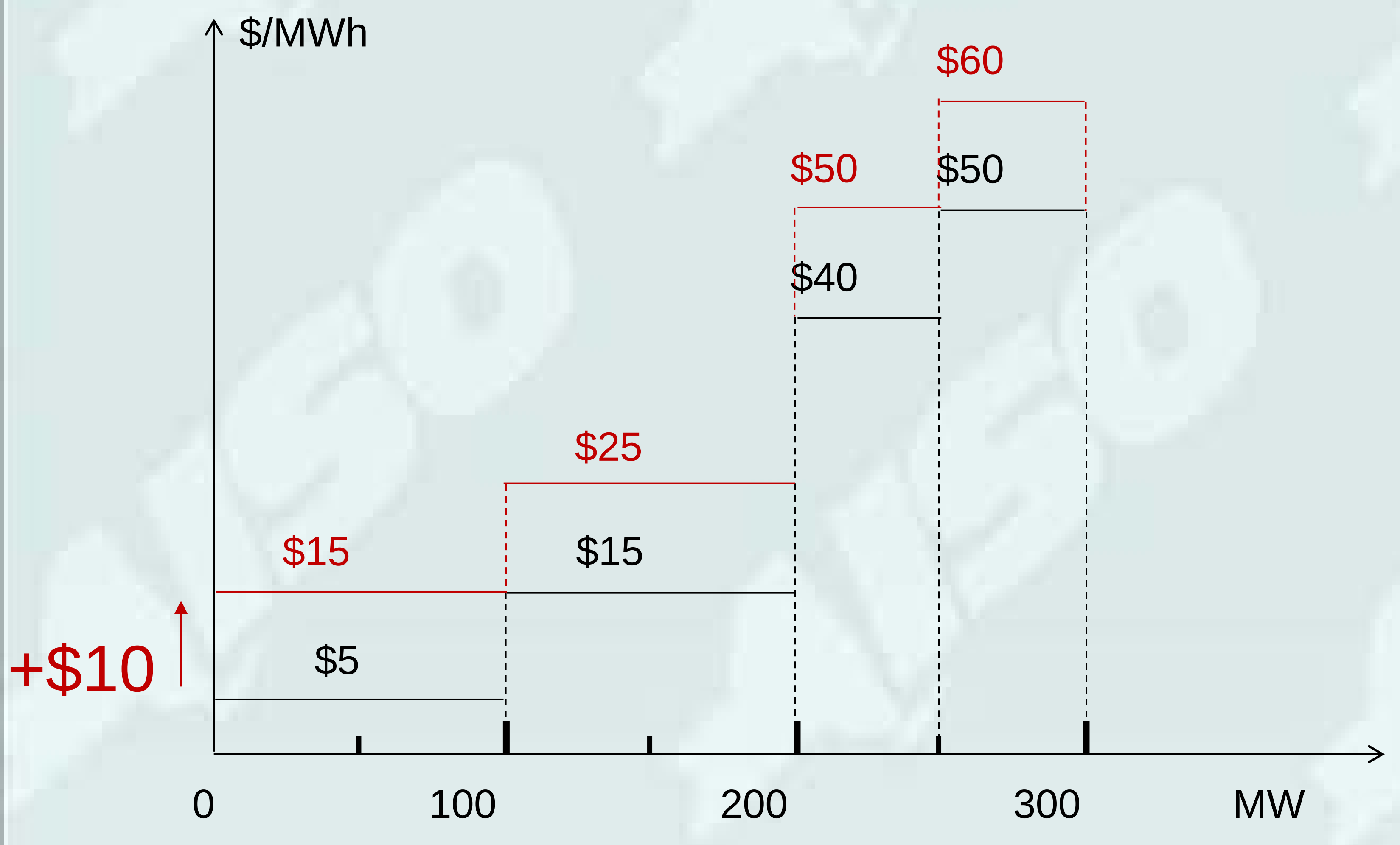


GEN 1 – TOTAL ENERGY CURVE

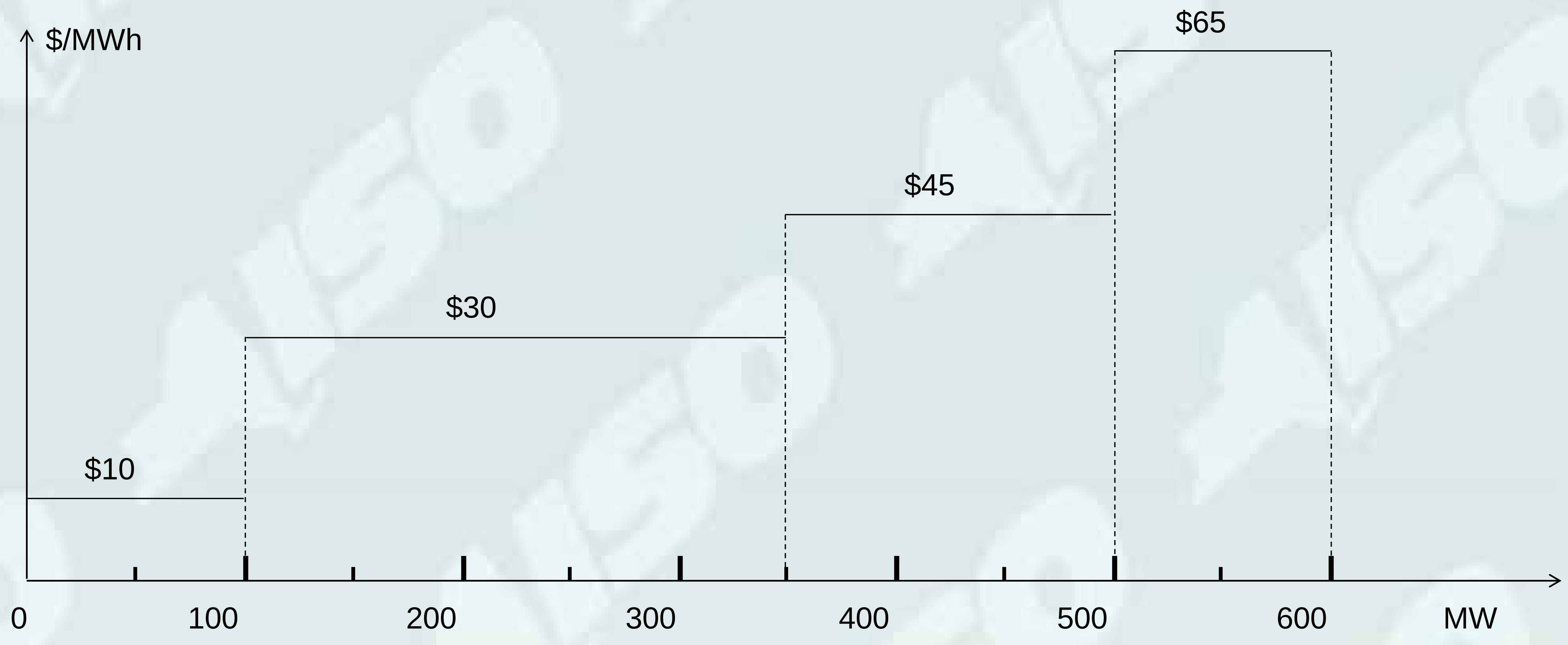


LOAD

TEC Example -- Today's Bid



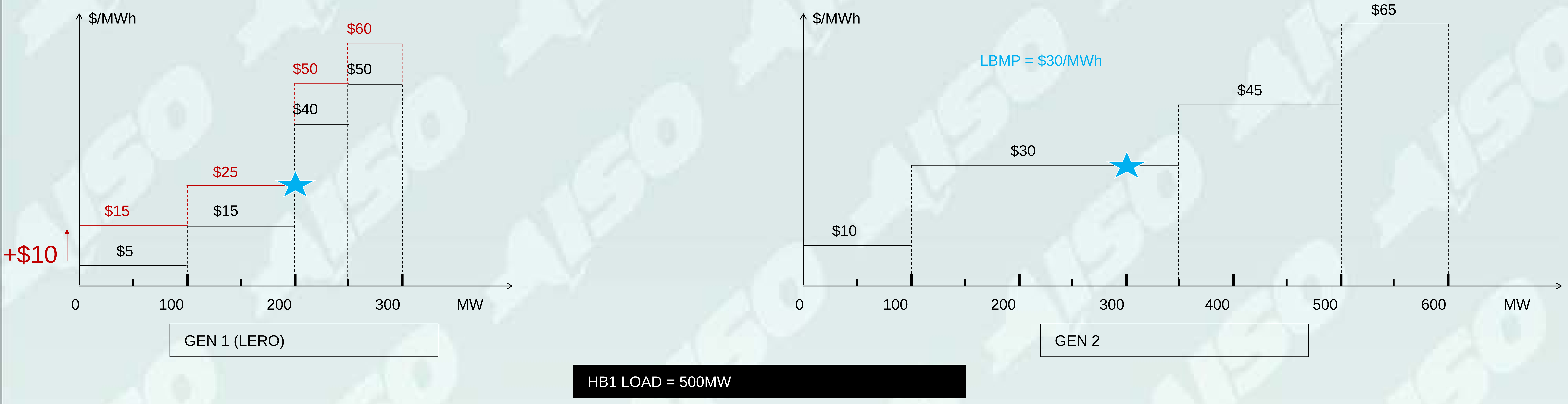
GEN 1 (LERO)



