Regulation Market Review

OC

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Regulation: Efficient, least cost market design requirements

- **Market design intended to minimize the cost to provide regulation using two different products but clearing the resources in a single market**
  - **Requires the use of an accurate marginal rate of substitution (marginal benefit factor) in the optimization**
  - **Requires the use of a single price (or a single two part price pair) for settlement**
  - **Requires that the two products be defined, cleared and settled in equivalent units throughout**

Regulation Market Current Design

- **Market design intended to minimize the cost to provide regulation using two different products but clearing the resources in a single market**
  - ~~**Requires accurate marginal rate of substitution (marginal benefit factor) be used in the optimization**~~
  - ~~**Requires the use of a single price (or a single two part price pair) for settlement**~~
  - ~~**Requires that the two products be defined, cleared and settled in equivalent units throughout**~~

Current Design

- **Due to the design issues the current market is:**
  - **Purchasing too much RegD in many hours**
    - **Negatively affecting the provision of regulation and reliability**
  - **Incorrectly compensating RegD in all hours**
    - **Sometimes too little**
    - **Sometimes too much**

Issue with current design: MBF not correctly defined

- **PJM has observed issues with regulation performance under conditions of system stress when the proportion of effective regulation provided by RegD exceeds 42 percent.**

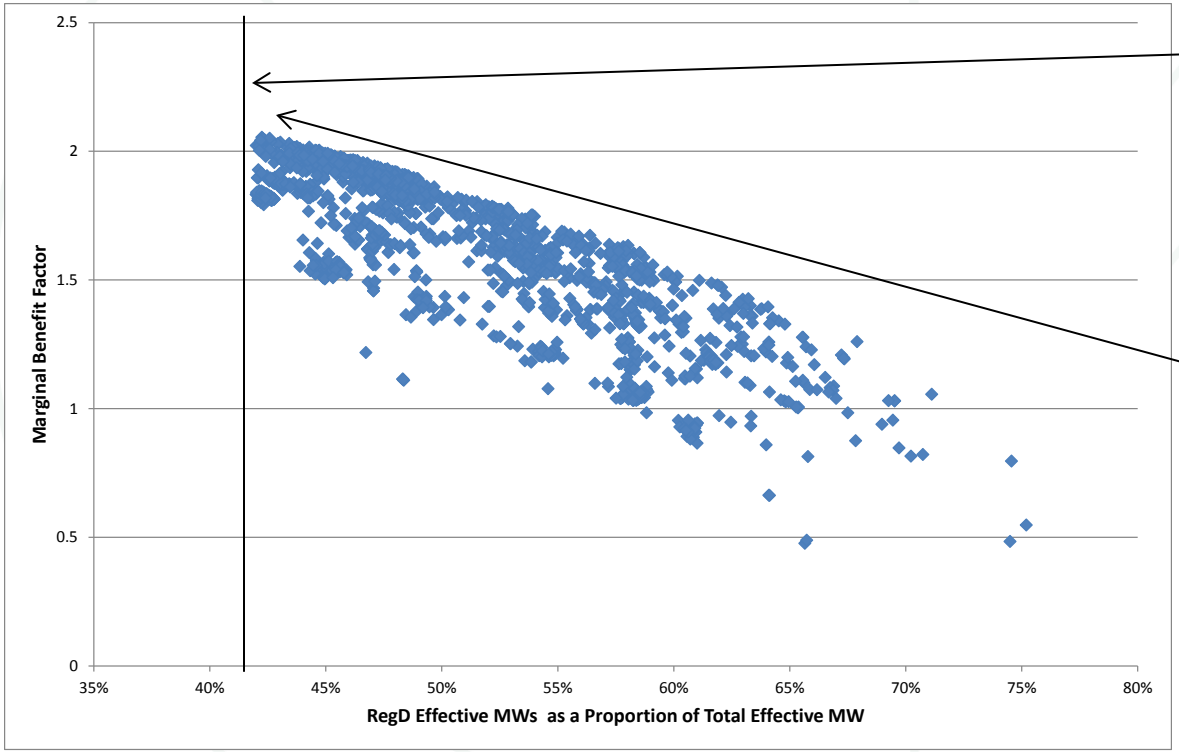
- **Over procuring RegD is counterproductive to providing reliable regulation service**

Issue with current design: MBF not correctly defined

- **System performance indicates that the market is buying too much RegD under certain market conditions**

- **Over procurement is a result of incorrect marginal benefit factor function describing the relationship between RegA and RegD**

Relationship Between Proportion of RegD Effective MWs and Marginal Benefit Factor (Peak Hours 2014)



Saturation Point 30 percent of peak hours

Marginal Benefit Factor should not be positive at this point

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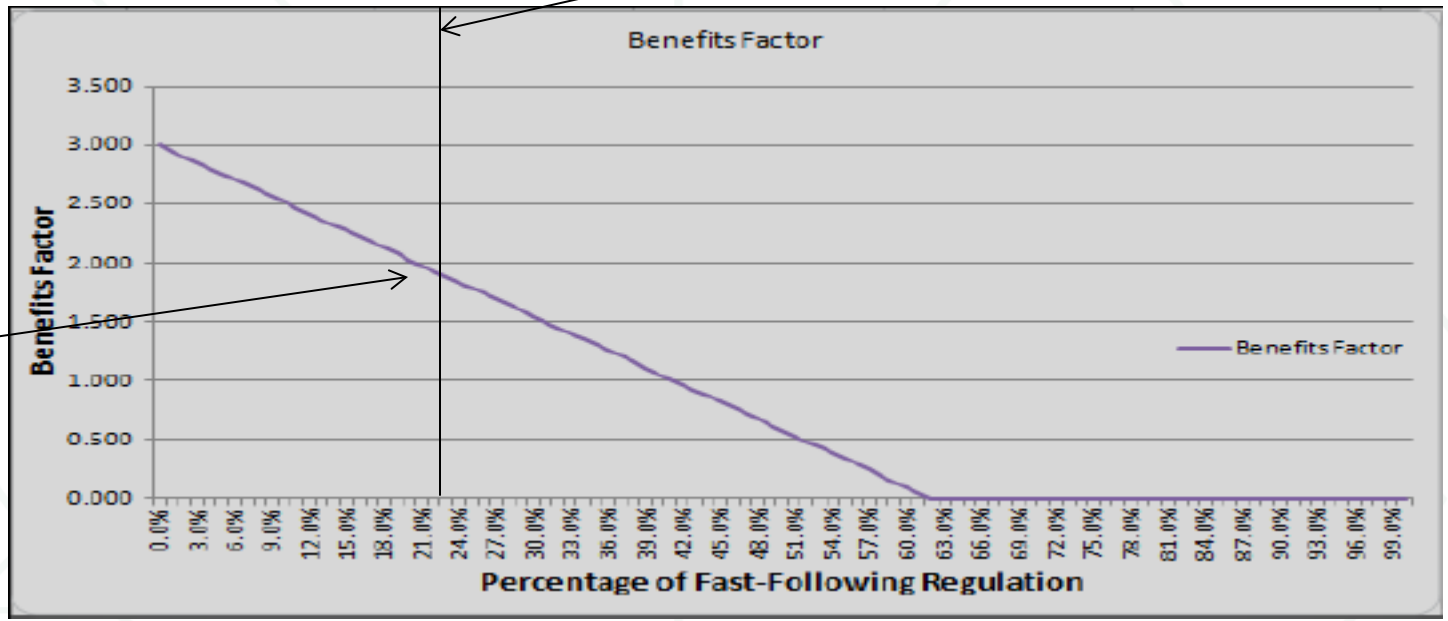
Issue with current design: MBF not correctly defined

- **42 percent of effective MW corresponds with roughly 23 percent or greater proportion of actual MW in actual practice.**

- **Indicates that marginal benefit factor function describing the relationship between RegA and RegD is incorrect.**

Issue with current design: MBF not correctly defined

RegD saturation



Marginal Benefit Factor should not be positive at this point

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Issue with current design: MBF not correctly defined

