Regulation Market Discussion: Basic Concepts

RPSTF

February 7, 2012

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Regulation Historically Provided by "Slow" Resources

- **Regulation has historically been provided by traditional generation resources (Slow) following a regulation signal (Reg A).**
- **PJM has always been able to meet its regulation performance objectives using Slow resources following the regulation signal (Reg A).**
- **KEMA study indicates that regulation can be achieved through a combination of Slow resources and fast response regulation sources (Fast).**

Regulation Can Be Provided by a Combination of Resources: Fast and Slow

- **Premise is that a combination of fast and slow would be more efficient at providing regulation:**
  - **Can use fewer resources to achieve the same amount of regulation**
  - **Lower cost to achieve the same amount of regulation**
- **For this premise to be true, there has to be a defined relationship between the use of fast and slow resources, for any level of regulation provided.**

Defining the Relationship Between Fast and Slow Resources

- **For this premise to be true, there has to be a defined relationship between the use of fast and slow resources, for any level of regulation provided.**
  - **The rate of substitution**
  - **KEMA Study indicates that the rate of substitution between Fast and Slow is not constant**
    - **They are not perfect substitutes**
    - **Cannot completely replace Slow with Fast**
    - **Can replace Fast with Slow**
    - **There may be a better solution than using all Slow**

Regulation Production Function

- **What has been described is a production function for regulation**
  - **Production function describes the relationship between inputs in producing a product (regulation)**
  - **Given the prices for the inputs, production function permits finding the least cost (most efficient) combination of inputs needed to provide a given level of product.**
  - **The most efficient combination of inputs depends on:**
    - **price of the inputs**
    - **the rate of substitution between the inputs**

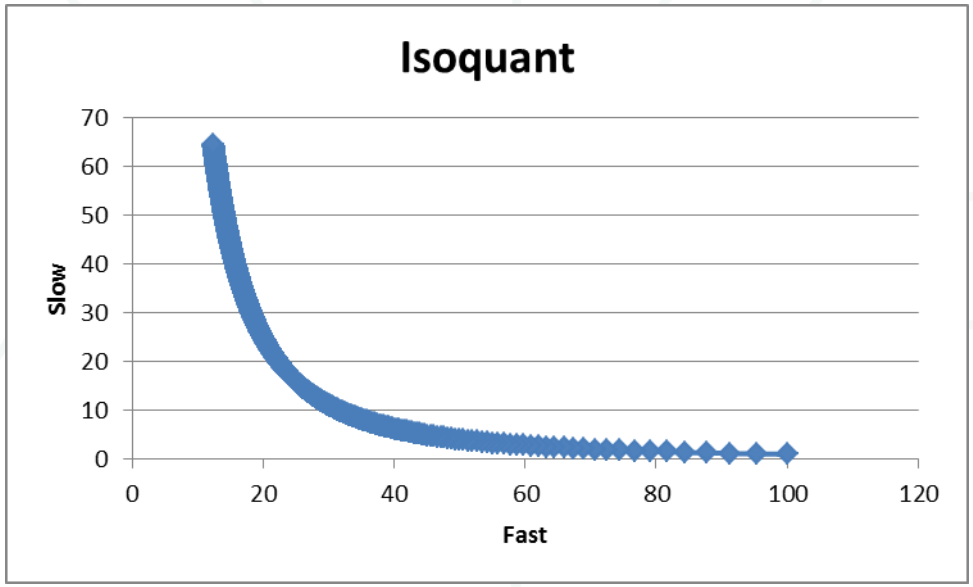
Defining the Optimal Mix: Fast and Slow

- **What has been described is a production function for regulation:**
  - **R = f(X,Y)**
  - **X= Units of Slow , Y = Units of Fast**
- **Cost of any combination of X and Y:**
  - **Cost(X,Y)= ($Price_X$ * $Quantity_X$) + ($Price_Y$ * $Quantity_Y$)**
- **Objective is to minimize the cost for a given amount of regulation (R)**
  - **The amount of regulation means meeting the CPS/BAAL requirements**