GEN 2

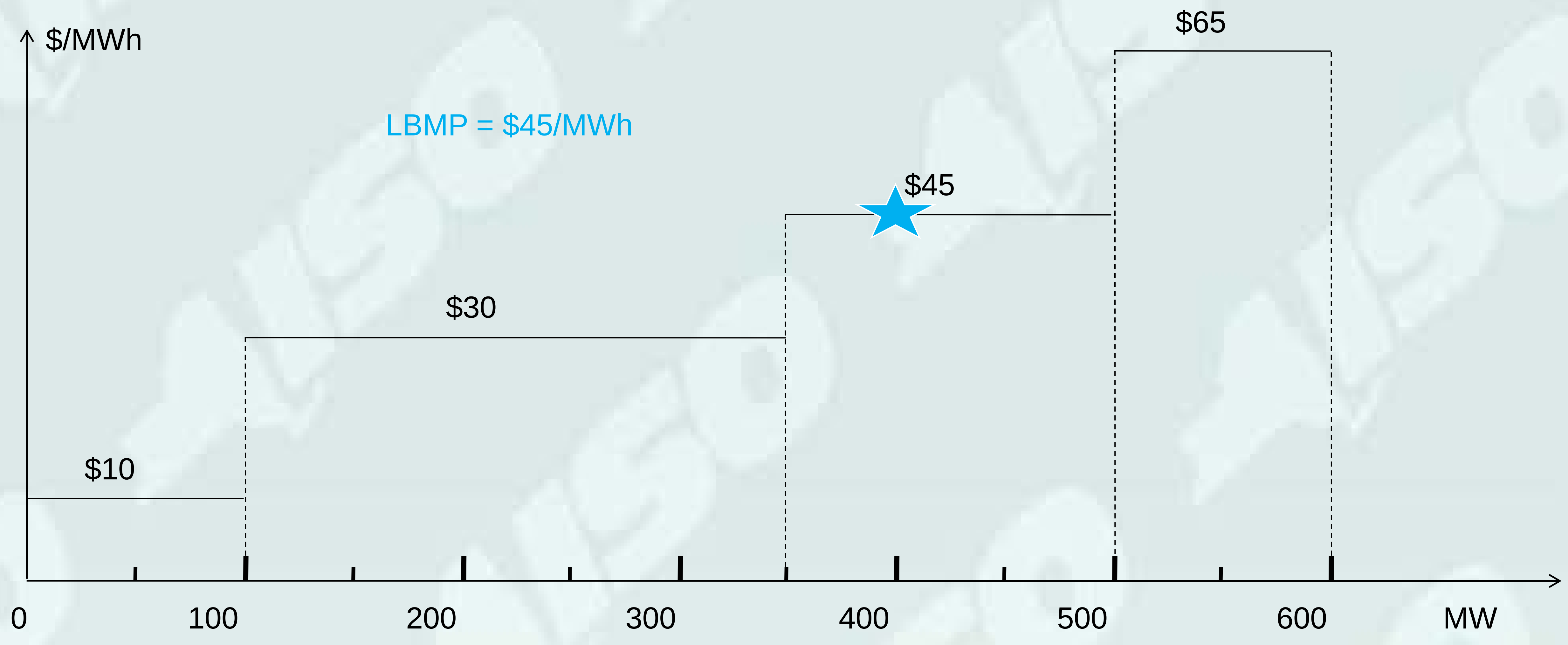
HB1 LOAD = 500MW

TEC Example -- Today's Bid



TEC Example -- Today's Bid

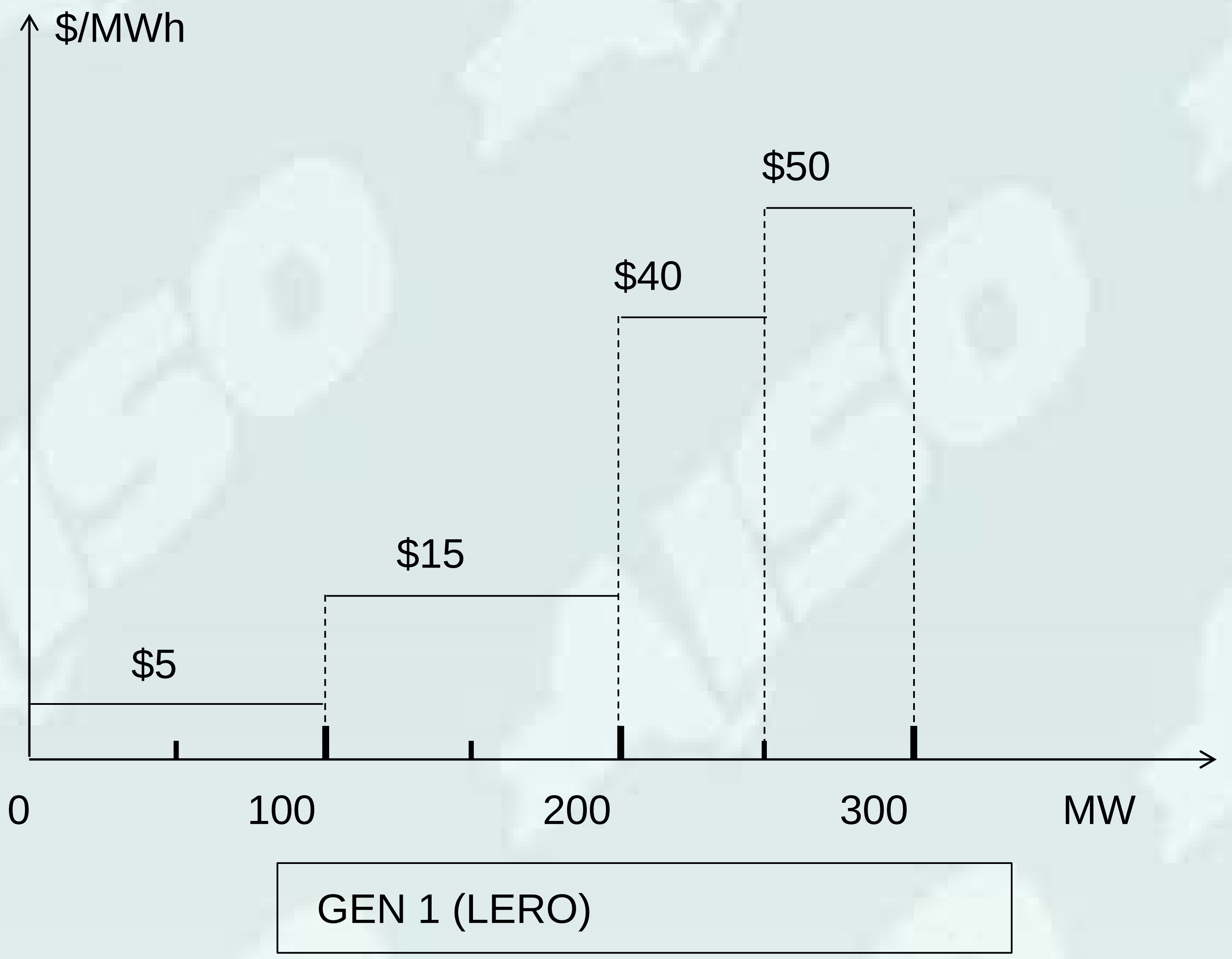
GEN 1 (LERO)