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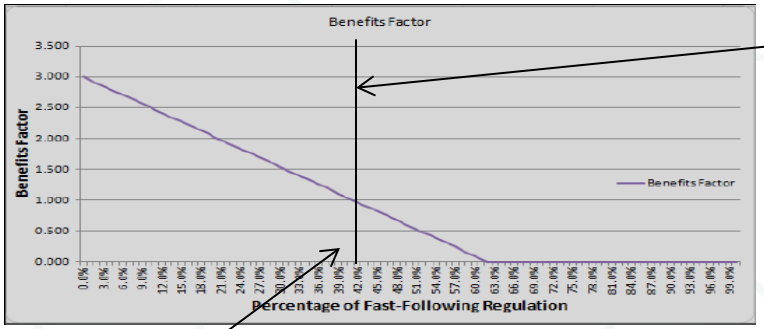

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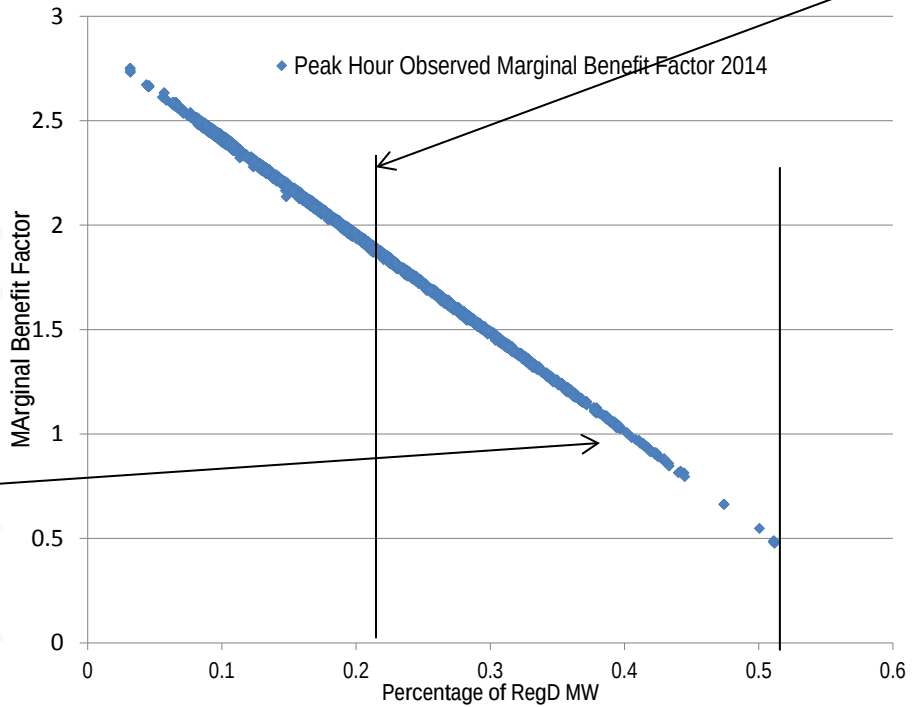

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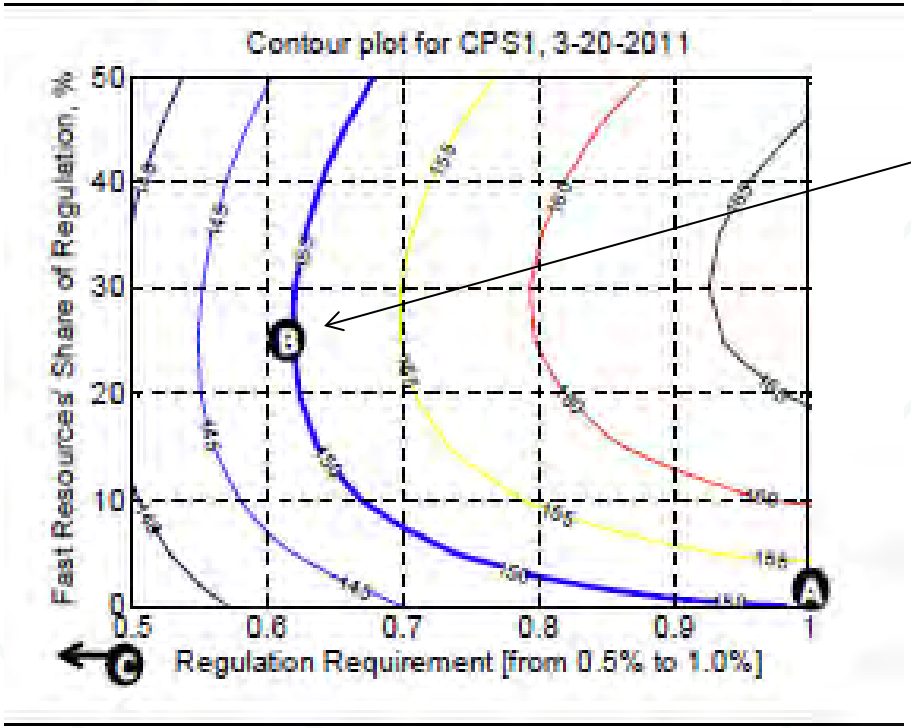
KEMA Study

- **KEMA study of RegA/RegD interactions indicated that there were diminishing returns to RegD as a substitute for RegA in providing regulation service.**
- **KEMA study showed that the marginal rate of substitution could go to zero or be negative.**
- **KEMA study showed that MRS function (curve) varies with system conditions.**

Issue with current design: MBF not correctly defined

- **PJM experience indicates market is operating, in some hours, where MBF is zero or negative.**
- **PJM experience indicates that MBF does vary with system conditions.**
- **The current assumed MBF is not sensitive to changes in system conditions.**

Issue with current design: MBF not correctly defined



RegD MW as Percent of Regulation MW

Combinations of RegA and RegD that provide the same CPS1 Scores

Slope of curve at any point describes marginal rate of substitution between RegA and RegD for a given CPS1 Score.

Slope is the Marginal Rate of Technical Substitution (MRTS) or the marginal benefit factor (MBF)

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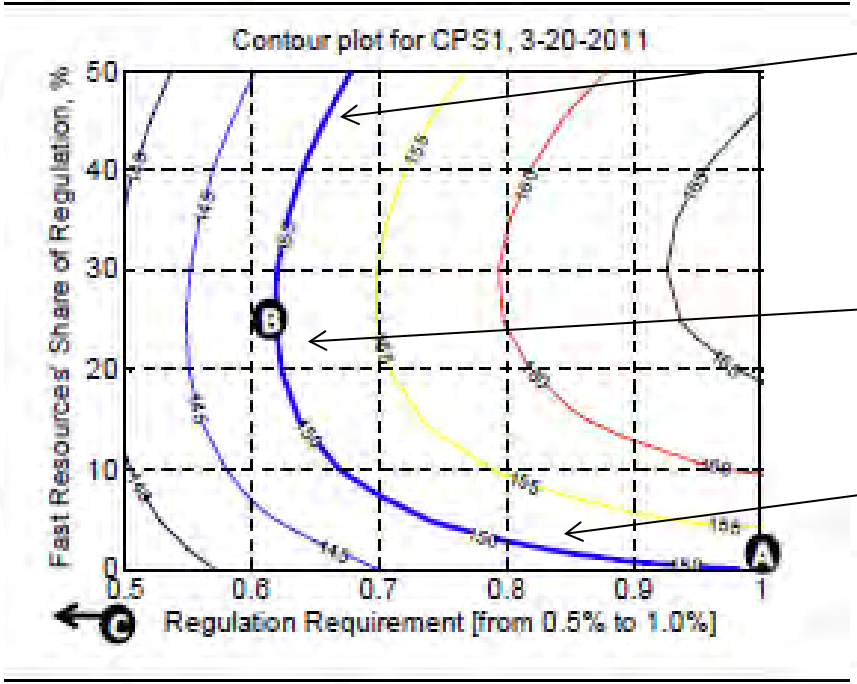
Issue with current design: MBF not correctly defined



MBF <0 ←

Where MBF < 0, additional MW of RegD requires ***additional*** MW of RegA to provide the same CPS1 score

MBF=0 ←

Where MBF = 0, additional MW of RegD provides no additional regulation benefit (no substitution for RegA).

