Forecasting Supply and Demand Balance In California's Greenhouse Gas Cap and Trade Market

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Cap and Trade:
Prices and Quantities

- Economists often frame question of caps vs. taxes as
  - Caps provide emissions certainty
  - Taxes provide price (cost) certainty
- Climate Policy: a more complicated picture
  - Uncapped sectors and regions increase quantity uncertainty
  - Complementary policies cause abatement apart from market price
- California's Cap and Trade is a hybrid
  - Auction reserve price (floor)
  - Price containment reserve ("ceiling?")
- Important to understand how relevant these price collars are
  - Large probability that prices are at either floor into containment reserve

General Approach

- Estimate probability model for future business-as-usual (BAU) emissions
  - BAU minus cap is "demand" for abatement
- Consider scenarios of complimentary measure impacts
  - Measures that are *not* directly responsive to allowance prices
- Consider scenarios of abatement ``supply'' in response to varying allowance price levels
- Combine these to forecast distribution of future allowance prices
  - Probability of prices at floor
  - Probability of prices in allowance reserve
  - Probability at price above allowance reserve

Assumptions on Timing

- Main analysis assumes years/phases fully integrated over time through banking
- Aggregate emissions, complimentary measures, and abatement over 8 years
- All calculations based upon 8 year totals
- Implication is prices should rise at the rate of interest
  - We report results in 2012 prices
  - Means "real" floor price is about $15
  - Breakdown in banking increases risks of price swings

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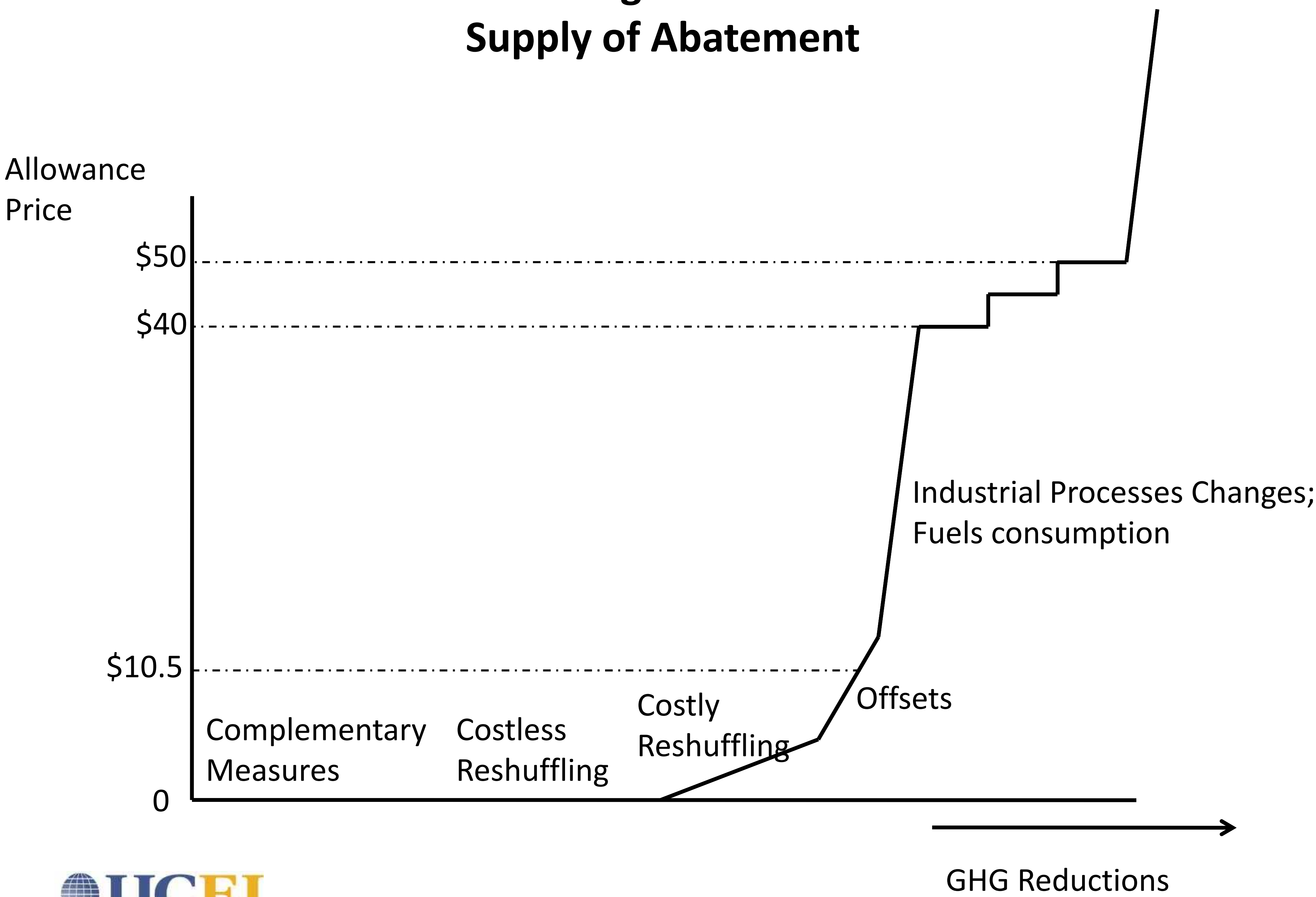
Figure 1
Supply of Abatement