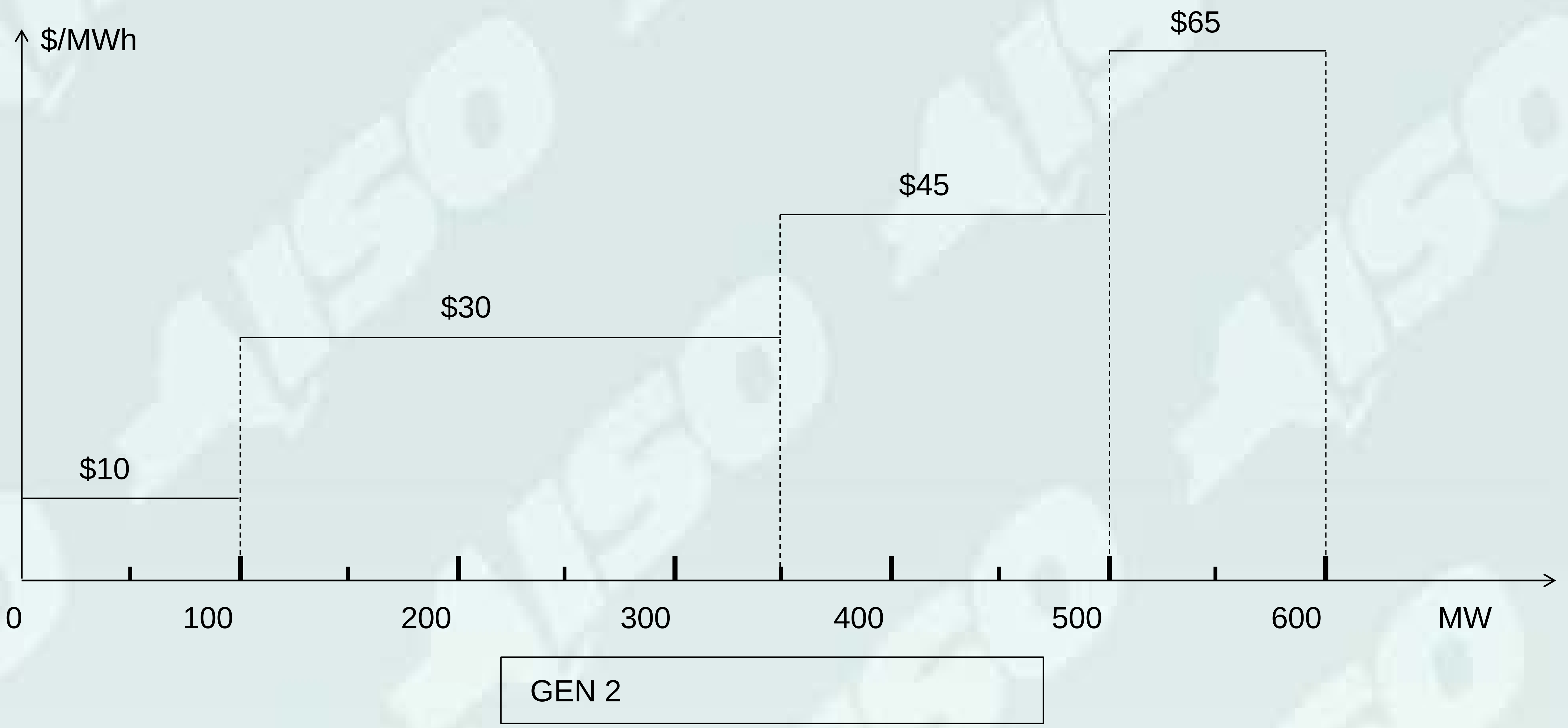


GEN 2

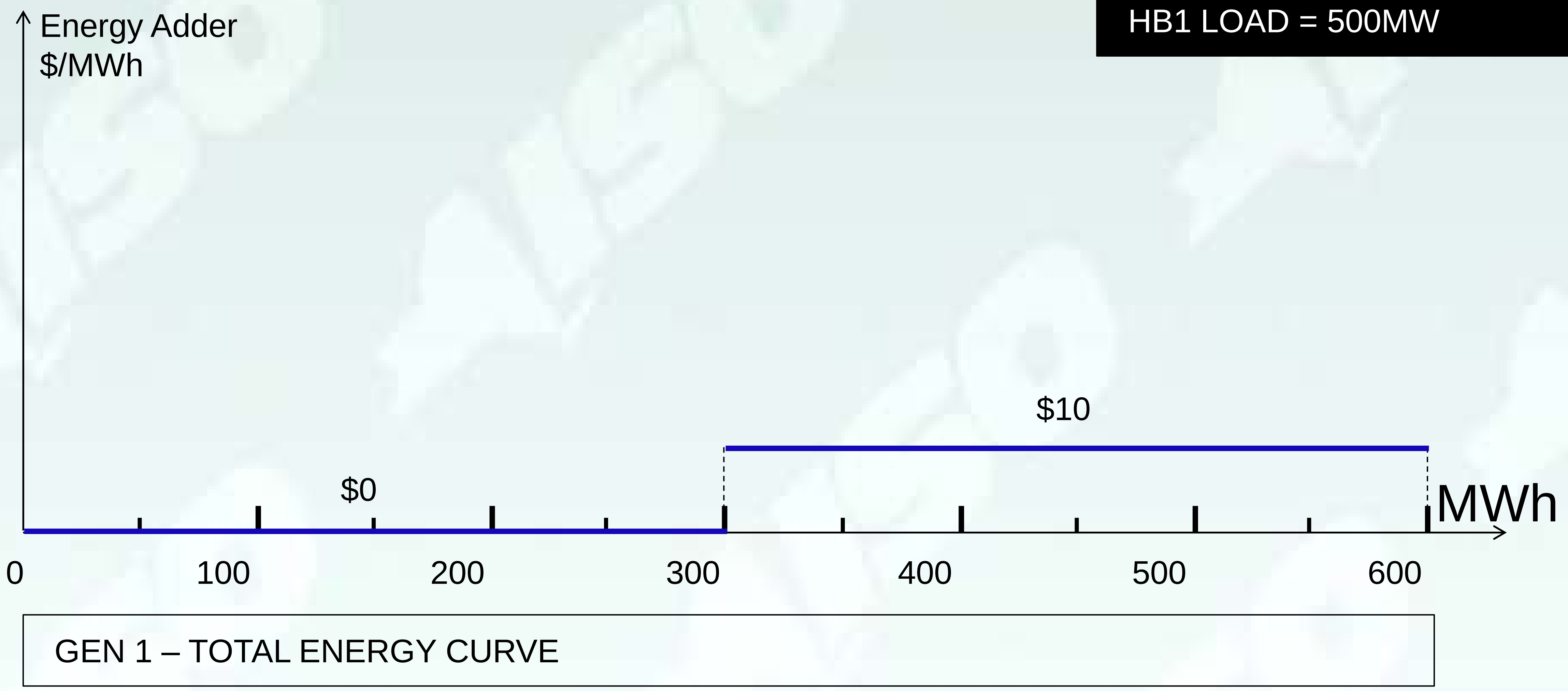
HB2 LOAD = 650MW

TEC Example -- LERO's Bid

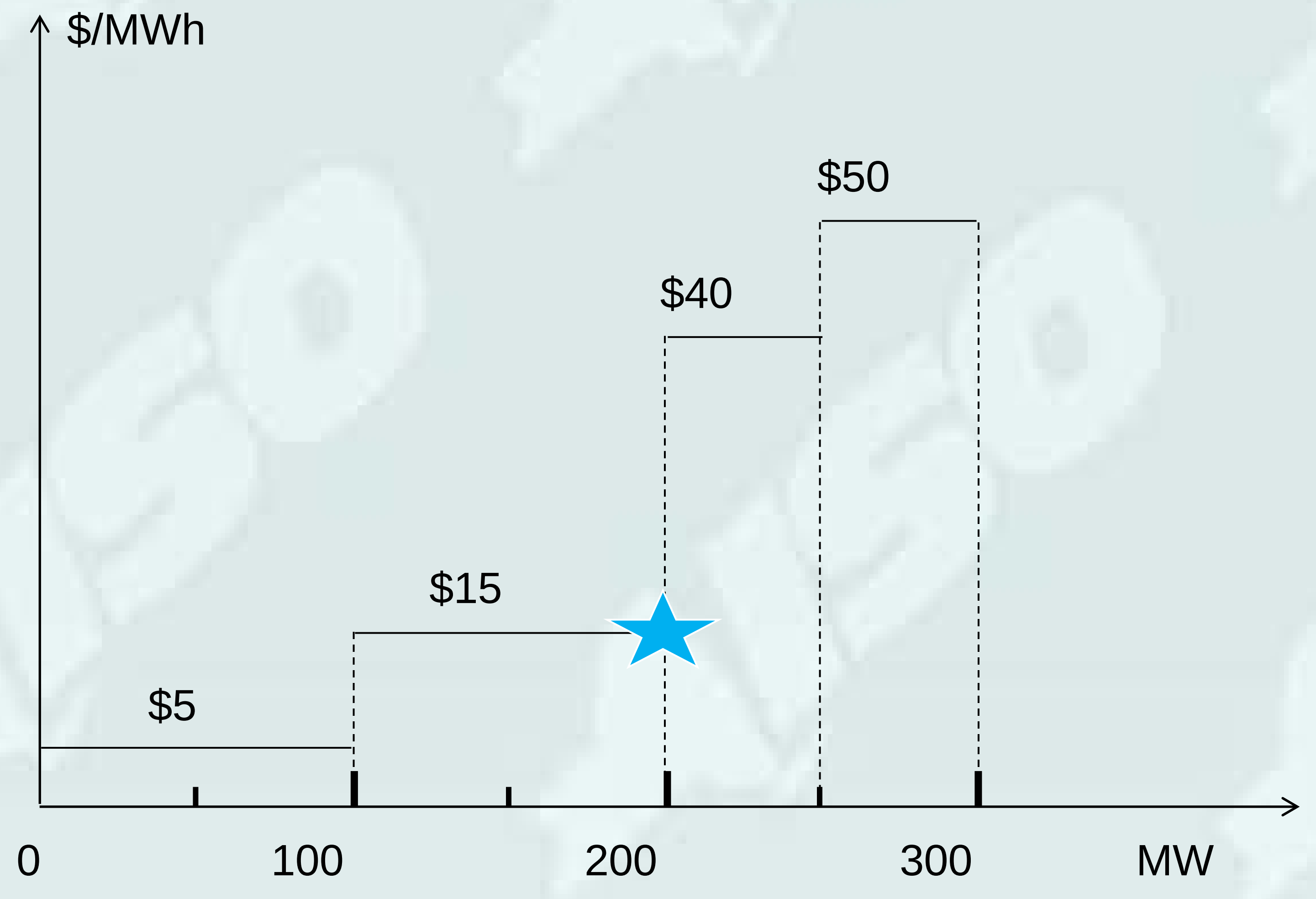




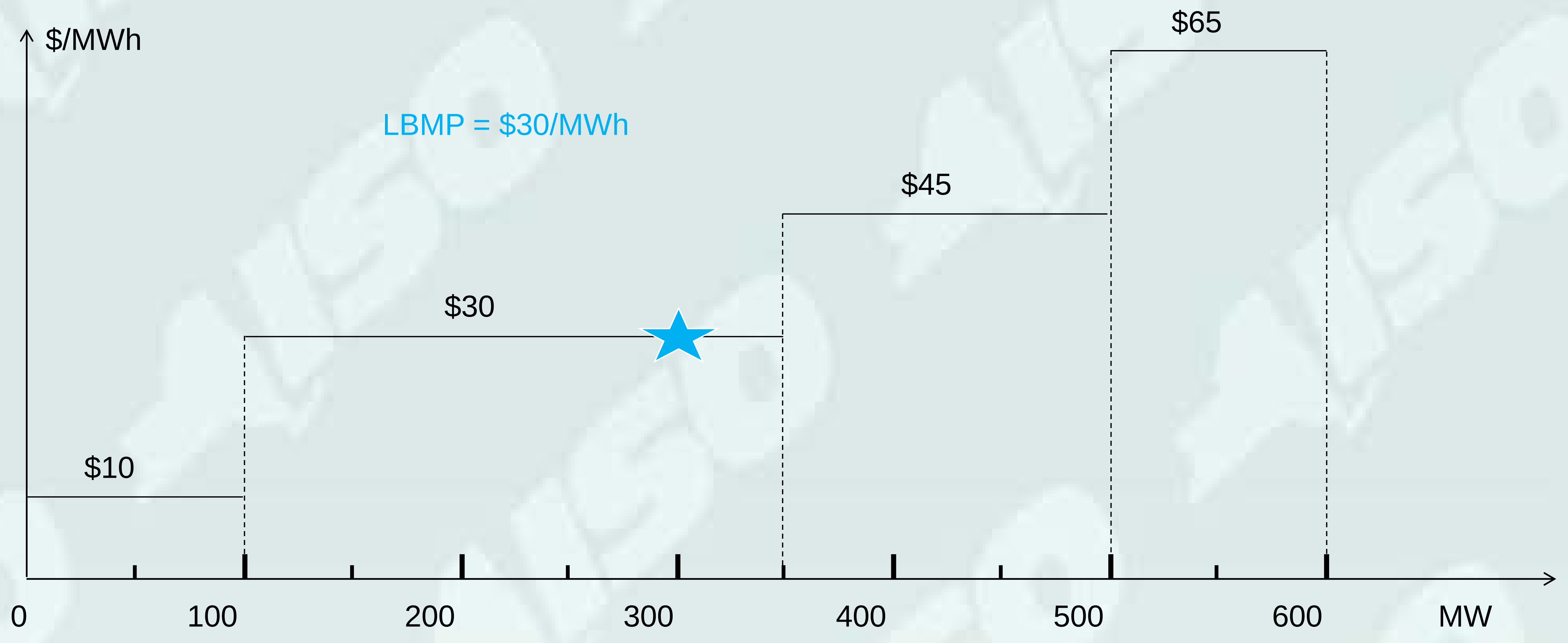
HB1 LOAD = 500MW



TEC Example -- LERO's Bid

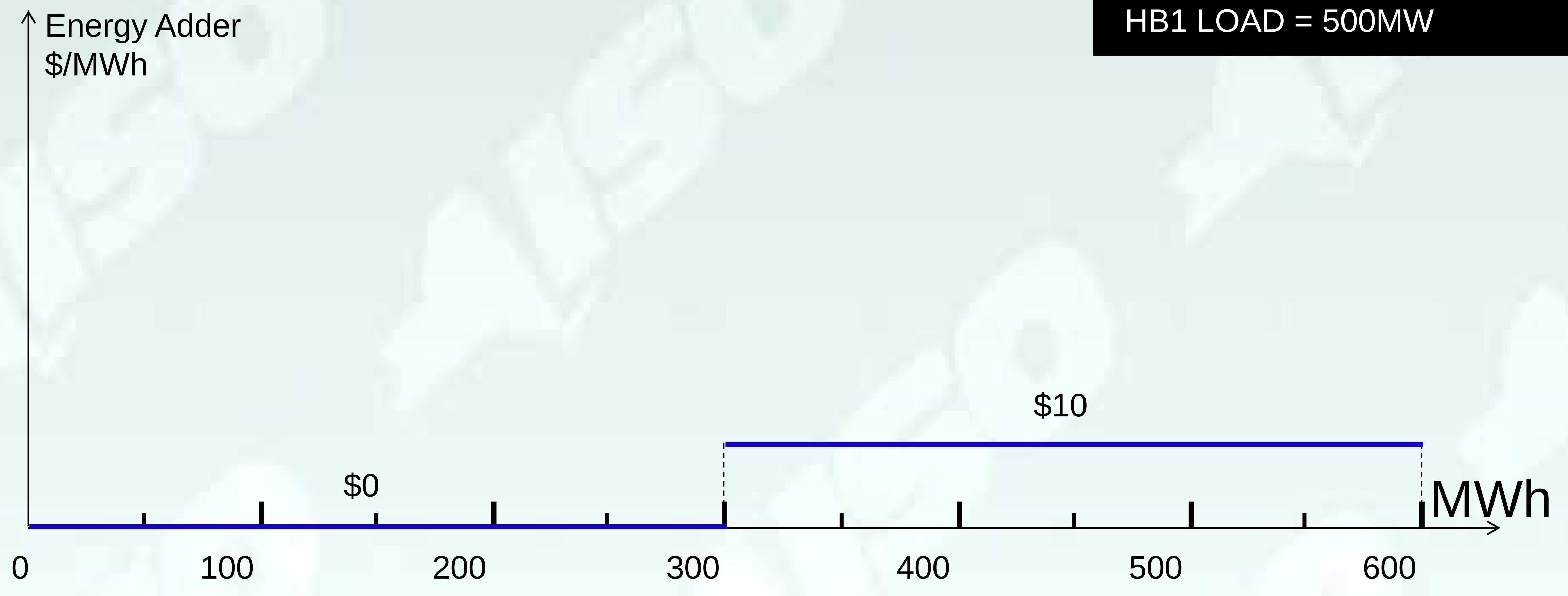


GEN 1 (LERO)