MBF > 0

Where MBF > 0, MW of RegD are substitutes for MW of RegA.

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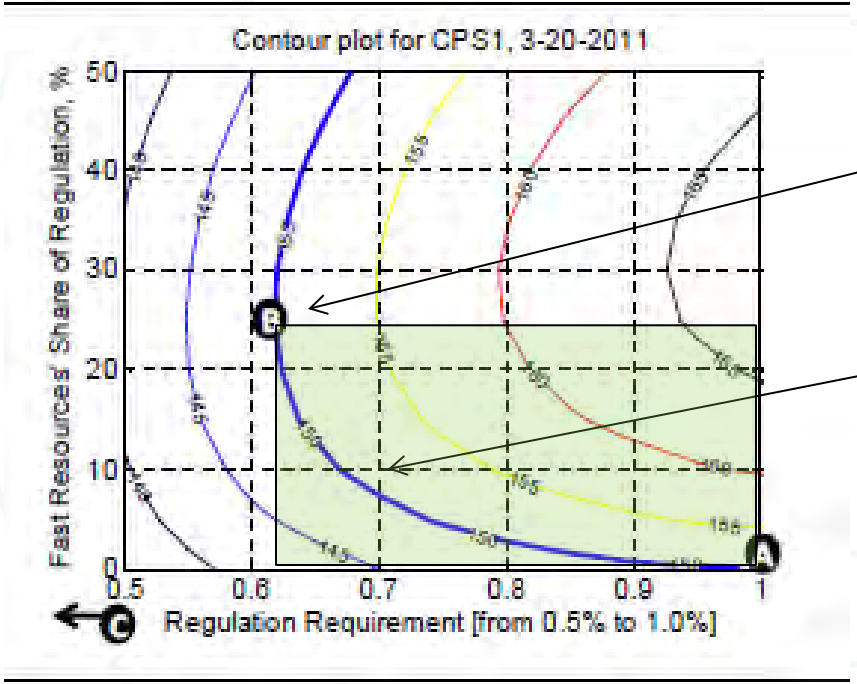
Issue with current design: MBF not correctly defined



Combinations of RegA and RegD that provide the same CPS1 Scores

Properly defined BF in optimization would correctly limit solution space and result in least cost solution

$$\frac{MB_A}{P_A} = \frac{MB_D}{P_D}$$

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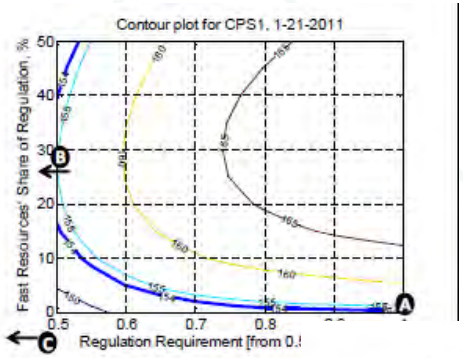
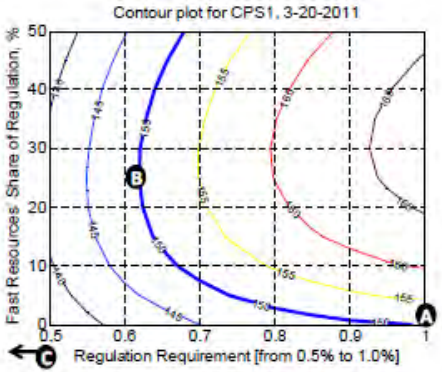
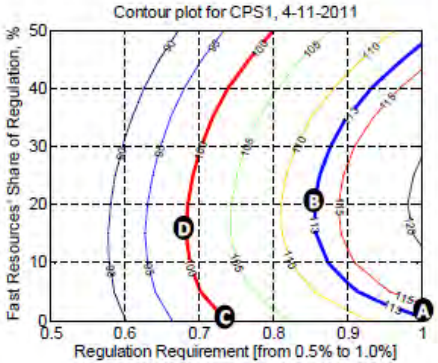
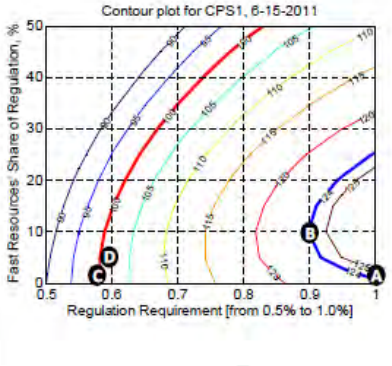
MBF varies with system conditions









Combinations of RegA and RegD that provide the same CPS1 Scores

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MBF varies with system conditions

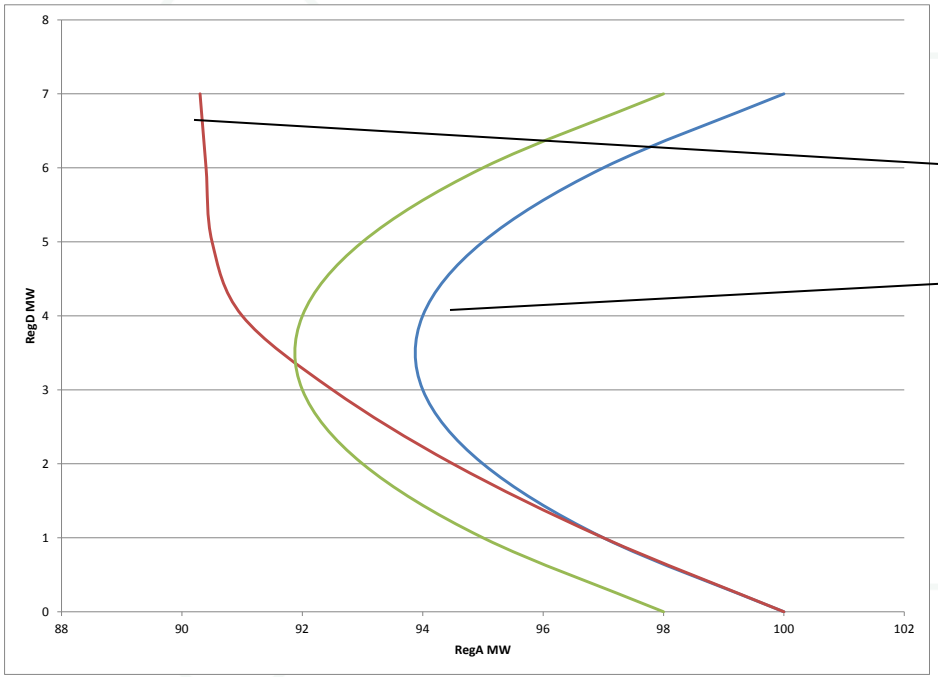
Combinations of Reg Req and Increased Fast Resources needed to maintain the same CPS1 Performance as Pi)