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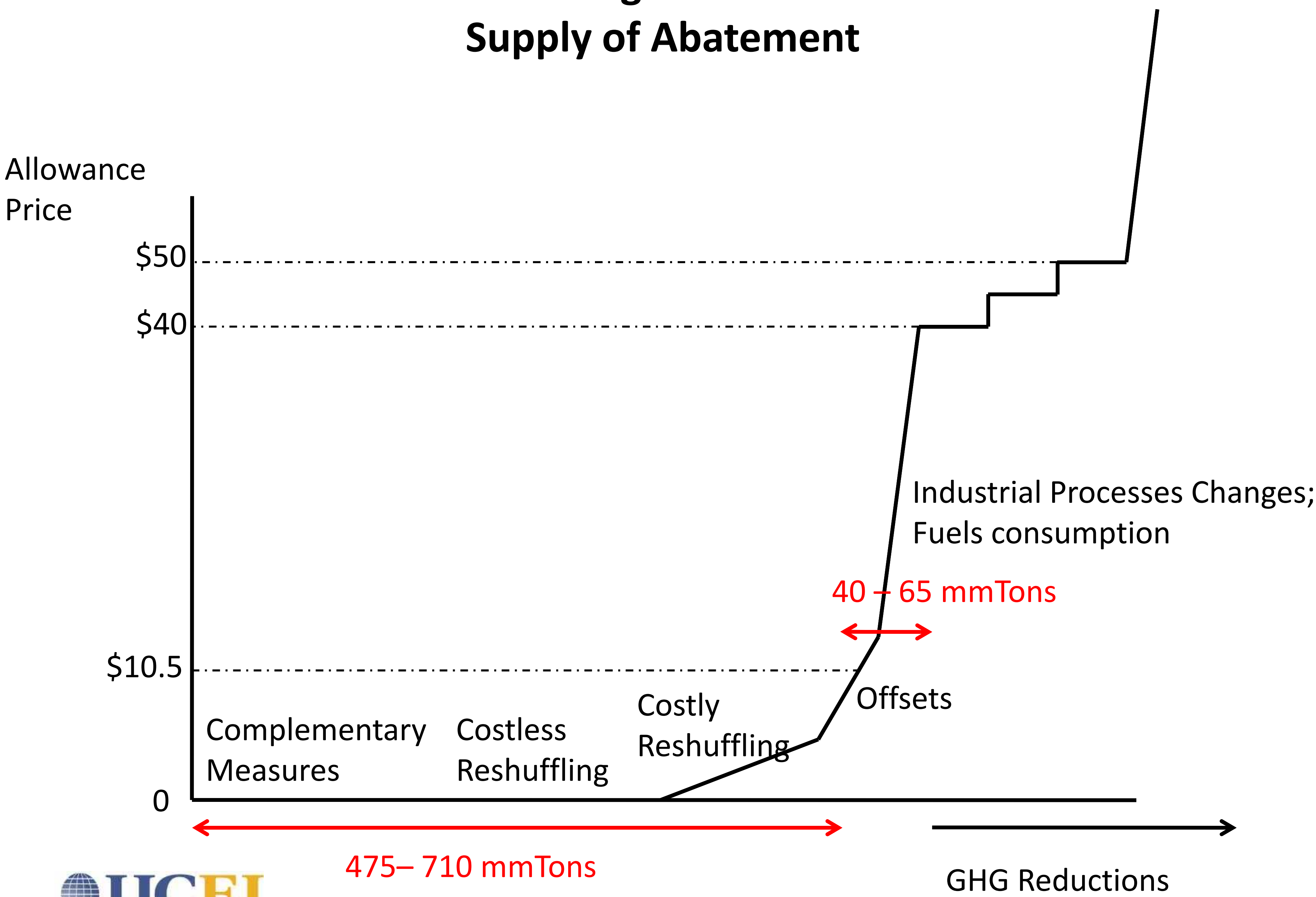