GEN 2

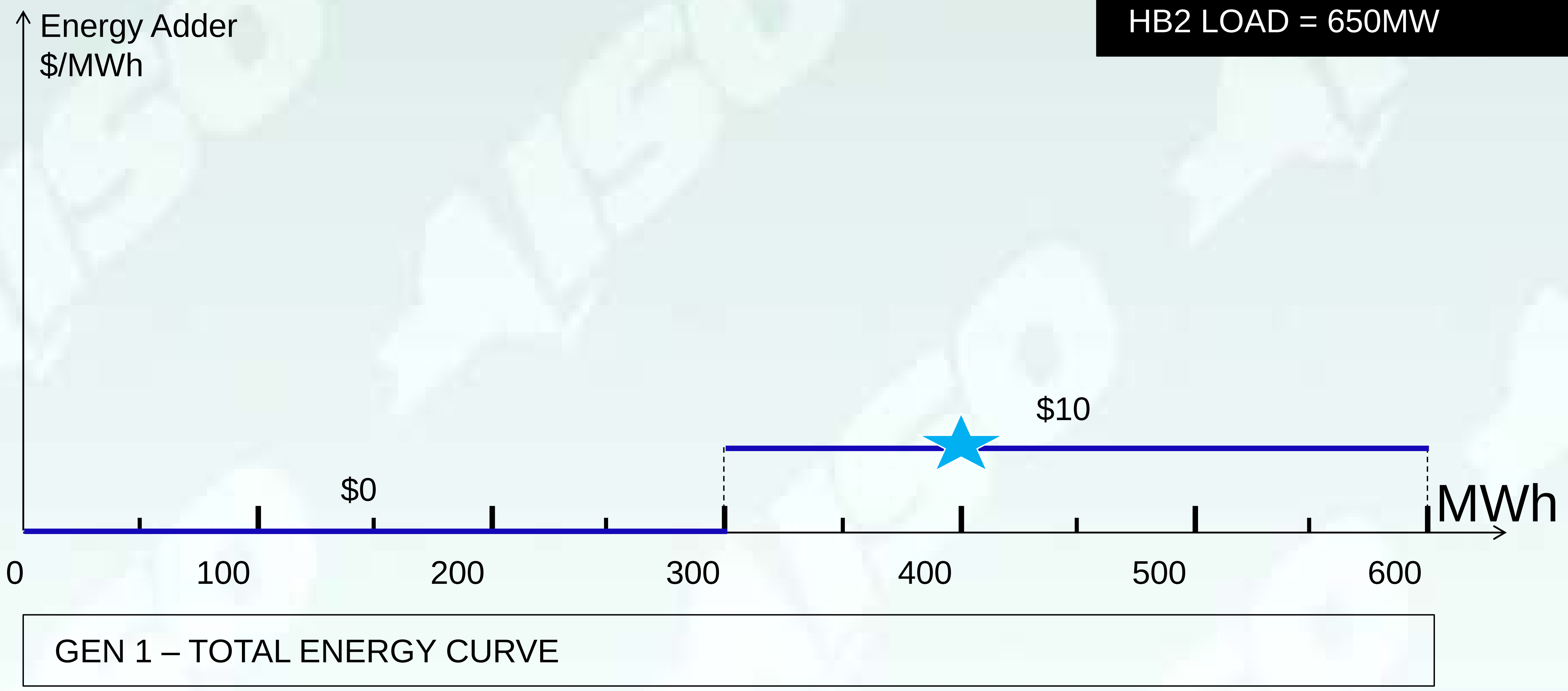
HB1 LOAD = 500MW



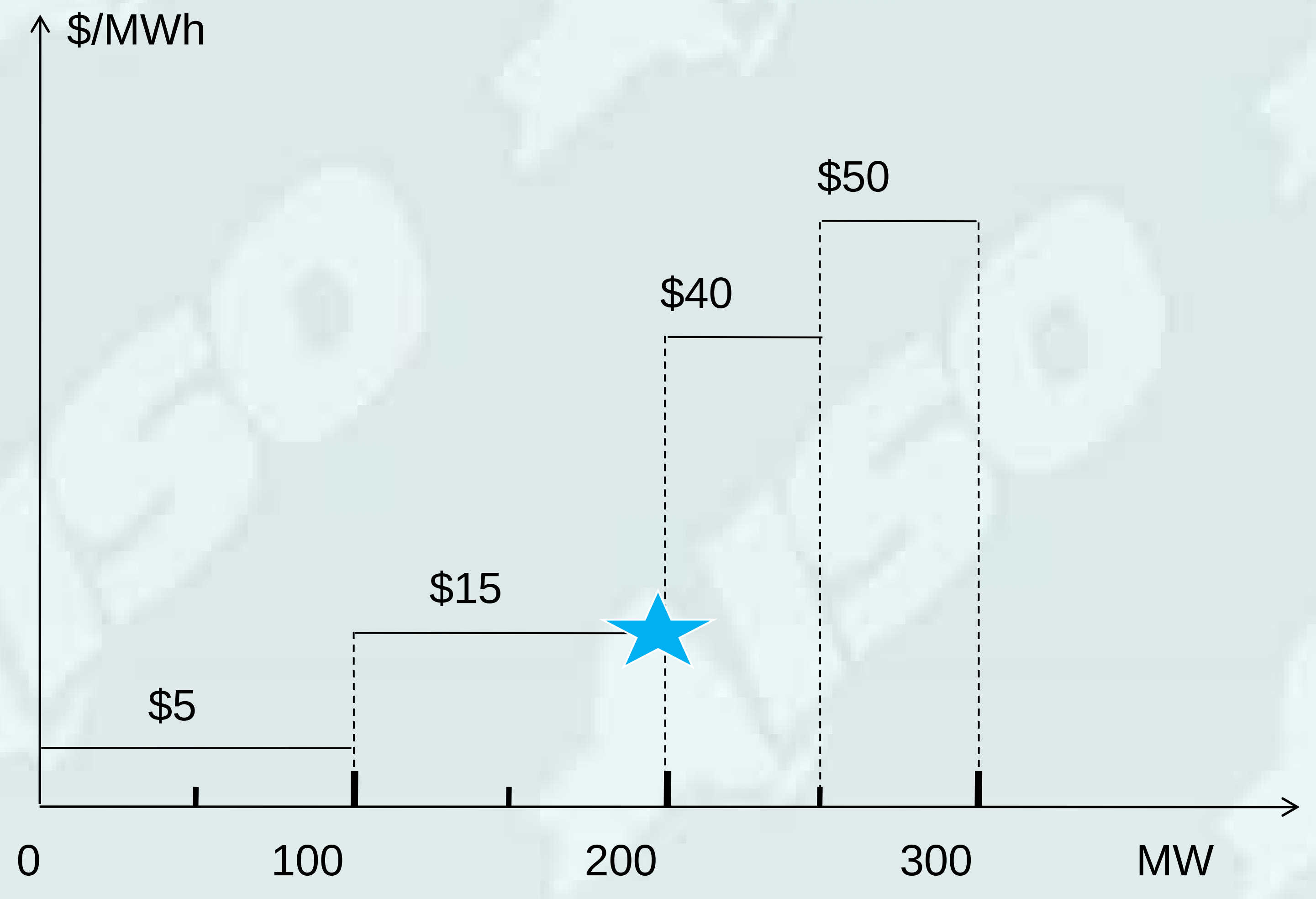
GEN 1 – TOTAL ENERGY CURVE

TEC Example -- LERO's Bid

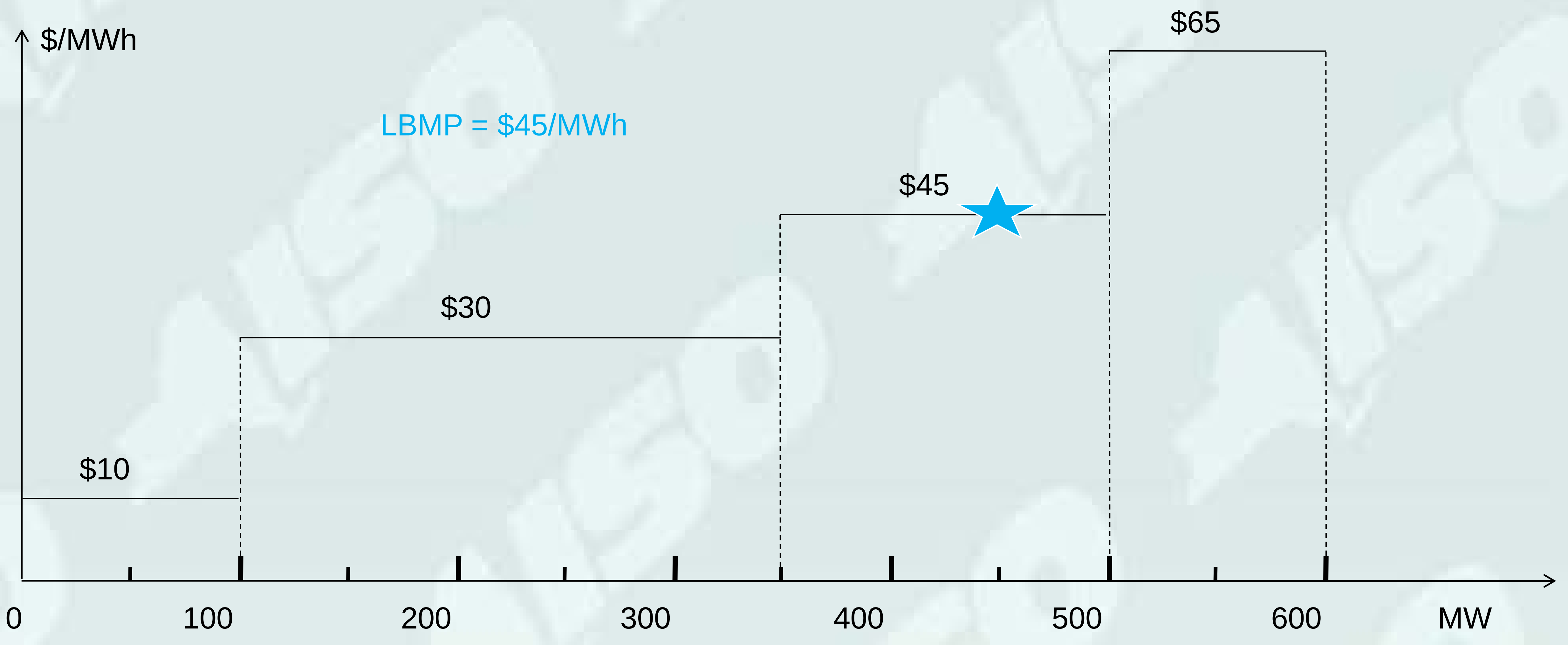
HB2 LOAD = 650MW



TEC Example -- LERO's Bid

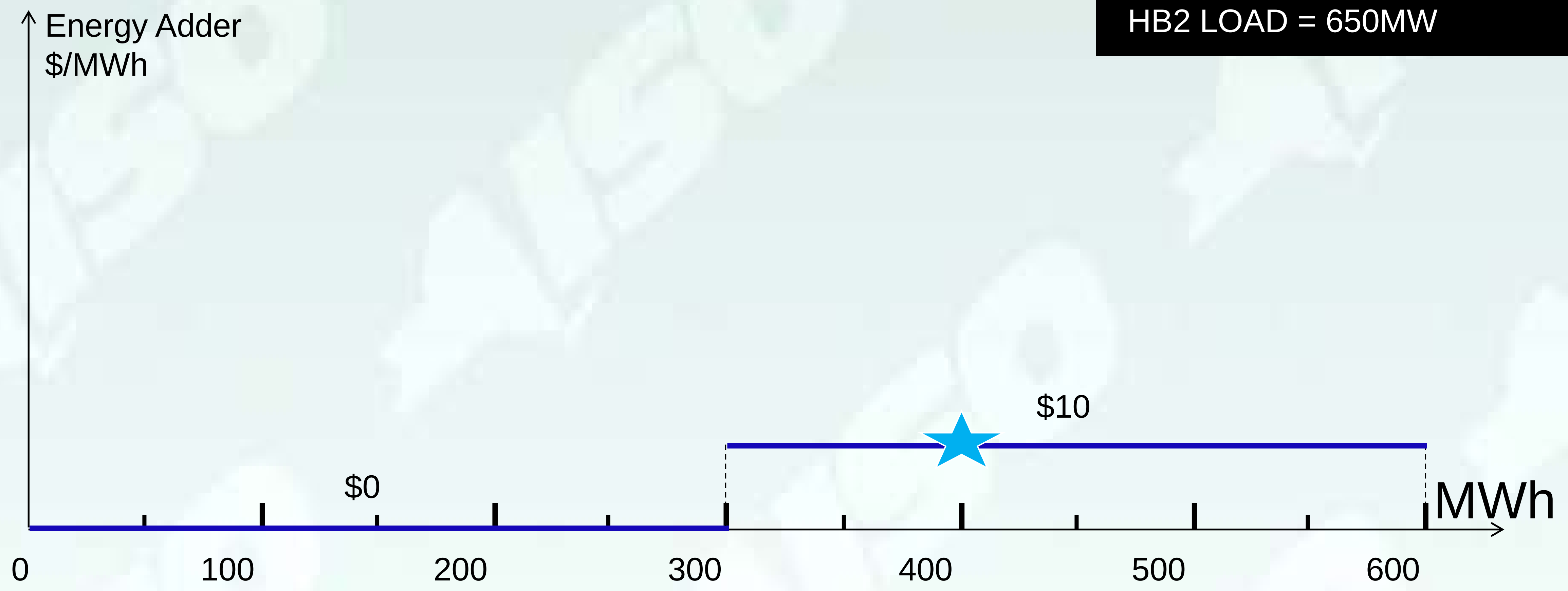


