Stochastic Nodal Adequacy Pricing (*SNAP*™): Methodology for Dealing with Demarginalization

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Outline

- What is the problem that ***SNAP***™ is focused on solving
- What is ***SNAP***™ (as a component of Nodal Level Adequacy or NLA) and how would it work?
- ***SNAP***™ Mathematics
- ***SNAP***™ Numerical Examples

What is the Problem? *Zero Marginal Cost*

- The potential for ***multiple*** zero marginal cost and/or negative bid units to set the market clearing prices happens today (e.g., curtailments) but clearly increases in likelihood as we move forward with new State level programs focused on ZERO emissions from the power sector.
- Between now and 2050 there is a need to significantly alter the way in which resource adequacy is defined and calculated
  - In the past there was a generally known and accepted probability of generating units going offline – caused primarily by physical failures.
  - Looking forward, the intermittency / uncertainty of renewable generation coming on and going offline no longer is a physical failure issue but is stochastics based on weather.

Conclusion: The structure of Least Cost Dispatch needs to be REDEFINED to incorporate:

- The use of Non-Zero Marginal Costs where they remain (LBMPs) for the transition to 2050 AND
- *Quantifiable measures of the value of resource adequacy*
  - Reflecting the value of *EVERY* energy resource
    - Positive or negative
    - Fossil or non fossil, schedulable or intermittent
  - Recognizing both the SPATIAL and TEMPORAL nature of the problem in a new framework.
- Requires an economically based stochastic (e.g., Monte Carlo) approach to resource adequacy rather than the engineering based approach as currently applied

The good news…We now have cloud computing

- With Cloud Computing we can run THOUSANDS of scenarios
- Incorporate the stochastic uncertainties of:
  - Traditional generation
  - Transmission
  - Demand
  - Behind-the-meter generation
  - Price based demand response
- Most importantly … Incorporate the stochastic Intermittency of renewable resources

Our Proposal: Stochastic Nodal Adequacy Pricing (*SNAP*™)

Identify the expected (probabilistically determined) value of resource adequacy at every node in the system such that the value of resource adequacy can be incorporated into the price of delivered energy as seen by consumers.

SNAP™: The Steps …

1. Develop / Quantify or simply define the ***VALUE OF LOST LOAD*** (VOLL) that reflects:
    - The cost to society of not supplying an incremental MWh
    - The monetary value of shed load.
    - [Initially a single value; overtime more complex by customer class, location and time block, etc.]
2. Energy Suppliers would offer into the ISO Day Ahead Market
    - Only those suppliers that are committed in the DAM to provide energy or ancillary services would be available to receive SNAP payments
3. The ISO would then solve the Day Ahead Market on an hourly basis for the next day as is done now.
4. Given knowledge of the offers and the sources and locations of those offers, ISO would perform the Day Ahead *SNAP* assessment and determine day-ahead adequacy payment to all suppliers *accepted* in DAM

Reliability Dispatch (RD): ISO would, as a matter of routine:

- Define and perform a ***very large number*** of RD Monte Carlos scenario simulations each testing the resource adequacy of the system for the Day Ahead horizon at each node.
- Each RD scenario is a Security Constrained Optimal Power Flow (SCOPF) calculation in which *all* available resources are entered into the analysis at zero cost.
- When there is load sheading the it sets the dispatch order and prices.
- RD assess the feasibility of the grid to serve demand under transmission and generation contingencies subject to system topology and availability of resources whether traditional or renewable
- The solutions are driven by weather and by load that is modeled stochastically to account for behind the meter generation, new electrification loads such as electric vehicles and any time or condition or price-based demand response.

Stochastic Nodal Adequacy Price (*SNAP*™) #1

- In each hour *h* for each node *n* and each scenario *k*, compute the ***Stochastic Nodal Adequacy Price*** (SNAP(*h,n,k*))
- If the system is feasible, SNAP(*h,n,k*) = 0 at all nodes.
- If the system is infeasible and load must be shed somewhere, the RD yields non-zero SNAP values varying by location.
- In each scenario *k*, a resource is paid SNAP at its node for each MW available for that scenario times the probability weight of that scenario.
- Actual payment is computed as a sum of payments over all scenarios.