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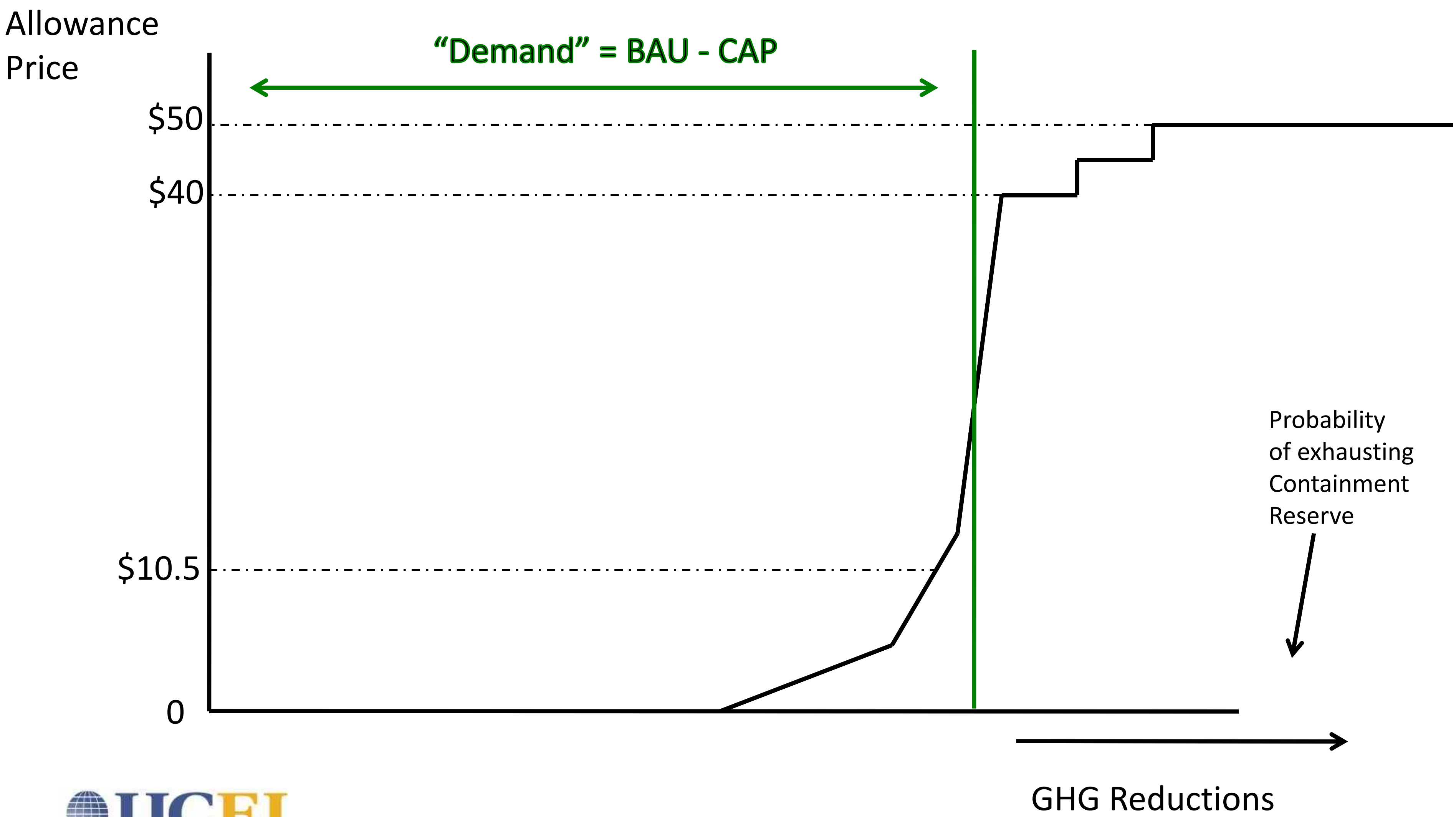
Figure 2
Hypothetical Distribution of Abatement Demand (BAU minus Allowances Outside Containment Reserve) vs Abatement Supply



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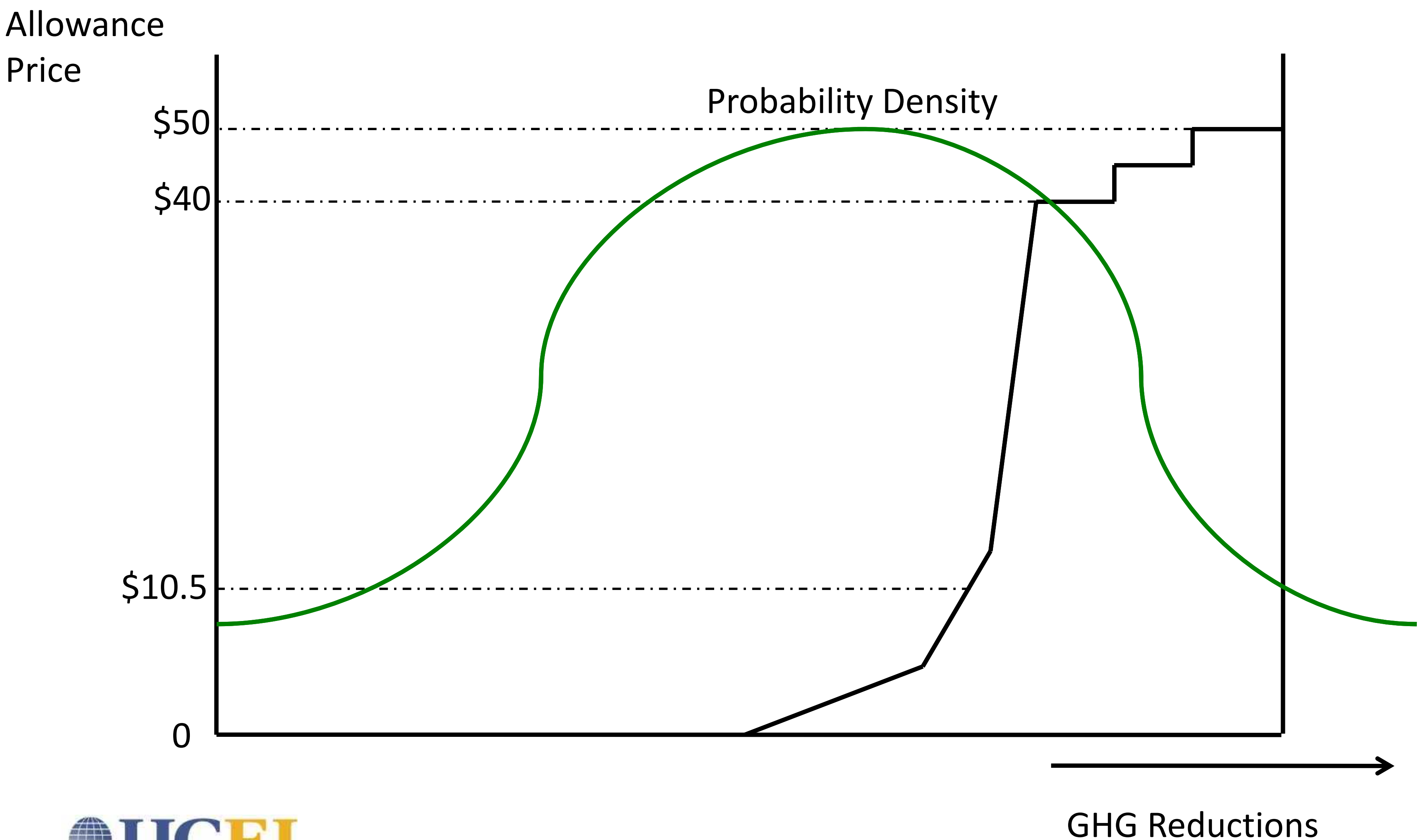