GEN 1 (LERO)



GEN 2

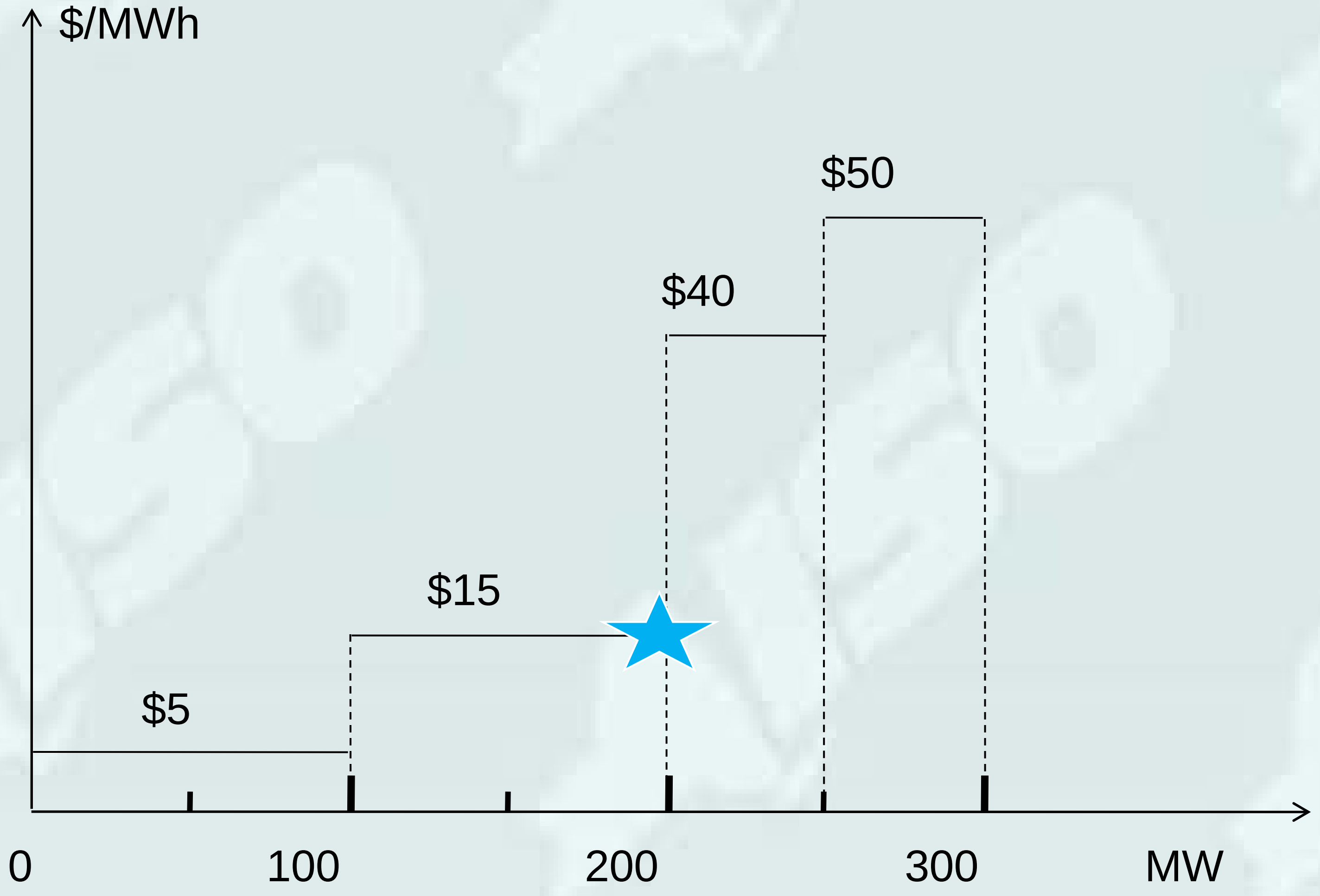
HB2 LOAD = 650MW



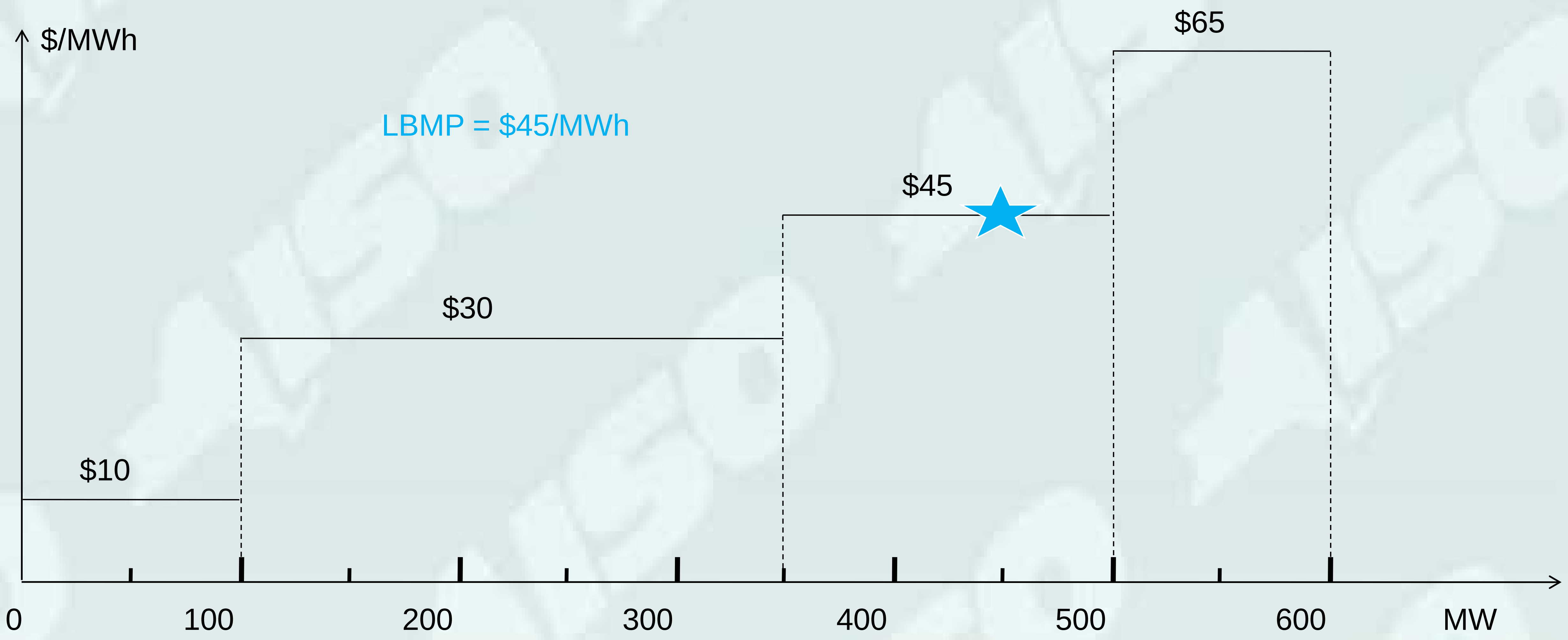
GEN 1 – TOTAL ENERGY CURVE

GEN SCHEDULE [MW]	Today's Bid		LERO's Bid	
	HB1	HB2	HB1	HB2
GEN1 (LERO)	200	250	200	200
GEN2	300	400	300	450