Production Function and Rate of Substitution

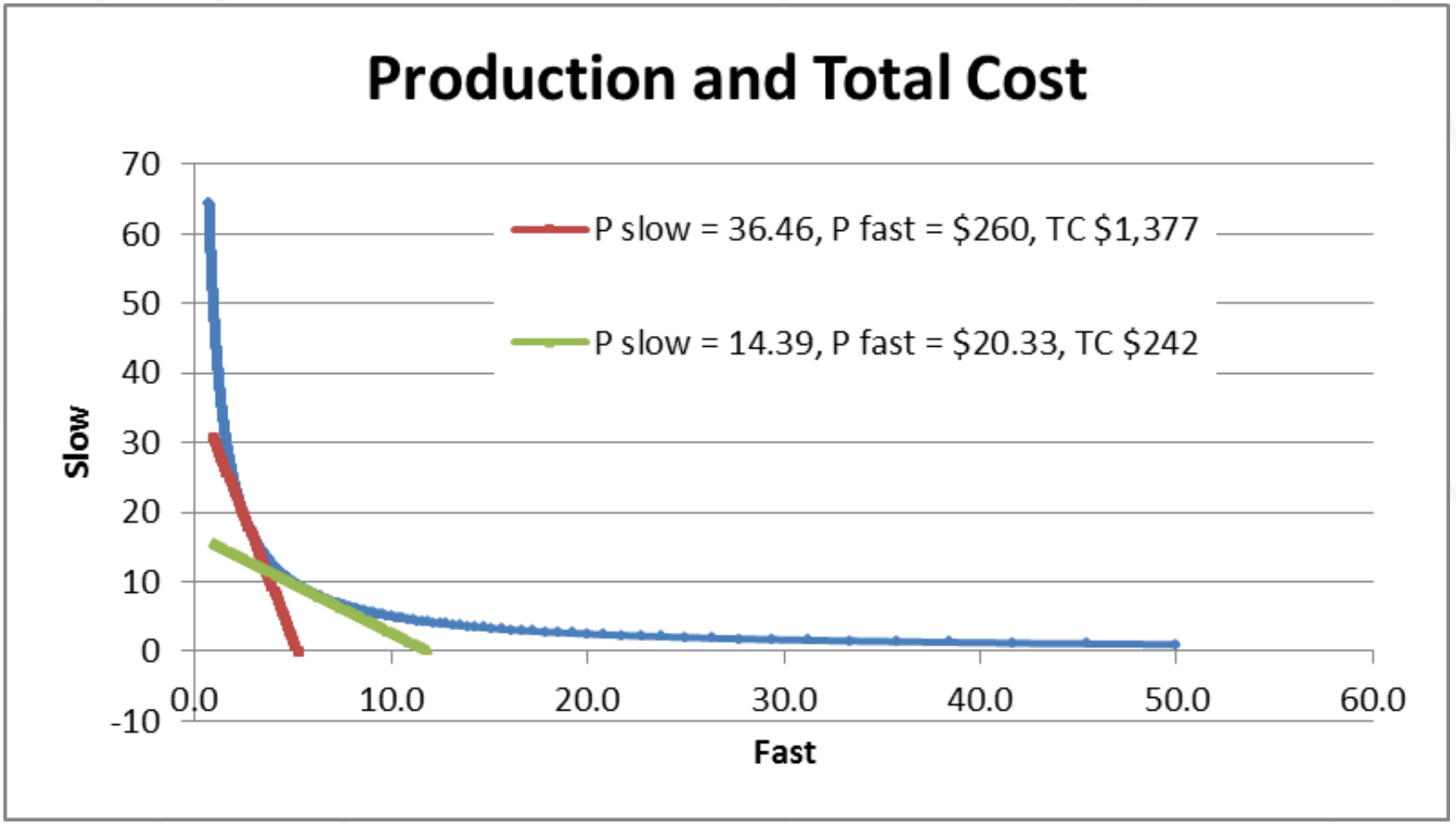
For an amount of regulation= 50;