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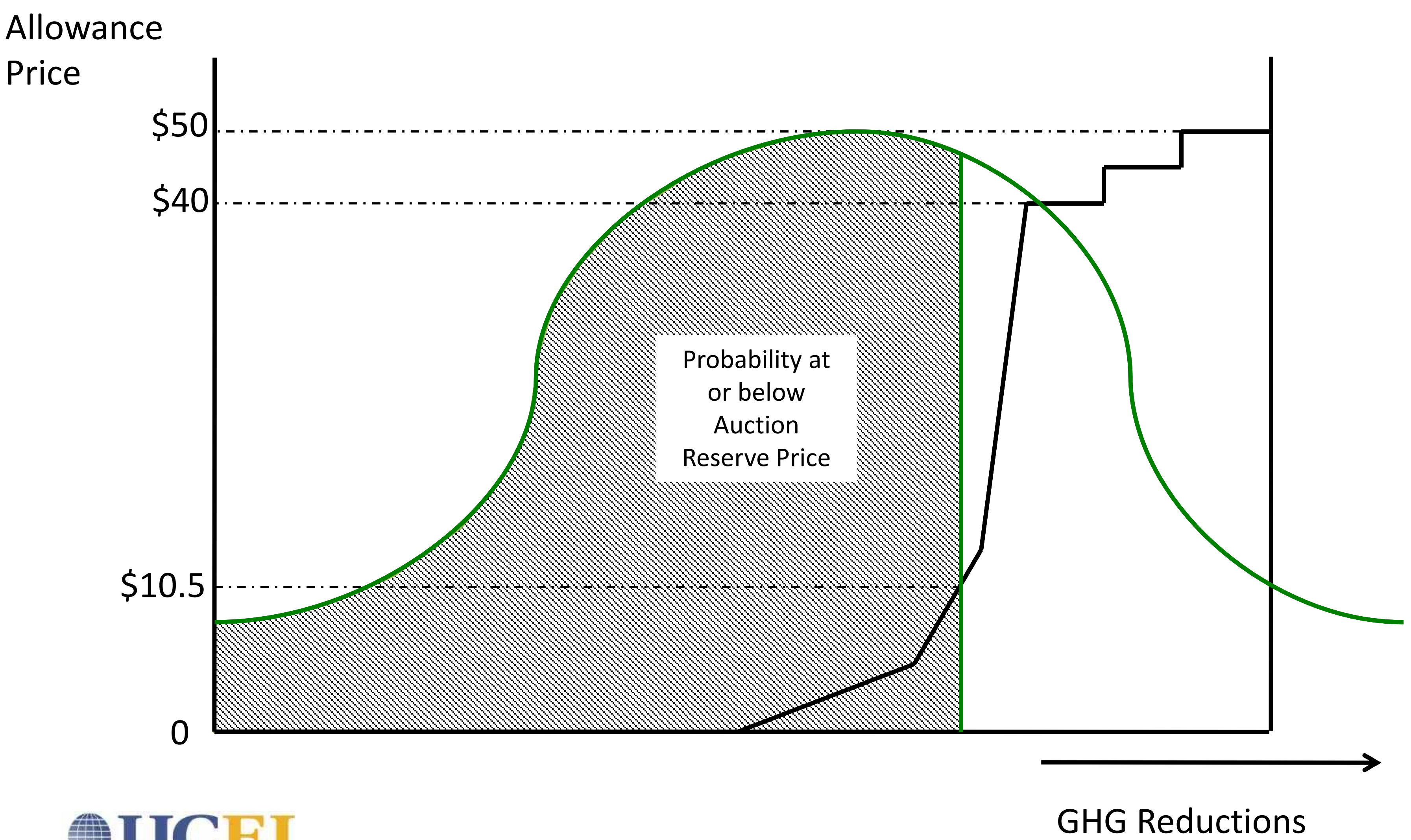