TEC Example -- LERO’s Bid

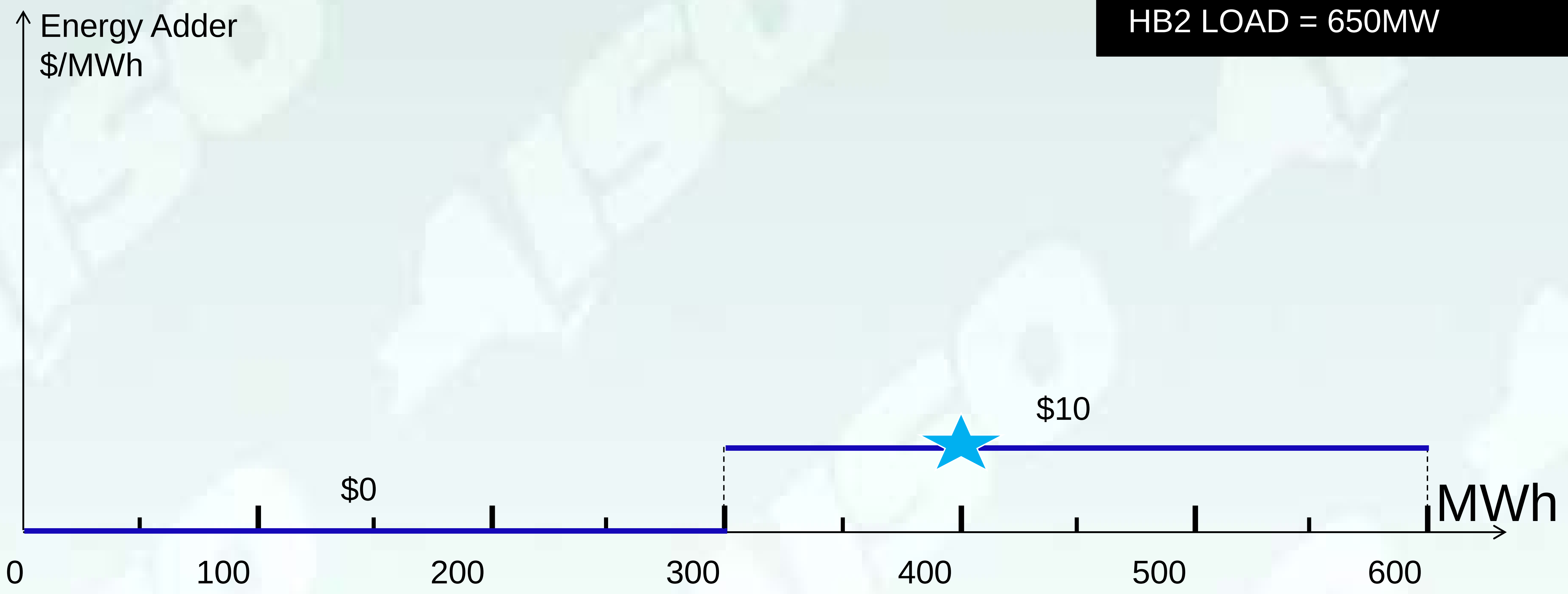


GEN 1 (LERO)



GEN 2

HB2 LOAD = 650MW



GEN 1 – TOTAL ENERGY CURVE

GEN SCHEDULE [MW]	Today's Bid		LERO's Bid	
	HB1	HB2	HB1	HB2
GEN1 (LERO)	200	250	200	200
GEN2	300	400	300	450

TEC Example -- Summary

- **Gen Schedule and LBMP:**
  - ***GEN1 activated the Total Energy Curve constraint***
  - ***GEN2 was marginal in both hours***

GEN SCHEDULE MW	Today's HB1	HB2	LERO's HB1	HB2
GEN1 (LERO)	200	250	200	200
GEN2	300	400	300	450
LBMP ($/MWh)	30	45	30	45

- **This example demonstrates how market efficiency and generator revenues can be improved through a generator's reflection of fuel cost adders in a Total Energy Curve rather than guessing when and where to place adders in hourly bids under the current bidding construct.**

Gen 1 Strategy	Gen 1 Actual Production Cost	Total System Production Cost	Gen 1 Net Revenue	Gen 2 Net Revenue2
Adder placed in HB1 hourly bids (current bid construct)	$ 7,500	$ 25,250	$ 9,750	$ 9,250
Adder in Total Energy Curve (Fuel Constrained Bidding)	$ 5,000	$ 25,000	$ 10,000	$ 9,250
Delta	$ (2,500)	$ (250)	$ 250	$ -

Option 2: Fuel Cost & Efficiency Curve Bidding (FEC)

- **This design would allow the Market Participant to submit:**
  - ***Hourly three-part bids for a generator or each generator in a portfolio, with fuel cost adders removed from their Incremental Energy bids***
  - ***A cost curve reflecting total fuel purchases (eg. MMBtu) and cost to procure incremental volumes of fuel ($/MMBtu) for the generator or portfolio***
  - ***Efficiency curve or heat rate curve reflecting the conversion between fuel (eg. MMBtu) and output (MWh) for the generator or each generator in the portfolio***

Option 2: FEC Problem Formulation

Prevailing objective function costs:

$$Min \sum_{i}\sum_{t}(C^{0}_{i,t} \times u_{i,t}) + \sum_{t}\sum_{i}\sum_{b}(C_{b,i,t} \times P_{b,i,t}) + \sum_{j}\sum_{bf}(CF_{bf,j} \times F_{bf,j}) \quad (8)$$

Energy balance constraint:

$$\sum_{i}\sum_{b} P_{b,i,t} = Load_t \quad (9)$$

Generator constraint:

$$P^{min}_{b,i} \times u_{i,t} \leq P_{b,i,t} \leq P^{max}_{b,i} \times u_{i,t} \quad (10)$$

$$P_{i,t} = \sum_{b} P_{b,i,t} \quad (11)$$

Total fuel constraint:

$$0 \leq F_{bf,j} \leq F^{max}_{bf,j} \quad (12)$$

$$\sum_{t}\sum_{i \in C_j}\left(HR^{MinGen}_{i,t} \times u_{i,t} + \sum_{b} IHR_{b,i,t} \times 10^{-3} \times P_{b,i,t}\right) = \sum_{bf} F_{bf,j} \quad (13)$$

Operational flow order constraint:

$$-(1 - u_{i,t}) \times UOL_{i,t} \leq P_{i,t} - P_{i,t-1} \leq (1 - u_{i,t-1}) \times UOL_{i,t}, i \in C_j \quad (14)$$

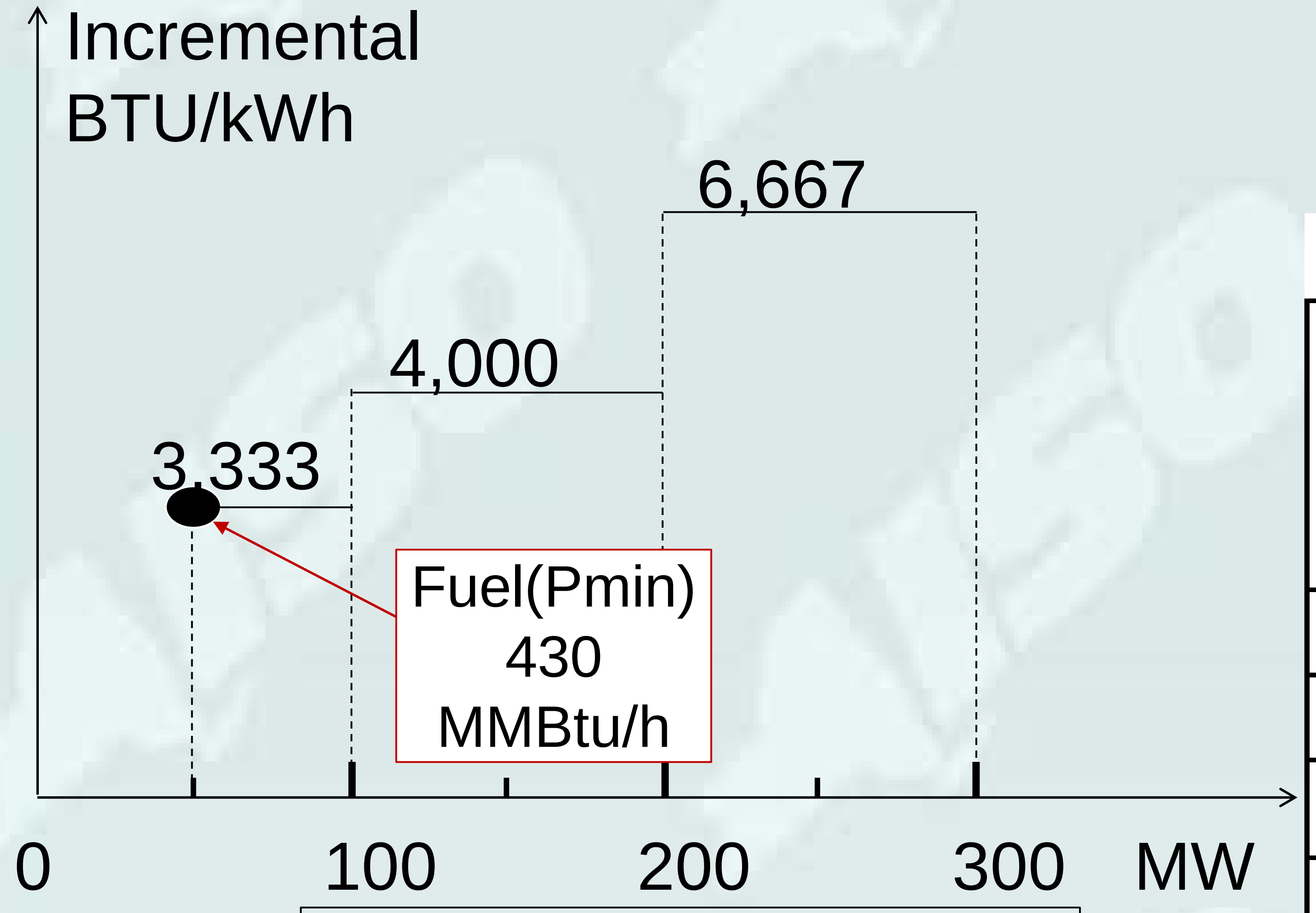
FEC Example

GEN1 fuel cost

Natural gas	7.5 $/MMBTU

GEN1 mingen

Mingen	50 MW
Fuel input at mingen	430 MMBTU/h
Mingen Cost	3,225 $/h
Start-up Cost	0 $