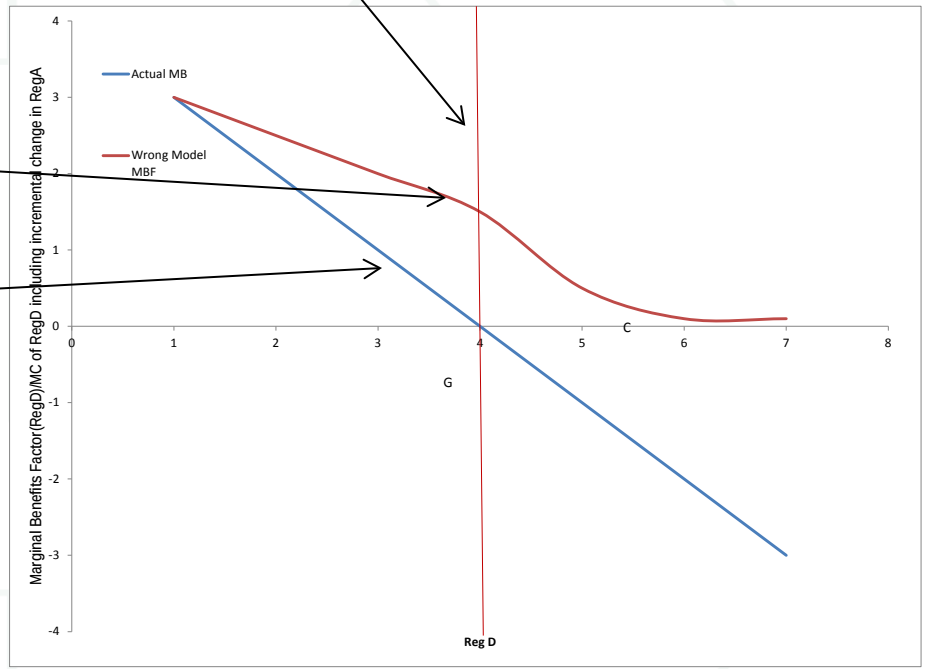
Date	CPS1 Target	Reg Req	Fast Res % of Reg Req
1/21/2011	154%	0.45%	30%
2/18/2011	147%	0.45%	35%
3/20/2011	150%	0.63%	25%
4/11/2011	113%	0.85%	20%
5/10/2011	134%	0.86%	20%
6/15/2011	124%	0.90%	10%
7/10/2011	148%	0.57%	15%
8/15/2010	151%	0.45%	25%
9/7/2010	145%	0.55%	15%

Source: KEMA study, December 13, 2011

Example of RegA/RegD Combination Assumptions

Actual saturation





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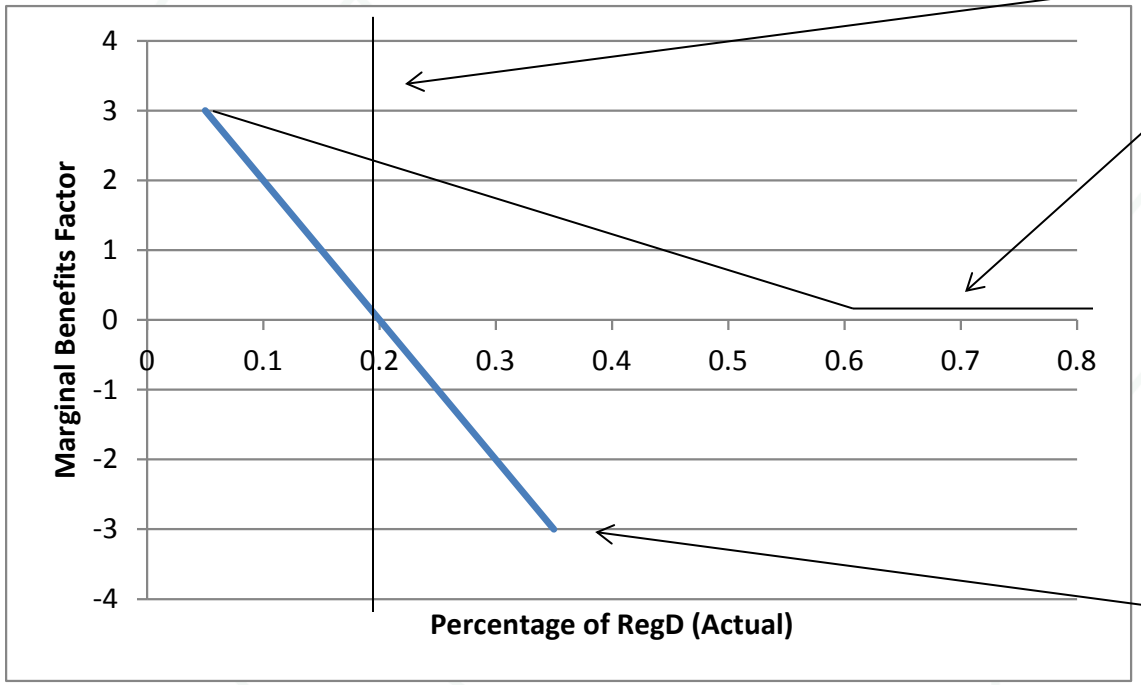
MBF varies with system conditions



RegD saturation

Current Marginal Benefit Function

System will over procure and overpay RegD:

1. MBF in optimization > than actual MBF (Make RegD look less expensive than it is)

2. Will clear more RegD than is efficient (total cost not minimized)

Potential Actual MBF

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Marginal Benefit Factor should be uniformly applied

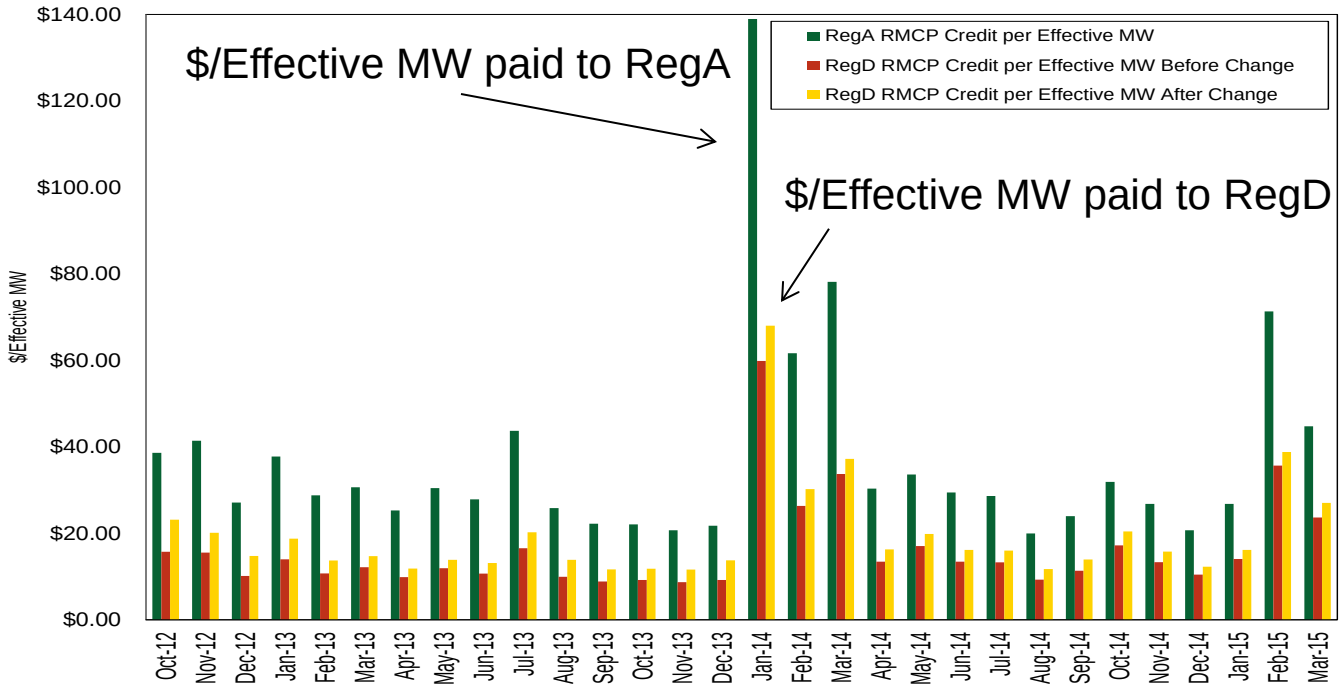
- **The Marginal Benefit Factor (MBF) should be uniformly applied so that the valuation used in optimization process is consistent with the valuation used in settlement.**

- **MBF used to convert all offers to effective MW of RegA MW and $/effective MW of RegA.**

Marginal Benefit Factor should be uniformly applied

- **RegA resources have a MBF of one (base unit of measure).**
- **RegD resource MBF varies with the amount of RegD used as a percentage of total effective MW**
- **Use of MBF allows comparison of offers on the basis of equivalent units (effective MW of RegA)**