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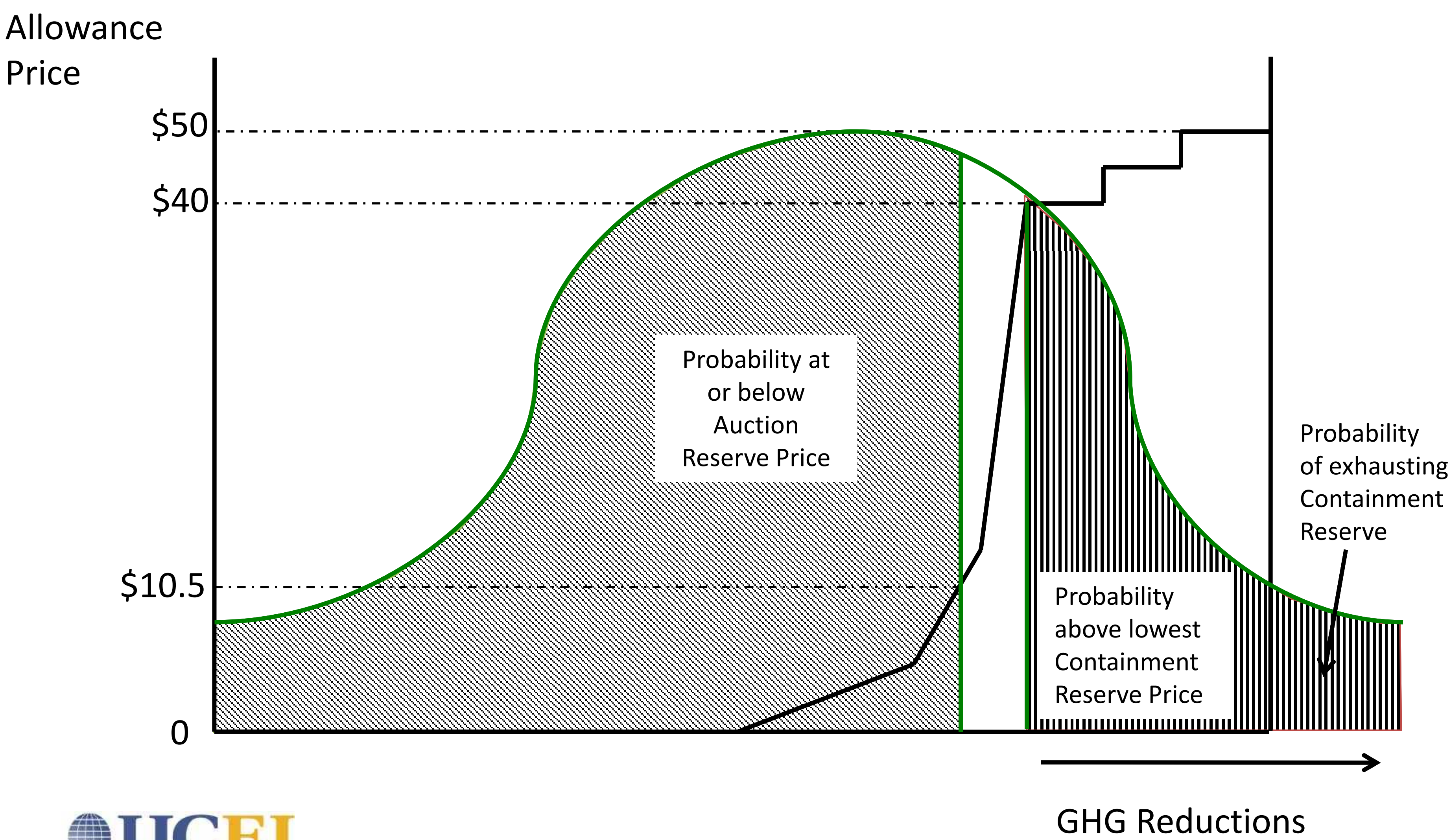