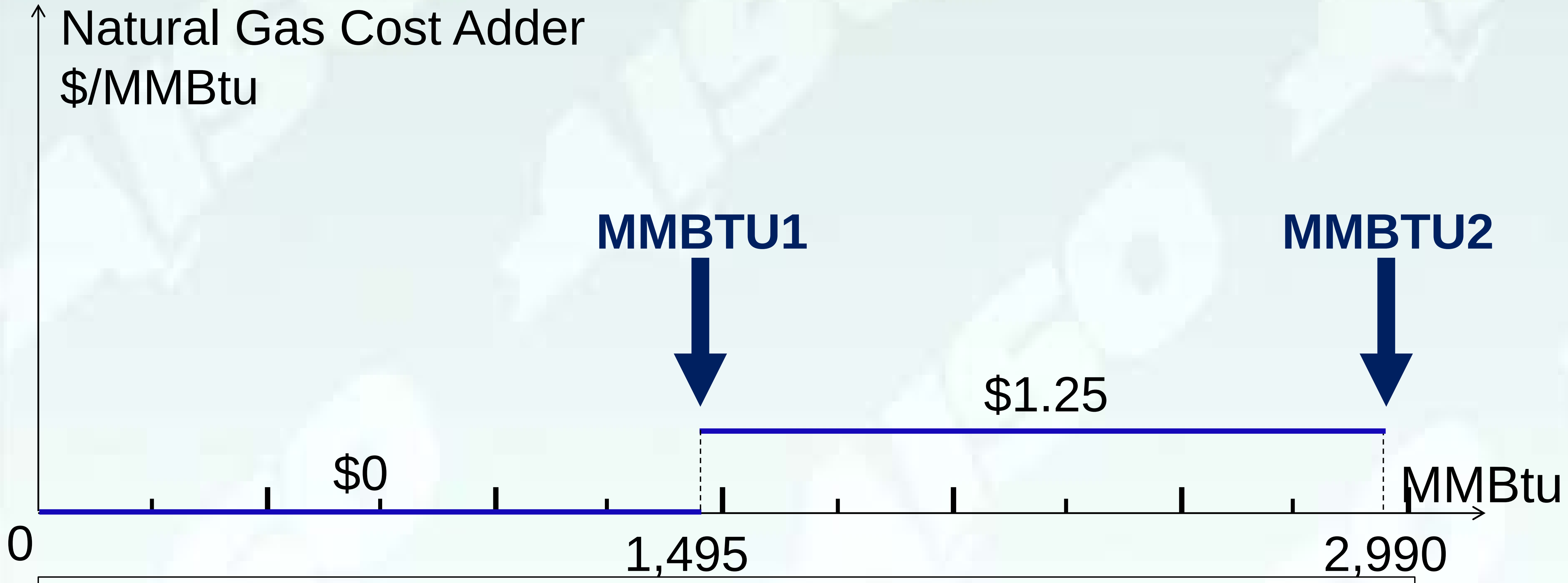


GEN 1 (LERO)

GEN1 Fuel Efficiency Curve			GEN1 Conversion values						
Block Index	*Break Point, MW*	*Incremental Heat Rate, BTU/kWh*	*Incremental Energy Cost, $/MWh*	*Fuel consumption, MMBTU/h*	*Average Heat Rate, BTU/kWh*	*Efficiency, %*	*Energy Output 1, MWh**	*Energy Output 2, MWh***	*Incremental Cost Adder, $/MWh*
1	50	2,667	20	430	8,600	40%	174	348	3.33
2	100	3,333	25	597	5,967	57%	251	501	4.17
3	200	4,000	30	997	4,983	68%	**300**	**600**	**5.00**
4	300	6,667	50	1,663	5,544	62%	**270**	**539**	**8.33**

* Conversion energy at MMBTU1 fuel consumption

** Conversion energy output at MMBTU2 fuel consumption



GEN 1 – FUEL COST CURVE

Note:

- *Base fuel cost is $7.5/MMBTU. Column “Incremental Energy Cost, $/MWh” shows equivalent energy bid*
- *Total fuel available to the generator is 2,290 MBTU*
- *If the unit consumes above1,495MMBTU, the unit will incur additional $1.25/MMBTU*

FEC Example

GEN1 fuel cost

Natural gas	7.5 $/MMBTU

GEN1 mingen

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Fuel input at mingen	430 MMBTU/h
Mingen Cost	3,225 $/h
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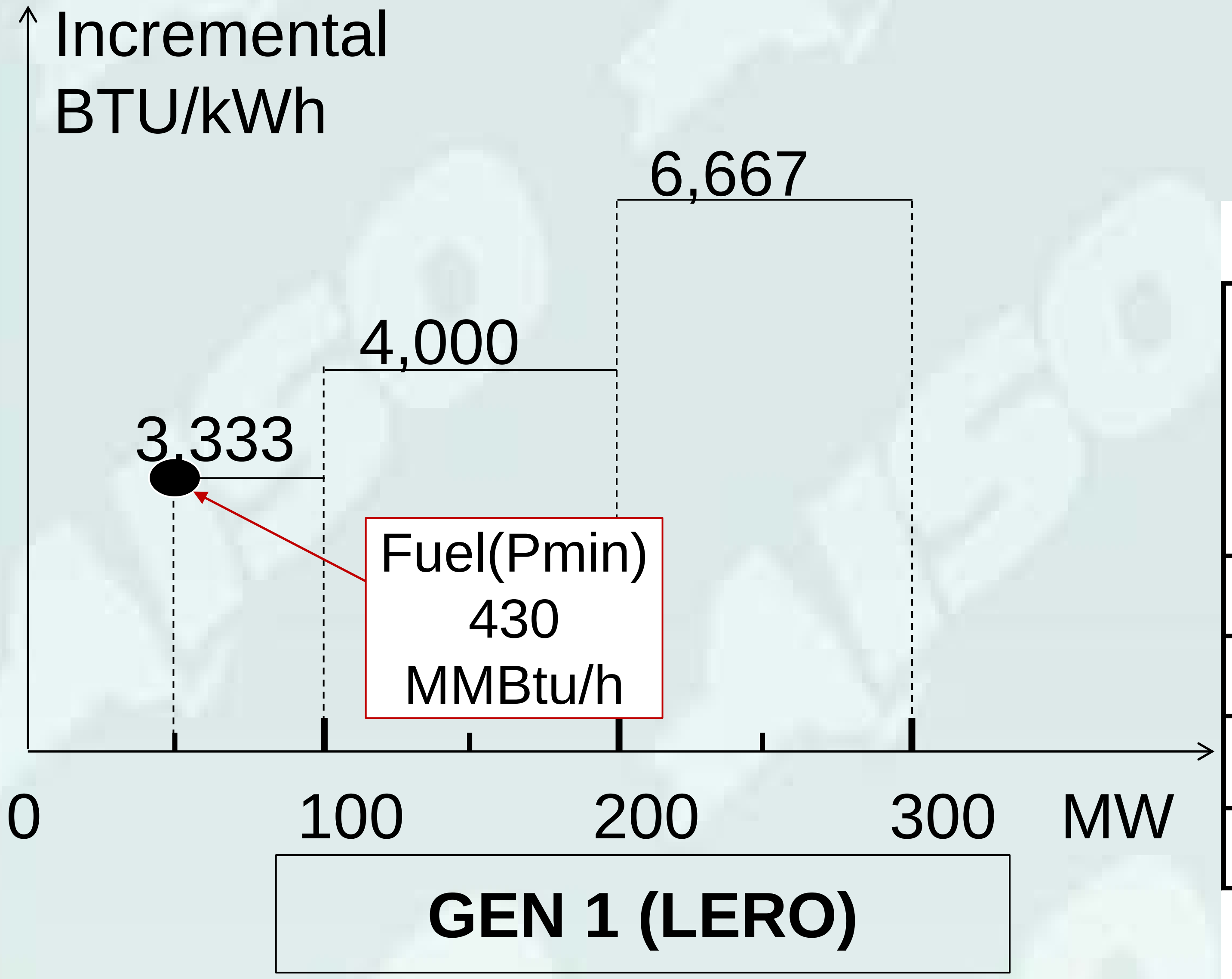