Stochastic Nodal Adequacy Price (*SNAP*™) #2

- Load payments under each scenario are determined by the *SNAP*™ value at the load node or zone times the load served after load shedding; multiplied by the scenario weight.
- In each scenario, a transmission facility earns the *adequacy rent* – the difference in *SNAP* values under that scenario times the flow determined in the RD solution and multiplied by the probability weight of the scenario.
- The total DAM payment to and by all parties is the sum of payments based on LBMPs and on *SNAP*s.

The Beauty of *SNAP*™ and NLA

- ***SIMPLICITY*** in concept
- Even if computationally intense

- This just ***Solved the scarcity pricing problem*** for all resources including transmission!

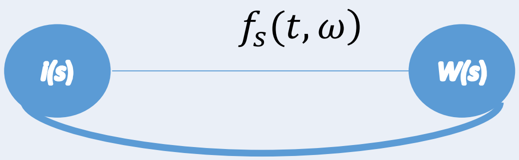
SNAP™ Mathematics

Formula	$SNAP(t,w) = -l\,(t,w)\mathbf{e} - \mathbf{\Psi}^{T}\,(\overline{\boldsymbol{\mu}}(t,w) - \underline{\boldsymbol{\mu}}(t,w))$
Discussion	SNAP is the LMP of reliability dispatch (RD), the most important output of the RD analysis. SNAP distribution in space, time and scenarios determine adequacy revenues for resources, adequacy payments by loads and adequacy revenues to transmission assets **EXAMPLE of SNAP** No transmission constraints, single VOLL across the system No load shed → SNAP(t,ω)=0, if load is shed → SNAP(t,ω)=VOLL $\mathbf{E}SNAP(t,w) = VOLL \times LOLP(t)$ $\sum_{t} \mathbf{E}SNAP(t,w) = VOLL \times LOLH$

Adequacy payments to resources

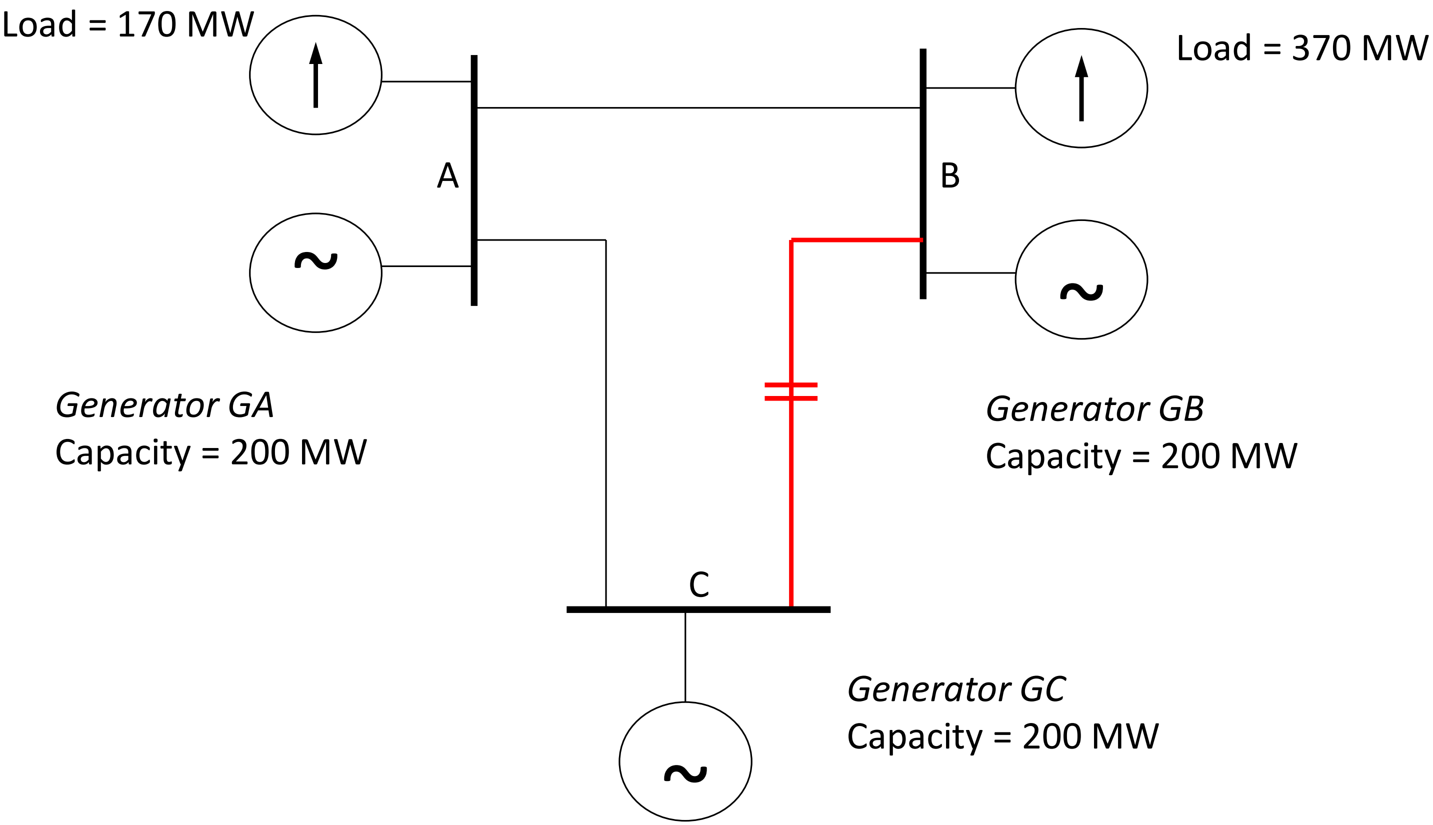
Formula	$AP_r = \sum_{t=1}^{T} \mathbf{E}\left[a_r(t,w)SNAP_r(t,w)\right]$
Discussion	The resource is paid SNAP in each instance it is available, it receives a positive adequacy contribution in each instance it is both available and needed (SNAP > 0). The resource may be charged for negatively affecting adequacy in each instance it is forced to run and not needed (SNAP < 0) The above formula also captures correlation between SNAP and resource's availability. It is important because the SNAP at resource's location is more likely to go up when resource is not available. In these instances, the resource won't be paid for adequacy. **EXAMPLE**: No transmission constraints, single VOLL, the number of loss of load hours in the system is LOLH, of those the resource was fully available in 90% cases and not available in 10%. The resource receives adequacy payment of $P_r X_r = 0.9 \times VOLL \times LOLH \times X_r$