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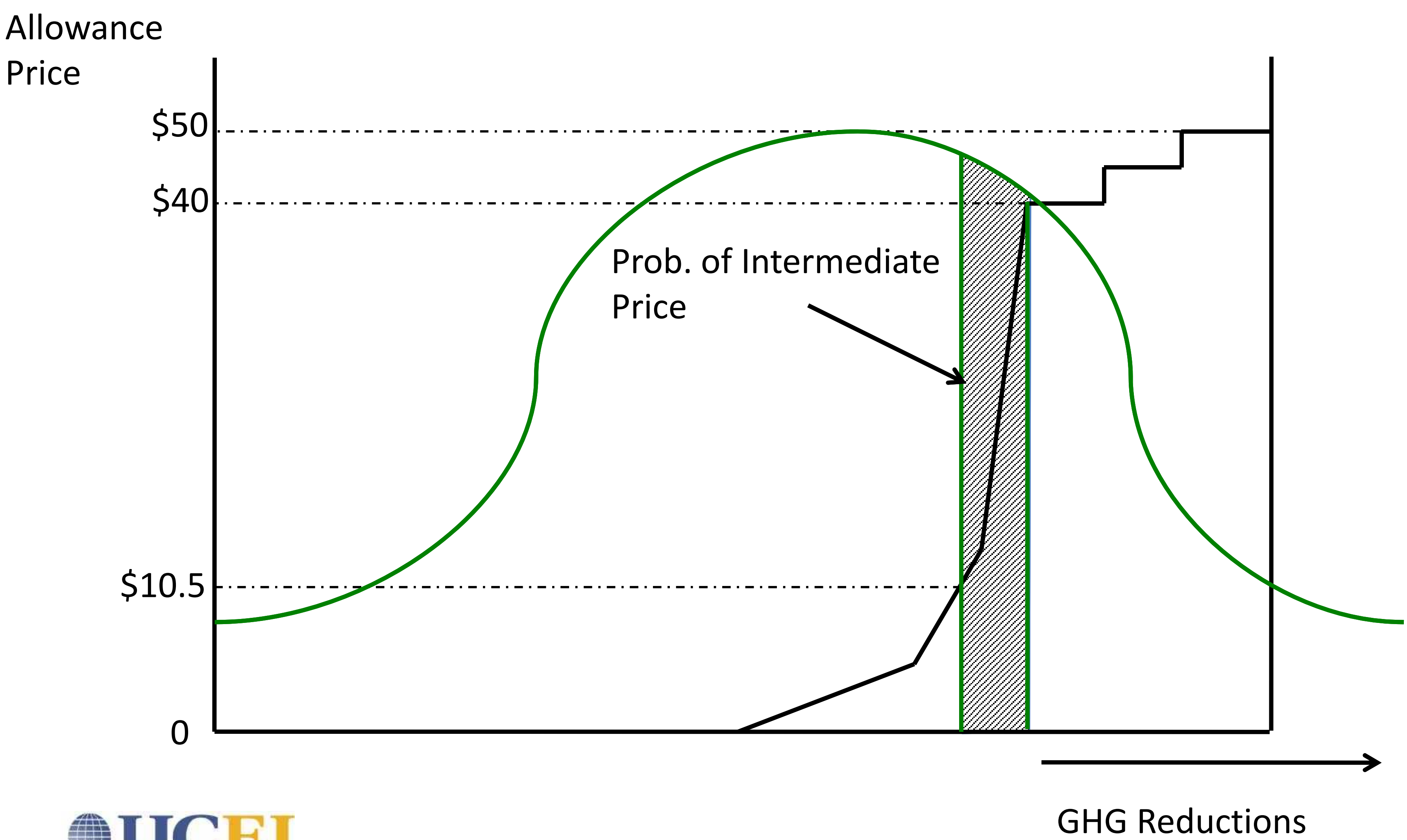

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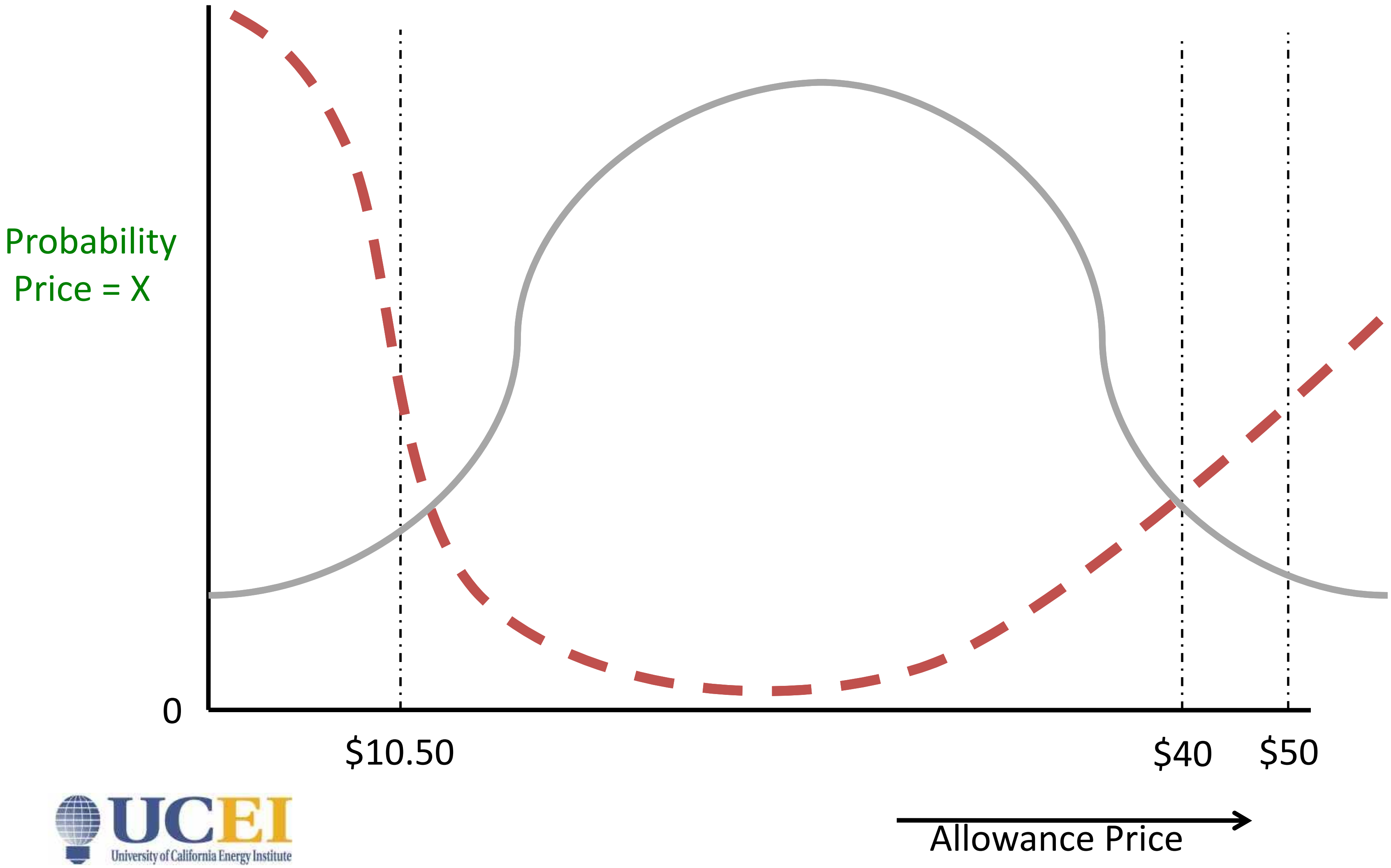
Figure 3
Possible Density Functions of Allowance Price