Curve shows all the combinations of X (Slow) and Y (Fast) that provides 50 “R”



Input Markets and Prices

Assuming Fixed Prices for Fast and Slow



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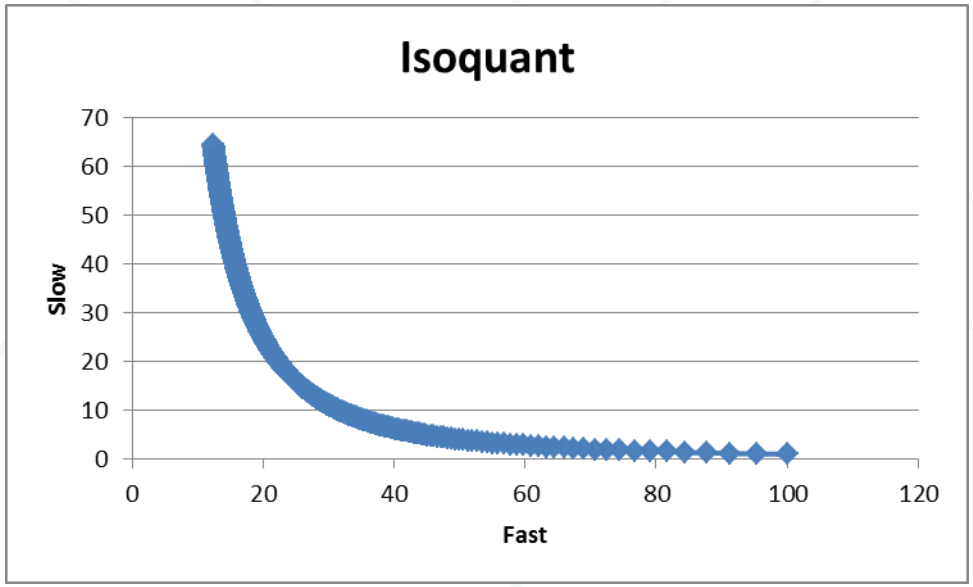

Input Markets and Prices

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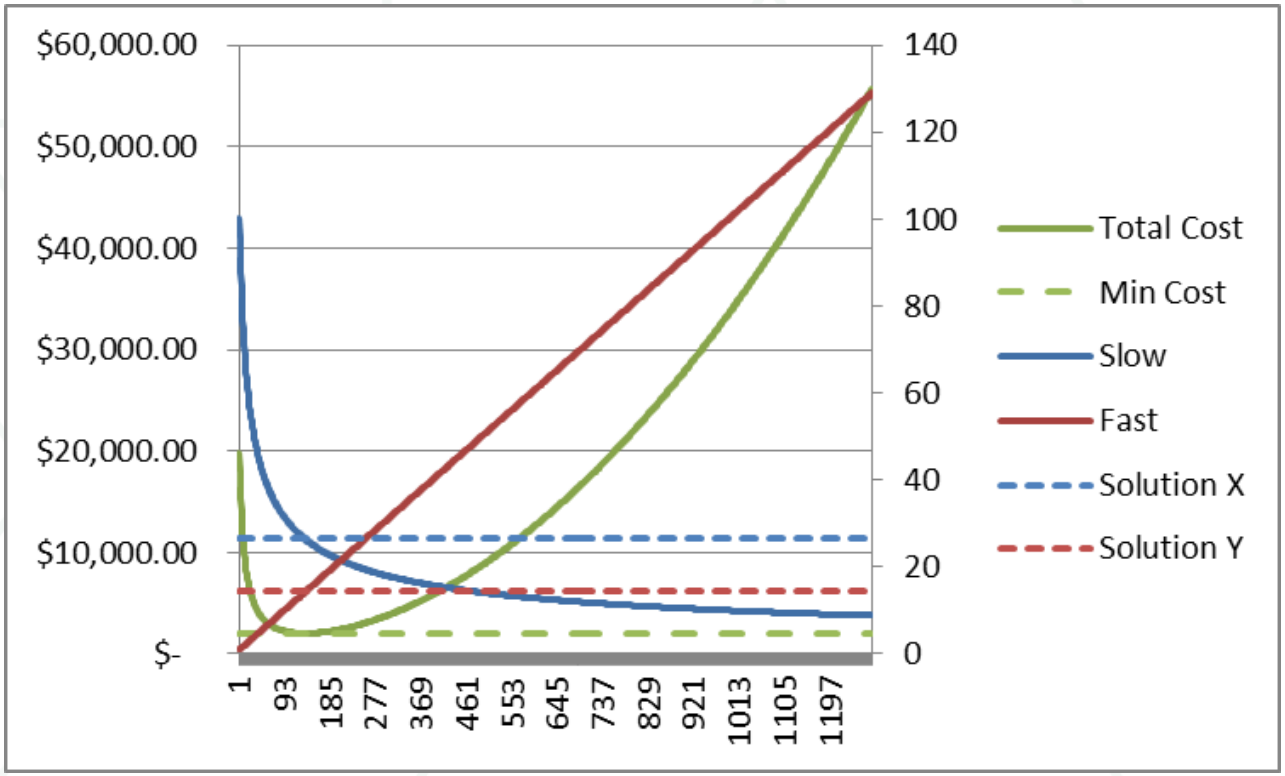
Minimize Total Cost