Credit per effective MW October 2012 – March 2015: IMM approach vs. Current



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IMM approach vs. Current

Year	Month	RegA RMCP Credit per Effective MW	RegD RMCP Credit per Effective MW Before Change	RegD RMCP Credit per Effective MW After Change	RegD RMCP Credit per Effective MW Should Be	RegD Underpayment Before Change	RegD Underpayment After Change	Percent RegD Underpayment Before Change	Percent RegD Underpayment After Change
2012	Oct	$38.61	$15.72	$23.16	$38.61	$22.89	$15.44	59%	40%
2012	Nov	$41.41	$15.54	$20.14	$41.41	$25.88	$21.27	62%	51%
2012	Dec	$27.11	$10.14	$14.77	$27.11	$16.97	$12.34	63%	46%
2013	Jan	$37.76	$13.98	$18.75	$37.76	$23.78	$19.02	63%	50%
2013	Feb	$28.79	$10.72	$13.72	$28.79	$18.07	$15.07	63%	52%
2013	Mar	$30.64	$12.15	$14.71	$30.64	$18.49	$15.93	60%	52%
2013	Apr	$25.31	$9.85	$11.84	$25.31	$15.45	$13.47	61%	53%
2013	May	$30.46	$11.94	$13.88	$30.46	$18.52	$16.58	61%	54%
2013	Jun	$27.84	$10.68	$13.13	$27.84	$17.15	$14.71	62%	53%
2013	Jul	$43.72	$16.56	$20.22	$43.72	$27.16	$23.49	62%	54%
2013	Aug	$25.81	$9.93	$13.86	$25.81	$15.88	$11.96	62%	46%
2013	Sep	$22.21	$8.87	$11.64	$22.21	$13.34	$10.56	60%	48%
2013	Oct	$22.07	$9.22	$11.81	$22.07	$12.85	$10.26	58%	46%
2013	Nov	$20.71	$8.72	$11.62	$20.71	$11.99	$9.08	58%	44%
2013	Dec	$21.77	$9.22	$13.74	$21.77	$12.55	$8.03	58%	37%
2014	Jan	$138.94	$59.88	$68.01	$138.94	$79.06	$70.93	57%	51%
2014	Feb	$61.64	$26.35	$30.24	$61.64	$35.29	$31.40	57%	51%
2014	Mar	$78.16	$33.72	$37.20	$78.16	$44.44	$40.96	57%	52%
2014	Apr	$30.33	$13.45	$16.28	$30.33	$16.89	$14.05	56%	46%
2014	May	$33.62	$17.03	$19.85	$33.62	$16.58	$13.76	49%	41%
2014	Jun	$29.45	$13.45	$16.16	$29.45	$16.00	$13.29	54%	45%
2014	Jul	$28.64	$13.29	$16.01	$28.64	$15.36	$12.63	54%	44%
2014	Aug	$19.96	$9.29	$11.73	$19.96	$10.67	$8.23	53%	41%
2014	Sep	$23.97	$11.35	$13.96	$23.97	$12.62	$10.02	53%	42%
2014	Oct	$31.91	$17.21	$20.45	$31.91	$14.70	$11.46	46%	36%
2014	Nov	$26.79	$13.34	$15.75	$26.79	$13.45	$11.03	50%	41%
2014	Dec	$20.70	$10.46	$12.28	$20.70	$10.24	$8.42	49%	41%
2015	Jan	$26.81	$14.08	$16.14	$26.81	$12.73	$10.67	47%	40%
2015	Feb	$71.32	$35.66	$38.80	$71.32	$35.66	$32.52	50%	46%
2015	Mar	$44.74	$23.65	$27.02	$44.74	$21.09	$17.72	47%	40%
Average		$37.04	$16.18	$19.56	$37.04	$20.86	$17.48	56%	46%

46% underpayment to RegD per effective MW, assuming current MBF function is correct

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IMM approach vs. Current Design

- **Assuming marginal benefit factor correct, current market design cost RegD resources $56.3 million dollars in lost revenue over the October 2012 through December 2014 period.**

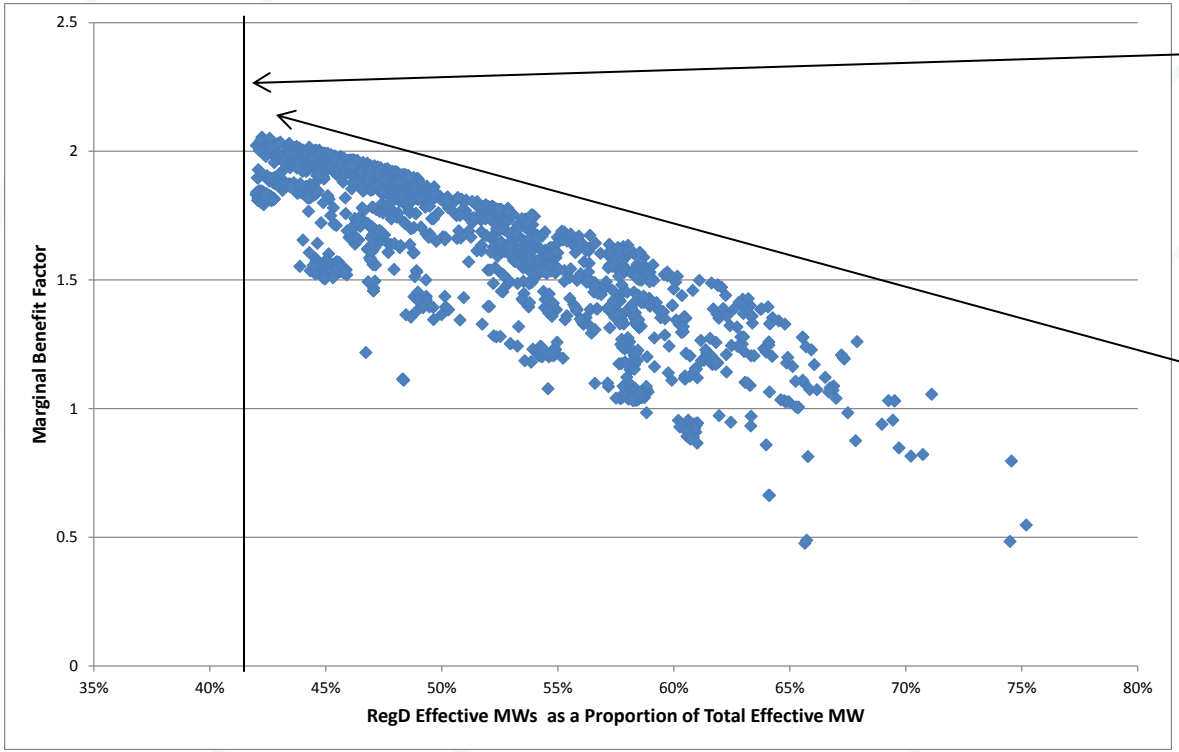
Correct Current Design

- **Correct solution to both issues is related**
  - **Benefits factor needs to correctly reflect the trade off between RegA and RegD in providing regulation service**
  - **Least cost solution requires that:** $\frac{MB_A}{P_A} = \frac{MB_D}{P_D}$
  - **Short term and long term efficiency requires same marginal valuation used in optimization is realized in market signals**

Third issue (assuming MBF function is corrected)

- **Current market solution/optimization does not consistently account for the amount of effective MW provided by RegD**
- **Current market solution requires a specific amount of total effective MW to clear**
- **Amount of effective MW attributed to a given amount of cleared RegD depends on the number of price steps that exist in the supply stack, not the proportion of RegD MW cleared.**

Relationship Between Proportion of RegD Effective MWs and Marginal Benefit Factor (Peak Hours 2014)