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Model for BAU Emissions

- Estimate time series model of drivers of sectoral greenhouse gas (GHG) emissions and sectoral emissions intensity
  - Includes Industrial & Nat Gas emissions, vehicle emissions, electricty emissions, GSP, VMT, Electricity consumption, Oil price
  - Model allows for economic activity in sector to increase yet GHG intensity of sector to fall
- Use model to construct a distribution of future GHG emissions from 2013 to 2020 that accounts for
  - Uncertainty in econometric model parameter estimates
    - Estimation Error
  - Uncertainty in future values of unobservables in econometric model
    - Prediction Error
- Model assumes all variables are 2^{nd}-order stationary in growth rates but allows for linear combinations of elements of model to be stationary
  - Co-integration restrictions imposed in estimation and simulation that reflect "equilibrium" relationships between variables in model
  - Imposing these restrictions improves forecasting accuracy of model
  - Model uncertainty is a third source of uncertainty
    - Not explicitly taken into account in distribution of future GHG emissions, but estimated distributions are very similar across a wide range of models that assumed variables are 2^{nd}-order stationary in growth rates

Model for BAU Emissions

From $F[(Y_{T+1}, Y_{T+2}, \ldots Y_{T+9}, Y_{T+10})|GSP(2011), GSP(2012)]$ can apply change of variables to compute an estimate of distribution of state-wide GHG emissions for

Phase I = electricity and industrial processes for 2013, 2014

Phase II = Phase I + transportation and natural gas for 2015 to 2020

Cap three emissions intensity measures at in-sample median, 75^{th} percentile, or maximum in constructing future GHG emissions

If realized value of intensity is greater than cap, then re-set value to equal cap and multiply by economic activity measure to obtain sectoral GHG emissions

Compute distribution of cumulative GHG emissions covered by cap for 2013 through 2020

Sum of GHG emissions covered from start of program though end of each year

Report E(Cumulative Sum of Covered GHG Emissions| GSP(2011),GSP(2012)] for each year from 2013 to 2020

Compute pointwise (for each year) upper and lower 95% confidence intervals for each conditional expectation of cumulative annual GHG emissions

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Figure 4a
Estimated Business-As-Usual Emissions
(with GHG Ratios to Other Factors Bounded Above at Median Levels)