Slow	Fast	Total Cost
100	1	$ 19,803.33
95.34626	1.1	$ 17,995.16
91.28709	1.2	$ 16,488.89
87.7058	1.3	$ 15,214.84
84.51543	1.4	$ 14,123.22
81.64966	1.5	$ 13,177.53
79.05694	1.6	$ 12,350.42
76.6965	1.7	$ 11,620.95
74.5356	1.8	$ 10,972.84
72.54763	1.9	$ 10,393.25
70.71068	2	$ 9,871.91
69.00656	2.1	$ 9,400.50
67.41999	2.2	$ 8,972.20
65.93805	2.3	$ 8,581.41
64.54972	2.4	$ 8,223.43
63.24555	2.5	$ 7,894.34
62.01737	2.6	$ 7,590.81
60.85806	2.7	$ 7,309.99
59.76143	2.8	$ 7,049.47
58.72202	2.9	$ 6,807.14
57.73503	3	$ 6,581.20
56.79618	3.1	$ 6,370.05
55.9017	3.2	$ 6,172.33

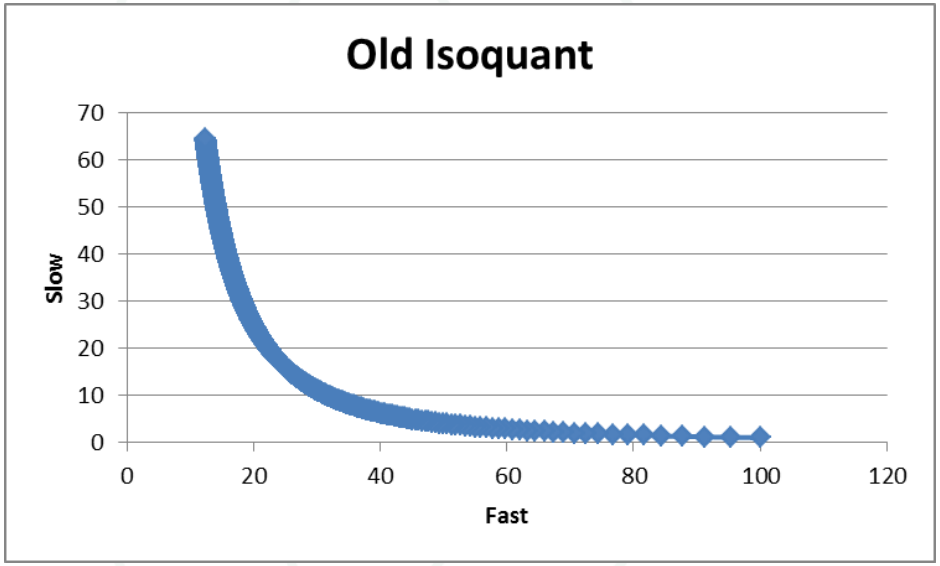


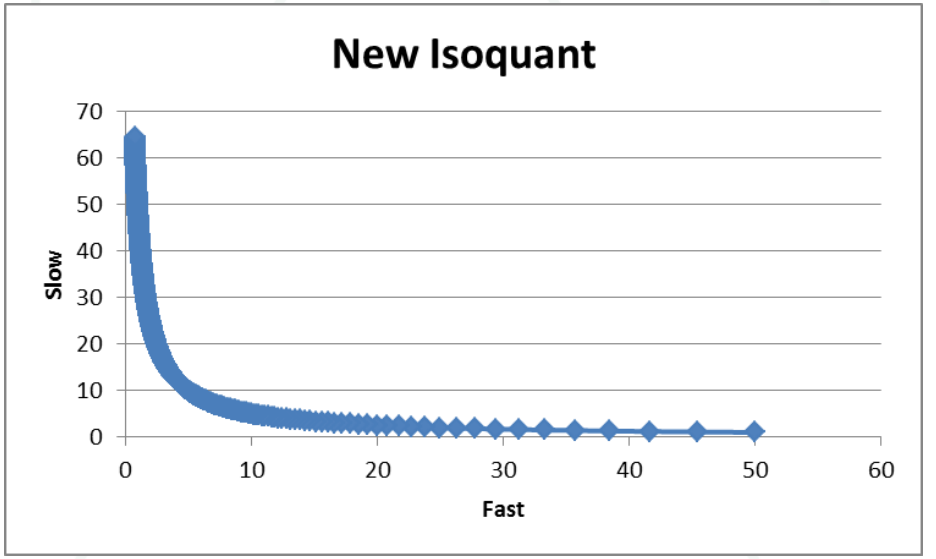
Slow	Fast	P of Slow	P of Fast
26	14	$50.89	$47.67

MIN COST
$ 2,027

New Production Function, New Isoquant

R= 50; Isoquant shows all the combinations of X (Slow) and Y (Fast) that provides 50 "R"