Saturation Point 30 percent of peak hours

Marginal Benefit Factor should not be positive at this point

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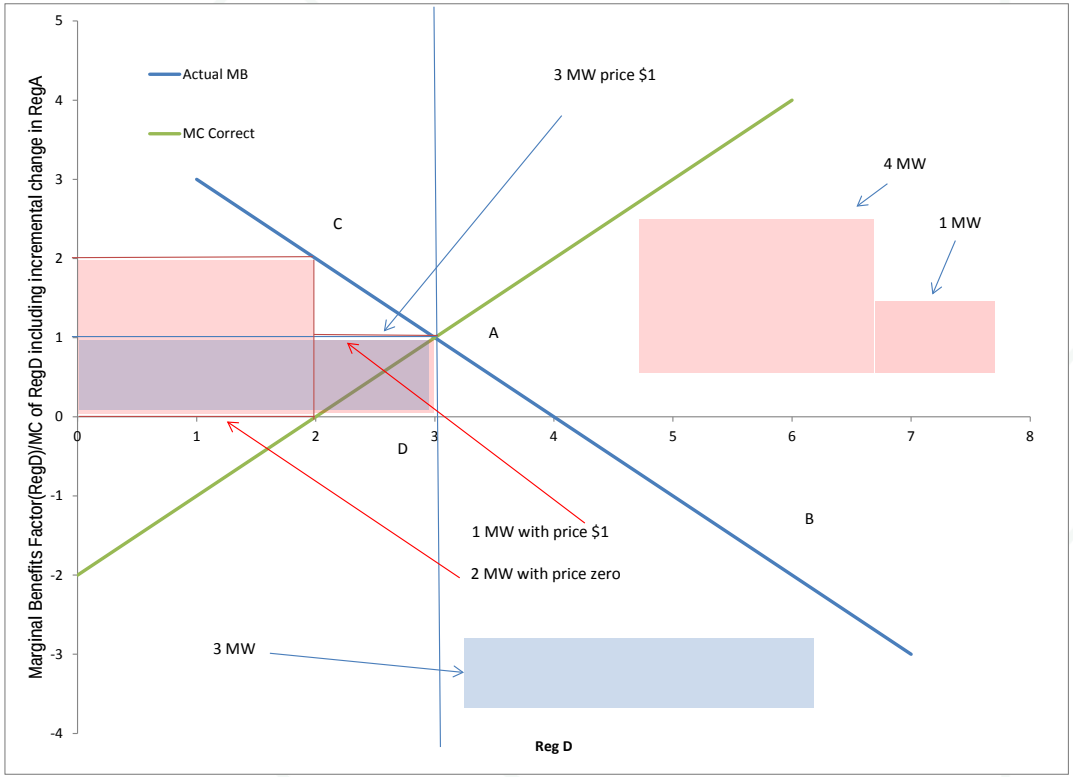
Other issue (assuming MBF function is corrected)



Effective MW = MBFstep1*Mwstep1+MBFstep22+ ….
Red lines show two price steps:
Effective MW = 5 = 2*2MW+1*1MW

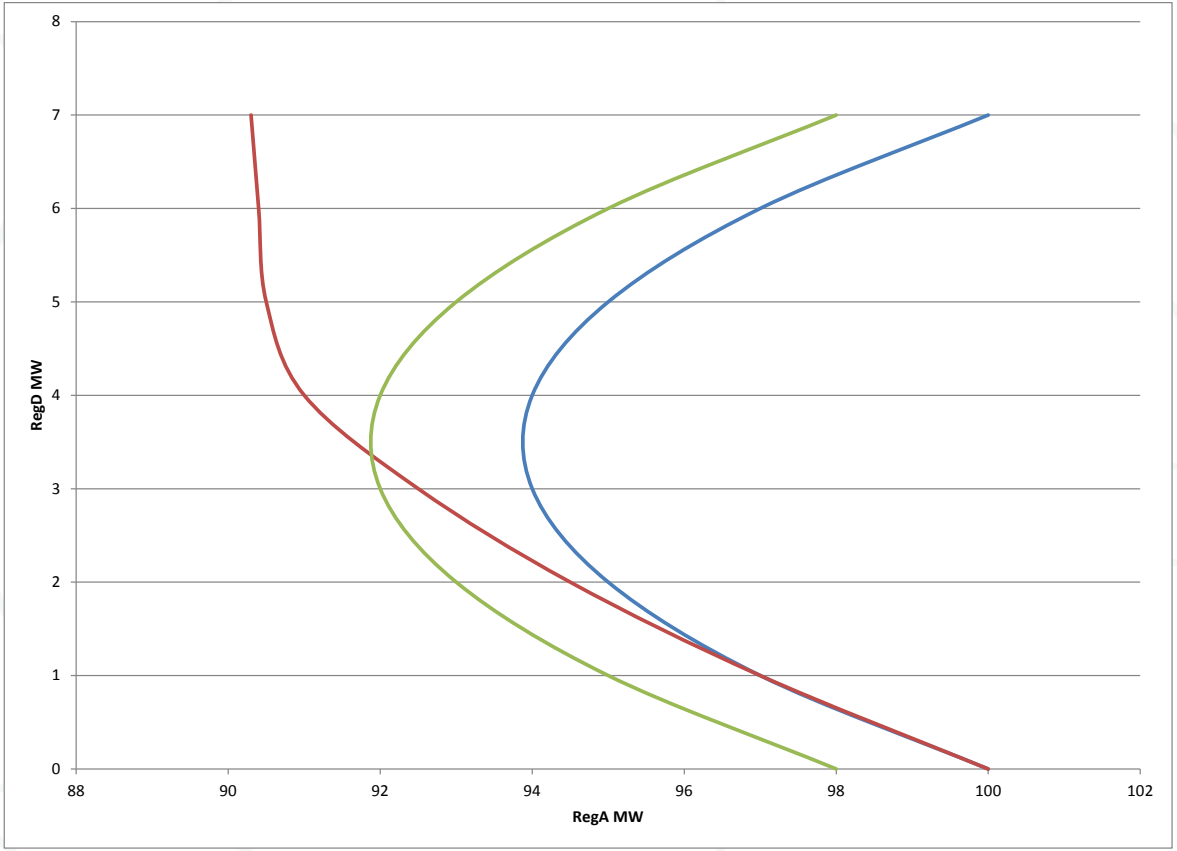
Blue line show one price step:
Effective MW = 3 = 3*1MW

Result is different effective MW based on number of price steps in supply stack for the same RegA actual MW. Results in different levels of total effective Reg clearing.