Adequacy payment to transmission

Formula	$T_s = \sum_{t=1}^{T} \mathbf{E}\left[f_s(t,w)(SNAP_{w(s)}(t,w) - SNAP_{i(s)}(t,w)) \right]$
Discussion	 Transmission assets are paid for their contribution to sustaining the adequacy of the system. The payment is the total over time expected value of asset’s contribution to reliability rent of the system. See illustrative examples on slides 14-19

SNAP values, are primarily driven by the probability and economics of load shedding

To illustrate the effect of NLA, we consider three scenarios of load shedding using a three-node system with all lines having identical impedance. Total demand is 540 MW, total available capacity is 600 MW. In all examples flow on the line C-B is limited



Summary of Example Scenarios

VOLL = $10,000/MWh	SNAP
- <u>Scenario 1</u>. Although the system has sufficient total capacity, transmission constraint on a flow from C to B forces shedding of 35 MW of load at B. As a result, SNAPs at all nodes are different, but non-negative and do not exceed VOLL	Ⓐ $5,000 Ⓑ $10,000 Ⓒ $0
- <u>Scenario 2</u>. Similar to Example 1, but load reduction at B is limited. As a result, SNAPs at all nodes double and at node B SNAP is twice the VOLL	Ⓐ $10,000 Ⓑ $20,000 Ⓒ $0
- <u>Scenario 3</u>. Similar to Example 2, but non-curtailable generator at node C is forced to operate at MinGen of 120 MW and load reduction at B above limit is priced at 3 x VOLL As a result, SNAP at B goes up to 3 x VOLL, while SNAP at C goes to negative – 3 x VOLL.	Ⓐ $0 Ⓑ $30,000 Ⓒ -$30,000