Fast is more capable in new production function

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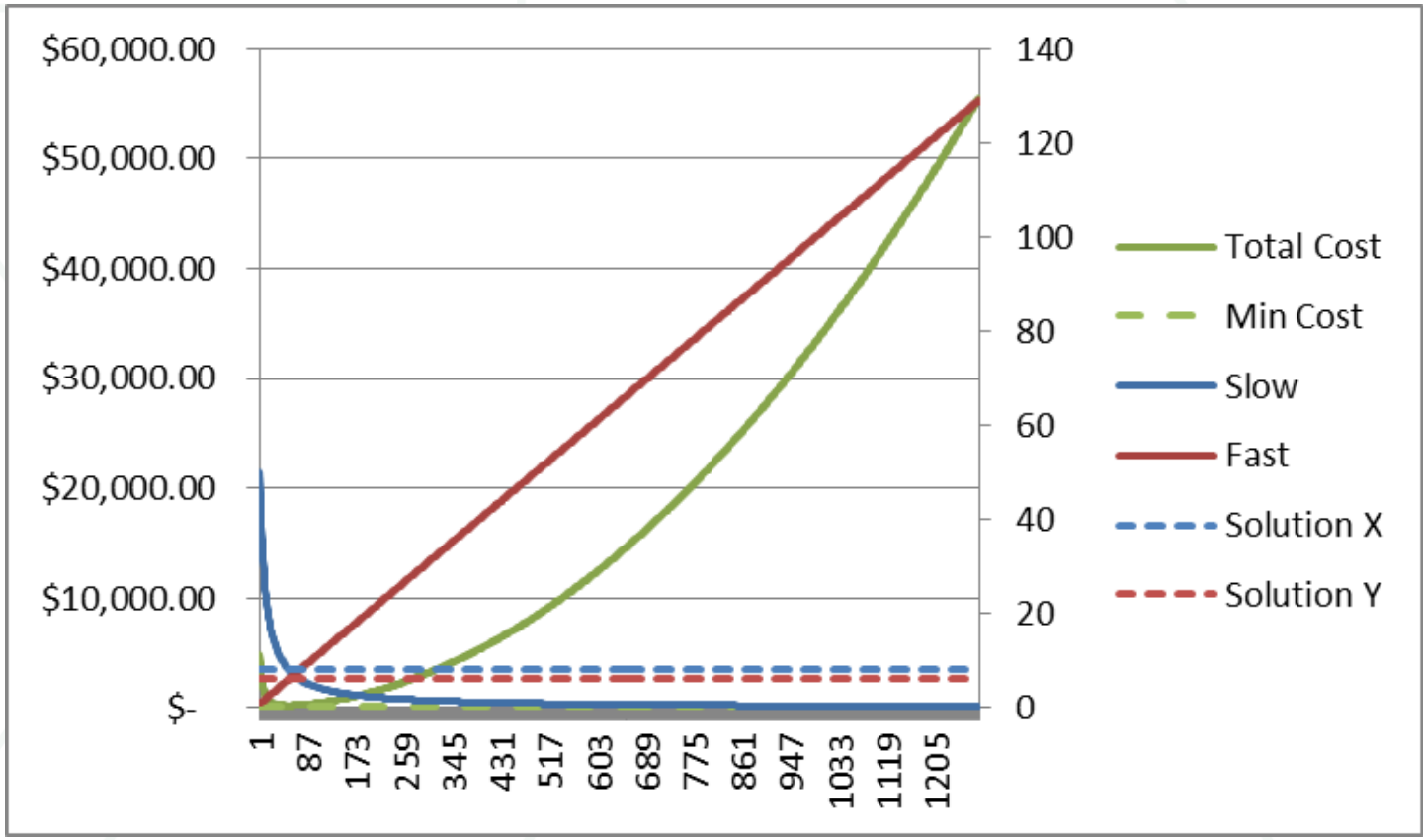
Same Input Prices

Different Optimal Market Result

Slow	Fast	Total Cost
50	1	$ 4,903.33
45.45455	1.1	$ 4,045.36
41.66667	1.2	$ 3,393.69
38.46154	1.3	$ 2,887.29
35.71429	1.4	$ 2,486.13
33.33333	1.5	$ 2,163.06
31.25	1.6	$ 1,899.16
29.41176	1.7	$ 1,680.91
27.77778	1.8	$ 1,498.45
26.31579	1.9	$ 1,344.44
25	2	$ 1,213.33
23.80952	2.1	$ 1,100.87
22.72727	2.2	$ 1,003.74
21.73913	2.3	$ 919.33
20.83333	2.4	$ 845.59
20	2.5	$ 780.83
19.23077	2.6	$ 723.72
18.51852	2.7	$ 673.13
17.85714	2.8	$ 628.17
17.24138	2.9	$ 588.08
16.66667	3	$ 552.22
16.12903	3.1	$ 520.07
15.625	3.2	$ 491.16
15.15152	3.3	$ 465.13
14.70588	3.4	$ 441.65
14.28571	3.5	$ 420.43
13.88889	3.6	$ 401.22
13.51351	3.7	$ 383.84
13.15789	3.8	$ 368.08
12.82051	3.9	$ 353.79
12.5	4	$ 340.83