Appendix

Example of RegA/RegD Combination Assumptions

A



Higher CSP1 and BAAL3 Scores

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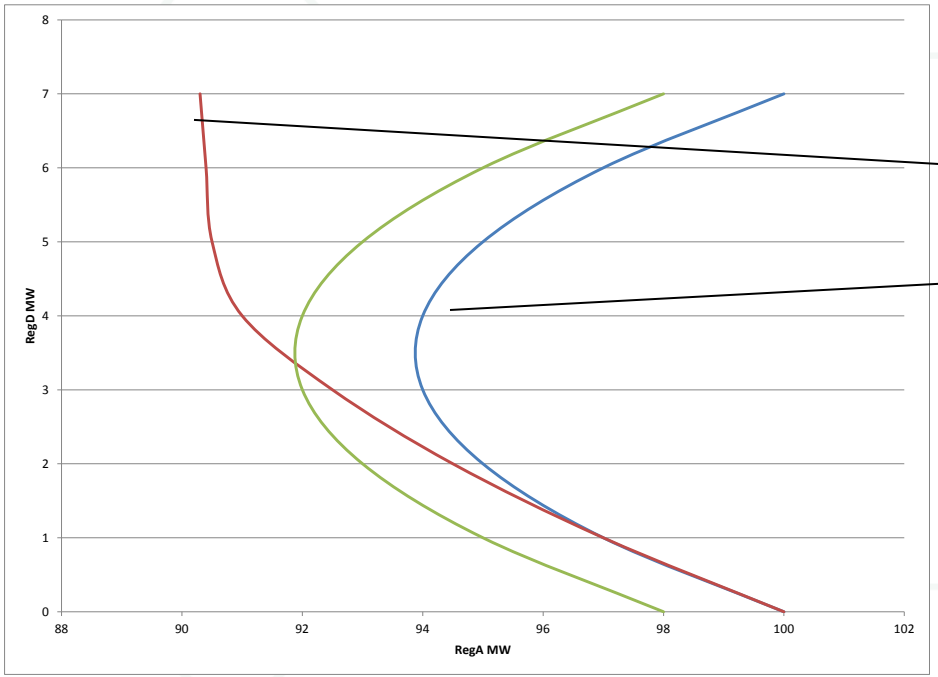
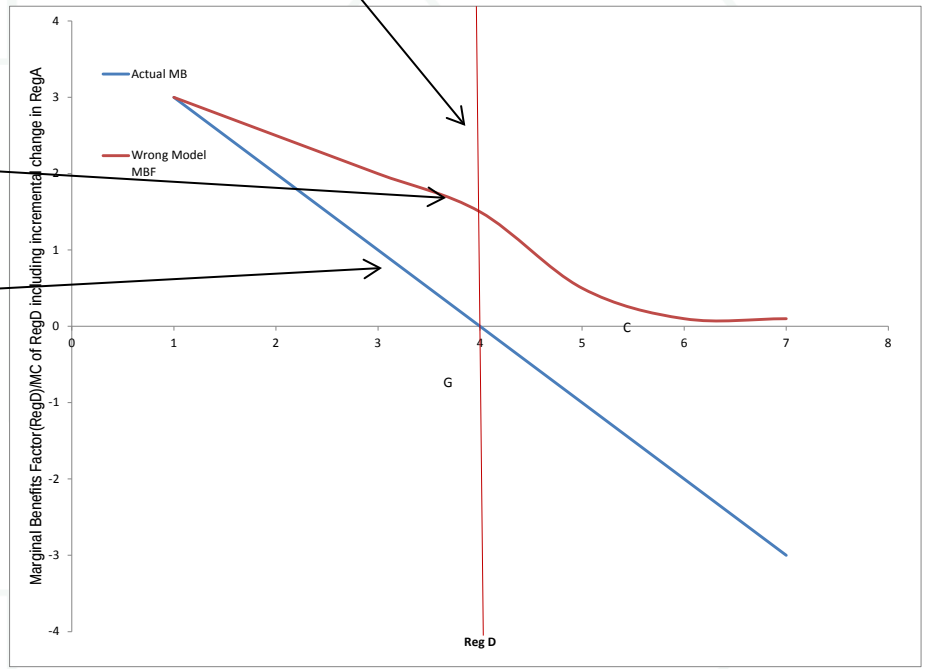
Example of RegA/RegD Combination Assumptions

Actual saturation





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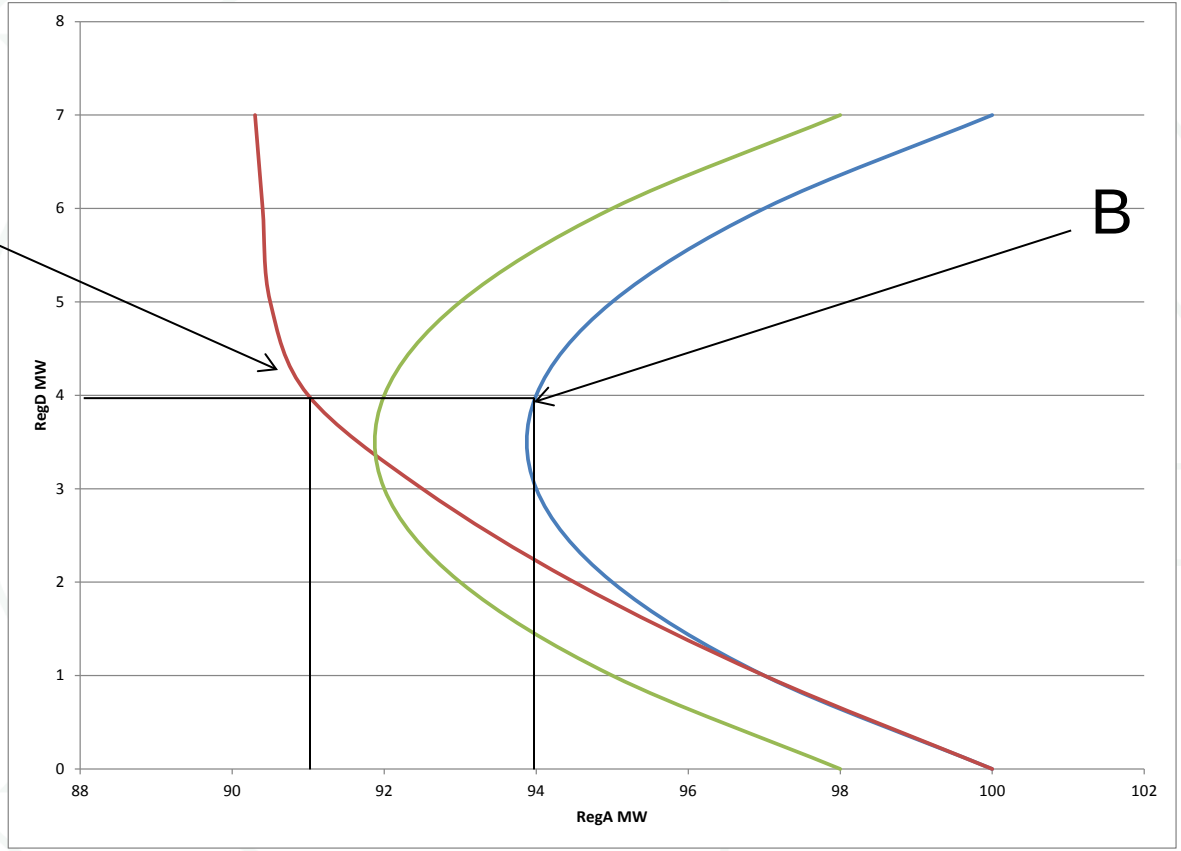
Example of RegA/RegD Combination Assumptions



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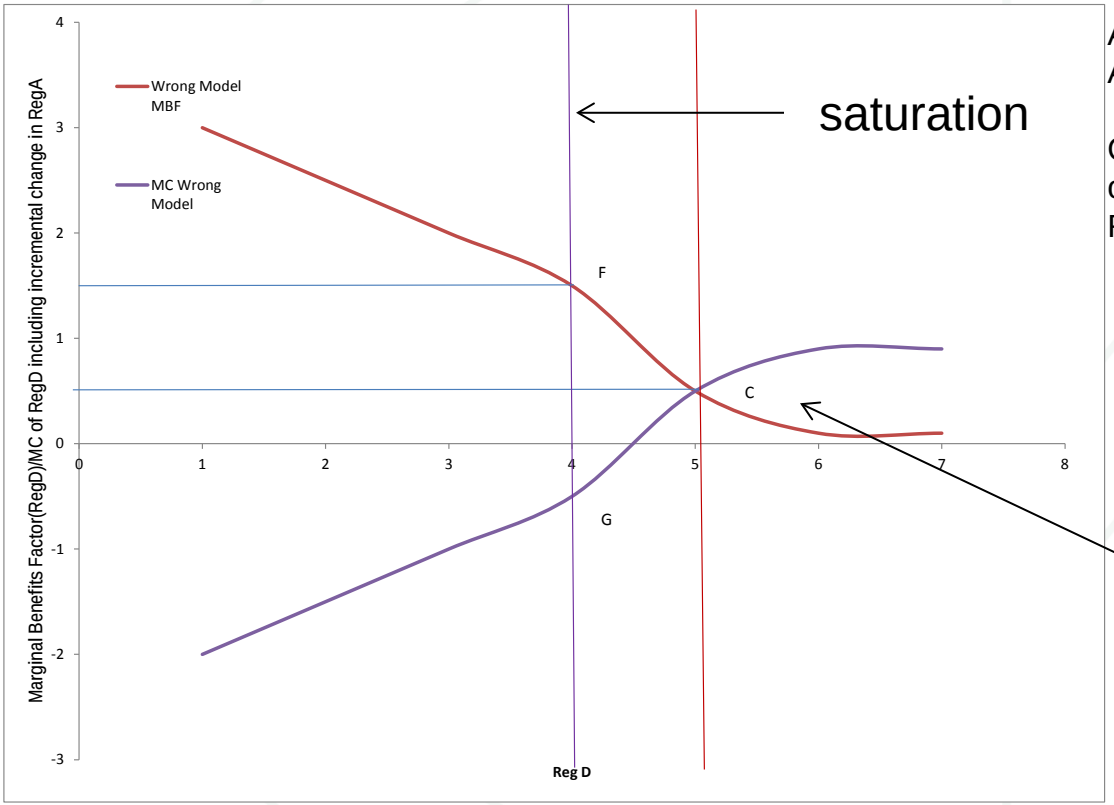
Example of RegA/RegD Combination Assumptions