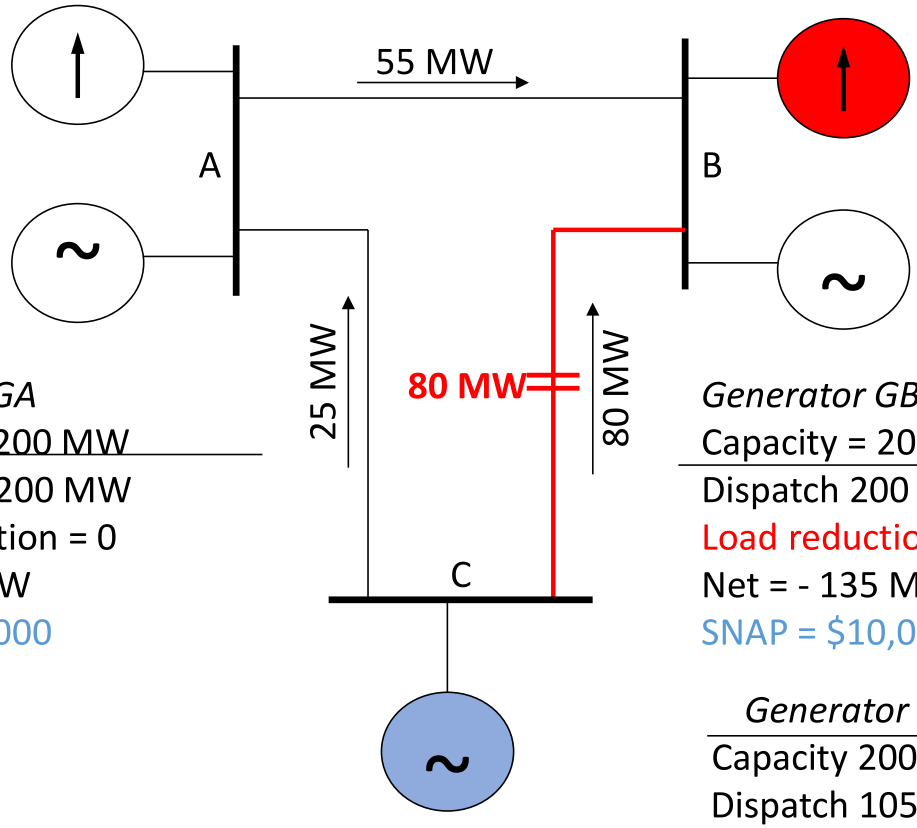
Scenario 1

VOLL = $10,000

UE = 35 MW
VUE $350,000

Load = 170 MW

Load = 370 MW



Generator GA
Capacity = 200 MW
Dispatch = 200 MW
Load reduction = 0
Net = 30 MW
SNAP = $5,000