Slow	Fast	P of Slow	P of Fast
8	6	$ 14.39	$ 20.33

MIN COST
$ 242

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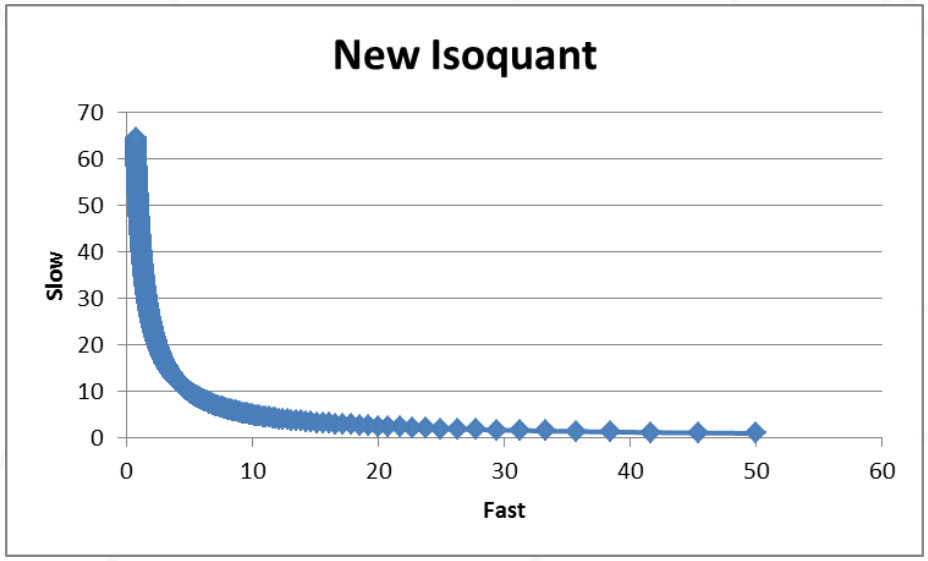
The Same Production Function

R= 50; Isoquant shows all the combinations of X (Slow) and Y (Fast) that provides 50 "R"



Fast is more capable in new production function

Price of Fast Changes (More Expensive)