Assume Price of RegA = $1/MW
Assume Price of RegD = $1/MW

Optimal Mix of RegA and RegD will be dependent on the assumed relationship between RegA and RegD:

$$\frac{MB_A}{P_A} = \frac{MB_D}{P_D}$$

Too much RegD relative to RegA

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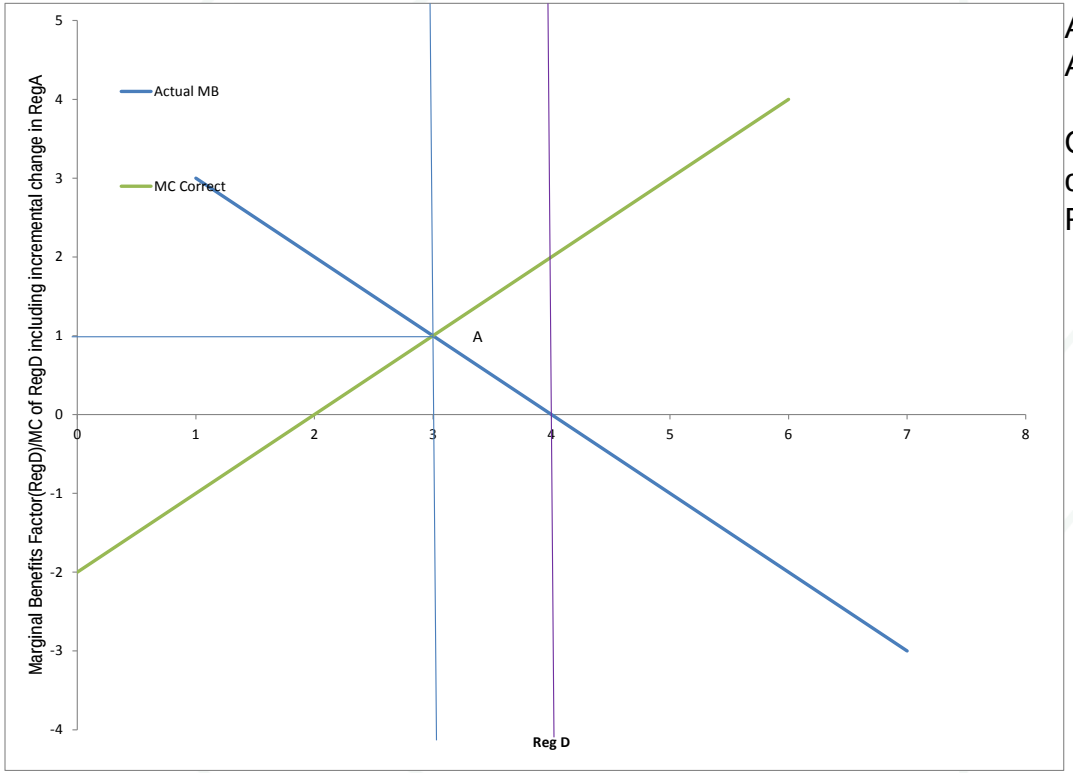
Example of RegA/RegD Combination Assumptions



Assume Price of RegA = $1/MW
Assume Price of RegD = $1/MW

Optimal Mix of RegA and RegD will be dependent on the potential relationship between RegA and RegD:

$$\frac{MB_A}{P_A} = \frac{MB_D}{P_D}$$

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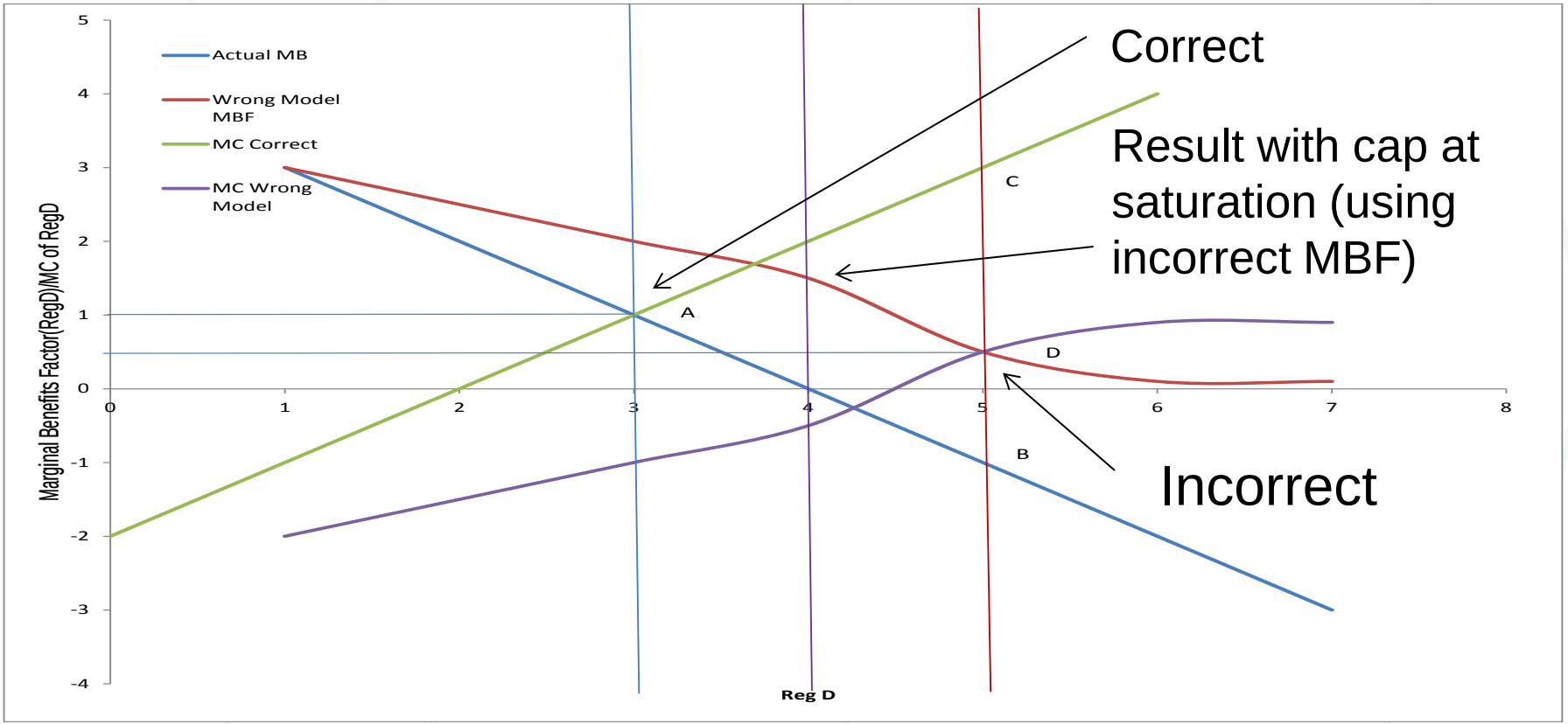
Example of RegA/RegD Combination Assumptions



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