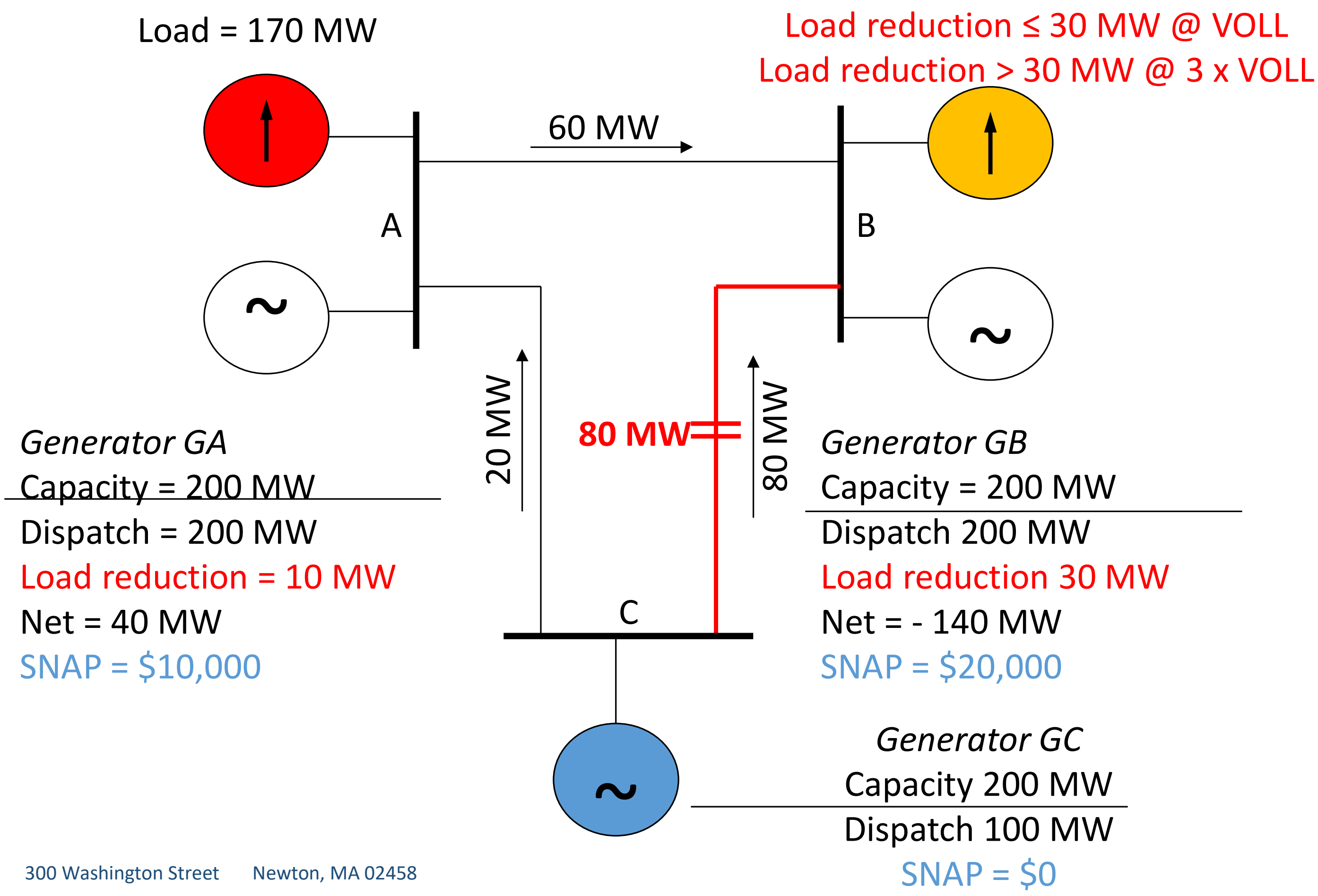
Generator GB
Capacity = 200 MW
Dispatch 200 MW
Load reduction 35 MW
Net = - 135 MW
SNAP = $10,000

Generator GC
Capacity 200 MW
Dispatch 105 MW
SNAP = $0

Scenario 2

VOLL = $10,000

UE = 40 MW
VUE $400,000



Load = 370 MW

Load reduction ≤ 30 MW @ VOLL
Load reduction > 30 MW @ 3 x VOLL

Load = 170 MW

Generator GA
Capacity = 200 MW
Dispatch = 200 MW
Load reduction = 10 MW
Net = 40 MW
SNAP = $10,000

Generator GB
Capacity = 200 MW
Dispatch 200 MW
Load reduction 30 MW
Net = - 140 MW
SNAP = $20,000