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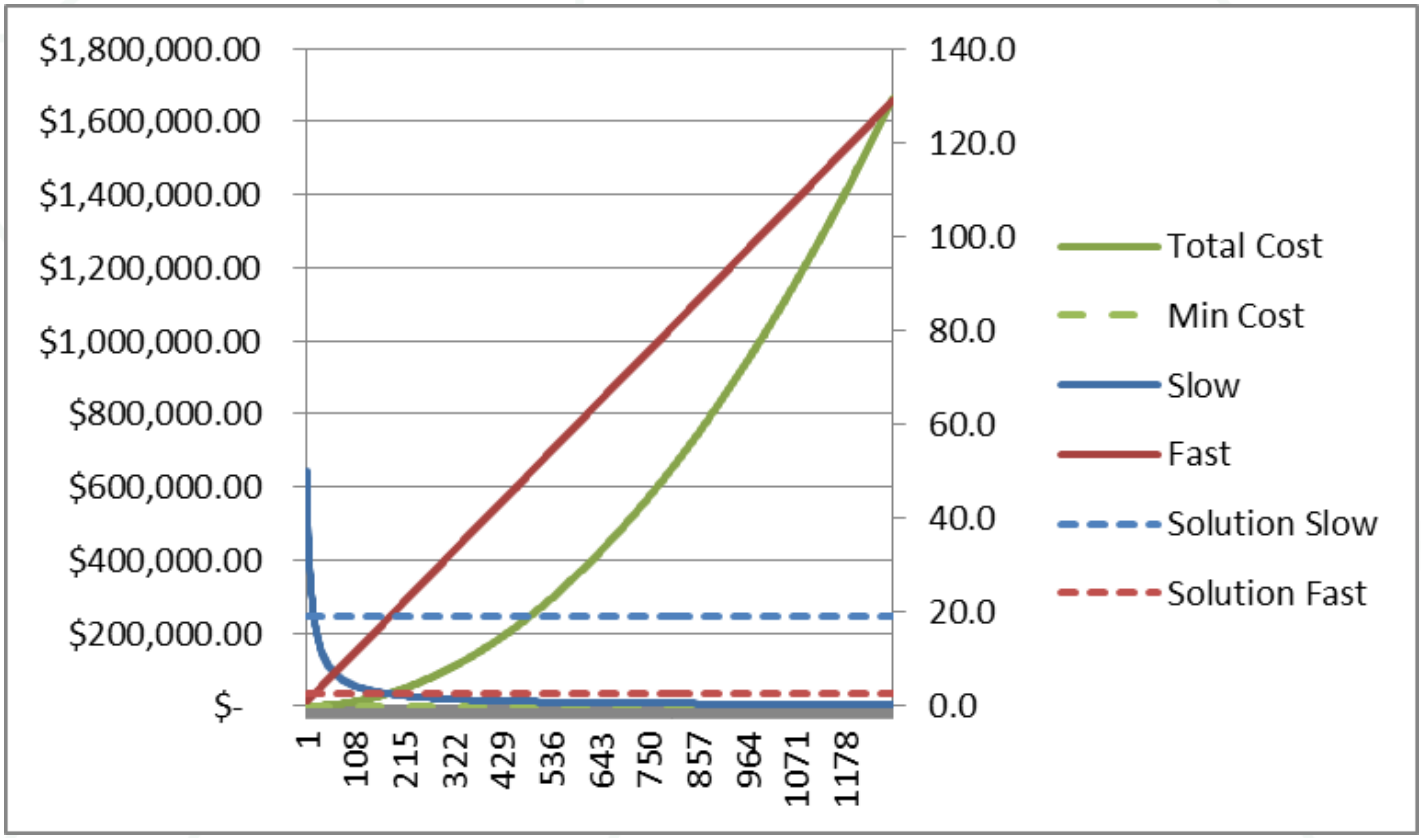
Different Optimal Market Result

Slow	Fast	Total Cost
50.0	1	$ 5,000.00
45.5	1.1	$ 4,162.32
41.7	1.2	$ 3,532.89
38.5	1.3	$ 3,050.66
35.7	1.4	$ 2,675.59
33.3	1.5	$ 2,380.56
31.3	1.6	$ 2,146.63
29.4	1.7	$ 1,960.28
27.8	1.8	$ 1,811.65
26.3	1.9	$ 1,693.41
25.0	2	$ 1,600.00
23.8	2.1	$ 1,527.17
22.7	2.2	$ 1,471.60
21.7	2.3	$ 1,430.70
20.8	2.4	$ 1,402.39
20.0	2.5	$ 1,385.00
19.2	2.6	$ 1,377.18
18.5	2.7	$ 1,377.83
17.9	2.8	$ 1,386.04
17.2	2.9	$ 1,401.05
16.7	3	$ 1,422.22
16.1	3.1	$ 1,449.03
15.6	3.2	$ 1,481.03
15.2	3.3	$ 1,517.83
14.7	3.4	$ 1,559.11
14.3	3.5	$ 1,604.59
13.9	3.6	$ 1,654.02
13.5	3.7	$ 1,707.20
13.2	3.8	$ 1,763.94
12.8	3.9	$ 1,824.09
12.5	4	$ 1,887.50
12.2	4.1	$ 1,954.05
11.9	4.2	$ 2,023.64
11.6	4.3	$ 2,096.16



New Result

Slow	Fast	P of Slow	P of Fast
19.2	2.6	$ 36.46	$ 260.00

MIN COST
$ 1,377

Two Input Markets: Fast and Slow

- Two input products (fast and slow)
- Two markets (fast and slow)
- Two sets of prices and quantities
- Optimal market solution requires understanding the engineering relationship (tradeoffs and mutual benefits)
- Objective to minimize total cost to provide the service given markets for each input

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