GEN1 Fuel Efficiency Curve			**GEN1 Conversion values**						
Block Index	*Break Point, MW*	*Incremental Heat Rate, BTU/kWh*	*Incremental Energy Cost, $/MWh*	*Fuel consumption, MMBTU/h*	*Average Heat Rate, BTU/kWh*	*Efficiency, %*	*Energy Output 1, MWh**	*Energy Output 2, MWh***	*Incremental Cost Adder, $/MWh*
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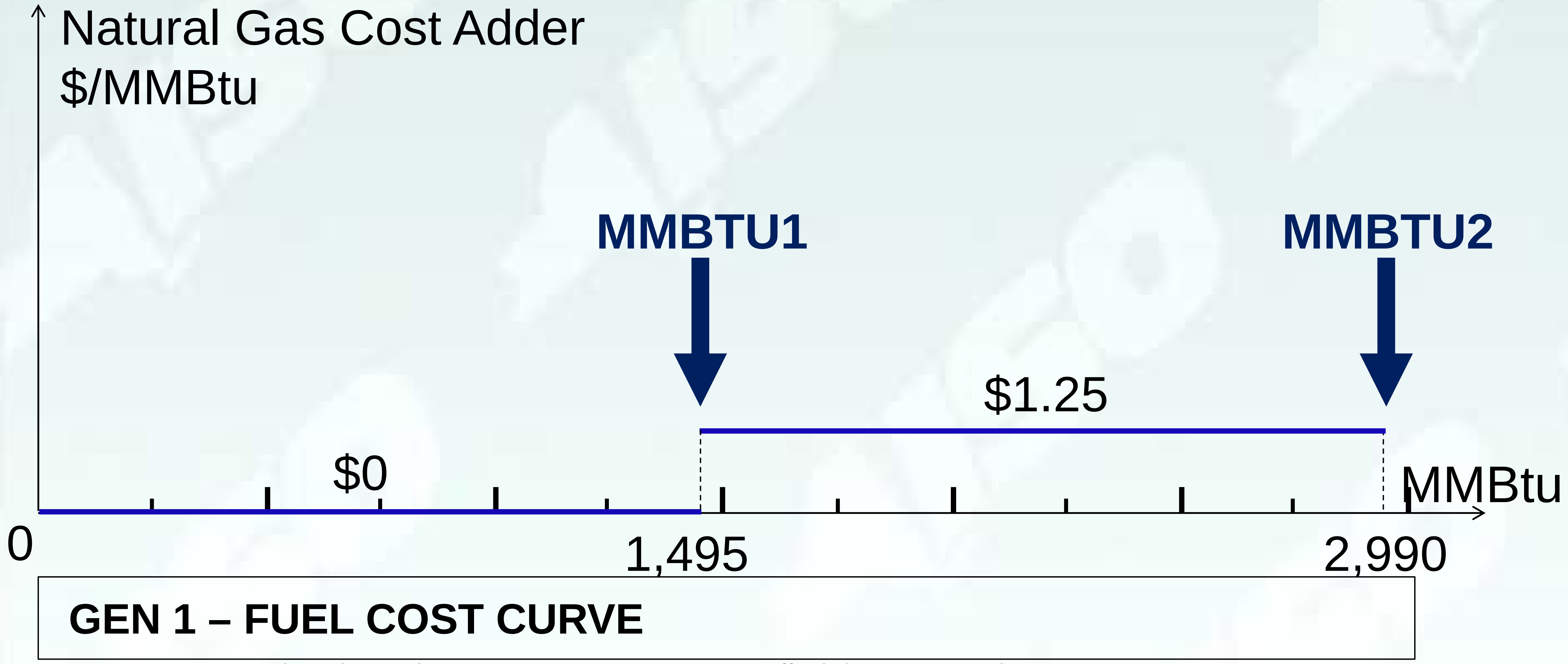
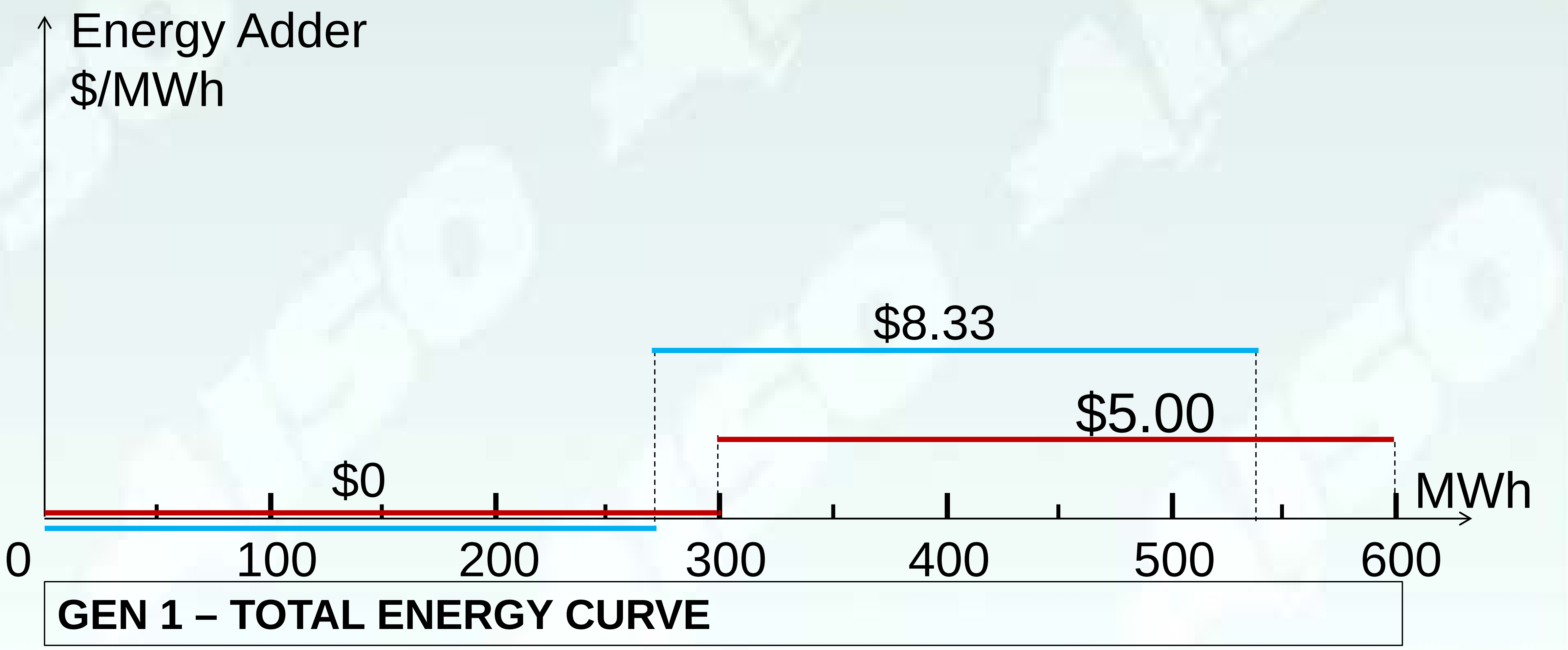
* Conversion energy at MMBTU1 fuel consumption

** Conversion energy output at MMBTU2 fuel consumption

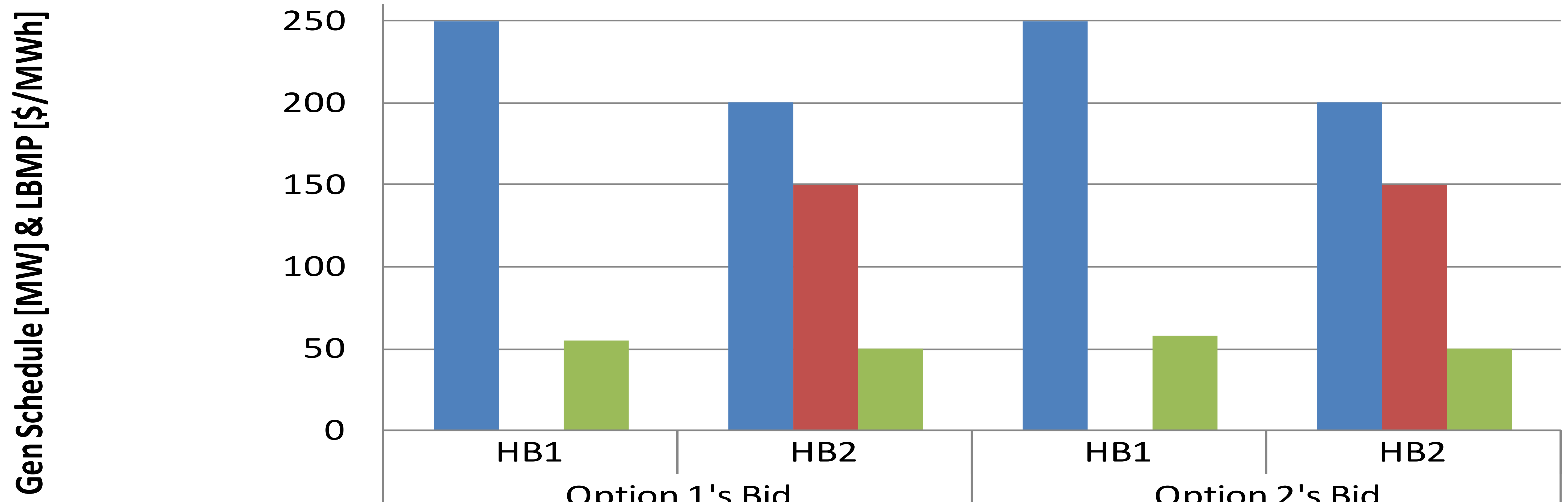




FEC Example -- 68% Efficiency Conversion*

- **68% Efficiency Conversion:** This example shows a lower revenue for Gen 1 in HB1 where it is marginal. Conversion at a lower power point ($5/MWh adder) than actual production ($8.33/MWh) resulted in **a revenue loss** for Gen 1. No change to gen schedule & prod cost.

Gen 1 Strategy	Gen 1 Actual Production Cost	Total System Production Cost	Gen 1 Net Revenue	Gen 2 Net Revenue
Adder in Total Energy Curve	$ 18,490	$ 25,490	$ 5,260	$ 500
Adder in Fuel Cost and Efficiency Curve	$ 18,490	$ 25,490	$ 6,093	$ 500
Delta	$ -	$ -	$ 833	$ -



	HB1 (Option 1's Bid)	HB2 (Option 1's Bid)	HB1 (Option 2's Bid)	HB2 (Option 2's Bid)
GEN1 (LERO) [MW]	250	200	250	200
GEN2 [MW]	0	150	0	150
LBMP ($/MWh)	$55.00	$50.00	$58.33	$50.00

*** Reference :** http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_miwg/meeting_materials/2016-03-23/agenda%208%20Fuel%20Constrained%20Bidding%20%20MIWG%2032316.pdf

Conclusion

- **Both options reduce the risk of estimating where and when to impose the energy/fuel cost adder**
- **Option 1: Total Energy Curve (output constraint) accurately optimizes the <u>limited energy</u> available to the generator(s)**
- **Option 2: Fuel Cost & Efficiency Curve (input constraint) accurately optimizes the <u>limited fuel</u> available to the generator(s)**
  - ***Option 2 will enable more complex future models such as emission control and gas-electric coordination***
- **If LERO generator/portfolio efficiency is uniform, Option 2 is identical to Option 1**

The Mission of the New York Independent System Operator, in collaboration with its stakeholders, is to serve the public interest and provide benefit to consumers by:

- ***Maintaining and enhancing regional reliability***
- ***Operating open, fair and competitive wholesale electricity markets***
- ***Planning the power system for the future***
- ***Providing factual information to policy makers, stakeholders and investors in the power system***

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