Generator GC
Capacity 200 MW
Dispatch 100 MW
SNAP = $0

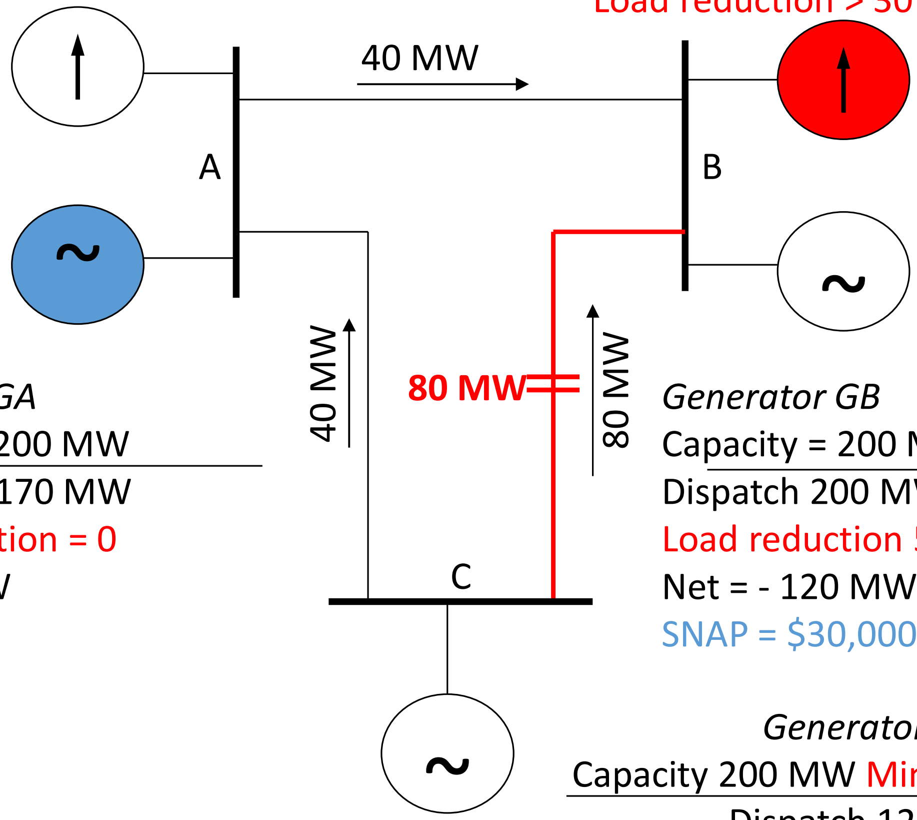
Scenario 3

VOLL = $10,000

UE = 50 MW
VUE = $900,000

Load = 170 MW

Load = 370 MW
Load reduction ≤ 30 MW @ VOLL
Load reduction > 30 MW @ 3 x VOLL



Generator GA
Capacity = 200 MW
Dispatch = 170 MW
Load reduction = 0
Net = 0 MW
SNAP = $0

Generator GB
Capacity = 200 MW
Dispatch 200 MW
Load reduction 50 MW
Net = - 120 MW
SNAP = $30,000

Generator GC
Capacity 200 MW MinGen = 120 MW
Dispatch 120 MW
SNAP = - $30,000

Example Settlement Summary

Generation	**GA**	**GB**	**GC**	**Total Gen**	**LoadA**	**LoadB**	**LoadC**	**Total Load**	**Rent**
Scenario 1	200	200	105	505	170	335	0	505	
Scenario 2	200	200	100	500	160	340	0	500	
Scenario 3	170	200	120	490	170	320	0	490	
SNAP									
Scenario 1	$ 5,000	$ 10,000	$ -		$ 5,000	$ 10,000	$ -		
Scenario 2	$ 10,000	$ 20,000	$ -		$ 10,000	$ 20,000	$ -		
Scenario 3	$ -	$ 30,000	$ (30,000)		$ -	$ 30,000	$ (30,000)		
Revenues									Rent
Scenario 1	$ 1,000,000	$ 2,000,000	$ -	$ 3,000,000	$ 850,000	$ 3,350,000	$ -	$ 4,200,000	$ 1,200,000
Scenario 2	$ 2,000,000	$ 4,000,000	$ -	$ 6,000,000	$ 1,600,000	$ 6,800,000	$ -	$ 8,400,000	$ 2,400,000
Scenario 3	$ -	$ 6,000,000	$ (3,600,000)	$ 2,400,000	$ -	$ 9,600,000	$ -	$ 9,600,000	$ 7,200,000
Average Revenue	$ 1,000,000	$ 4,000,000	$ (1,200,000)	$ 3,800,000	$ 816,667	$ 6,583,333	$ -	$ 7,400,000	$ 3,600,000

These are BIG numbers but they should be multiplied by the probability of each scenario

Distribution of adequacy rent to transmission assets

Flow	AB	AC	BC	Total Network
Scenario 1	55	-25	-80	
Scenario 2	60	-20	-80	
Scenario 3	40	-40	-80	
Delta SNAP				
Scenario 1	$ 5,000.0	$ (5,000.0)	$ (10,000.0)	
Scenario 2	$ 10,000.0	$ (10,000.0)	$ (20,000.0)	
Scenario 3	$ 30,000.0	$ (30,000.0)	$ (60,000.0)	
Revenue				
Scenario 1	$ 275,000	$ 125,000	$ 800,000	$ 1,200,000
Scenario 2	$ 600,000	$ 200,000	$ 1,600,000	$ 2,400,000
Scenario 3	$ 1,200,000	$ 1,200,000	$ 4,800,000	$ 7,200,000
Average Revenue	$ 691,667	$ 508,333	$ 2,400,000	$ 3,600,000

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