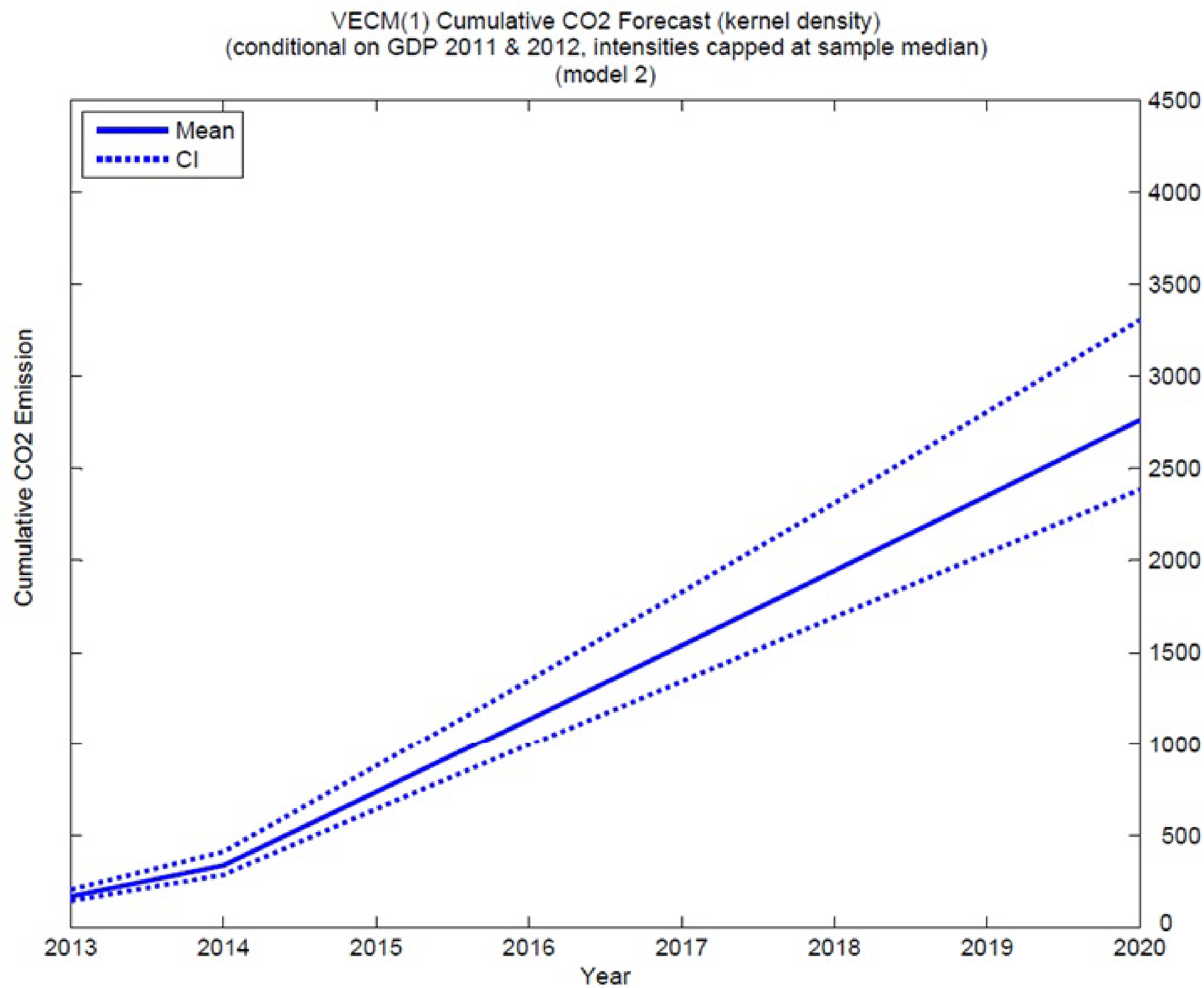

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Figure 4b
Estimated Business-As-Usual Emissions

(GHG Ratios to Other Factors Bounded Above at 75th Percentile)

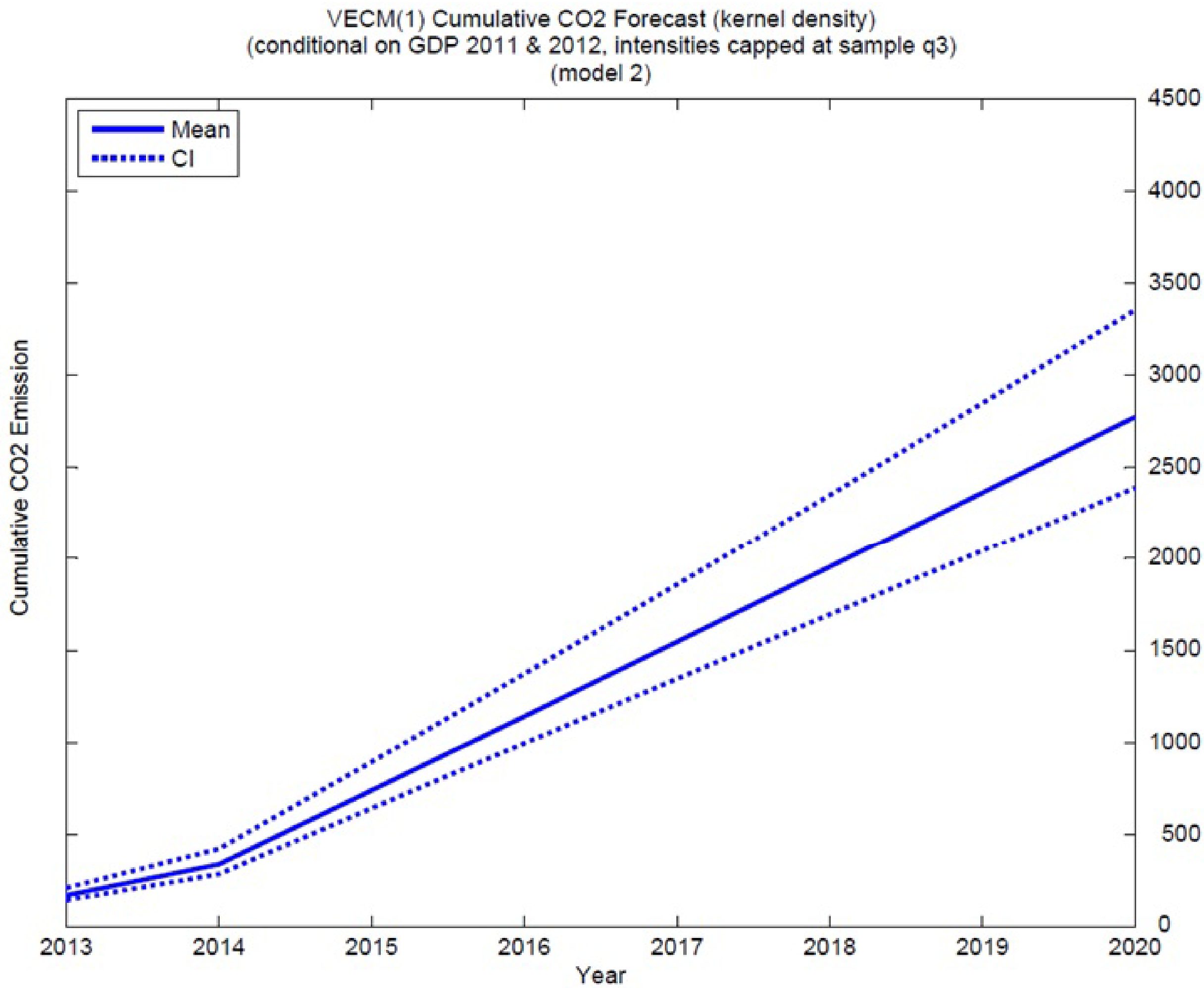

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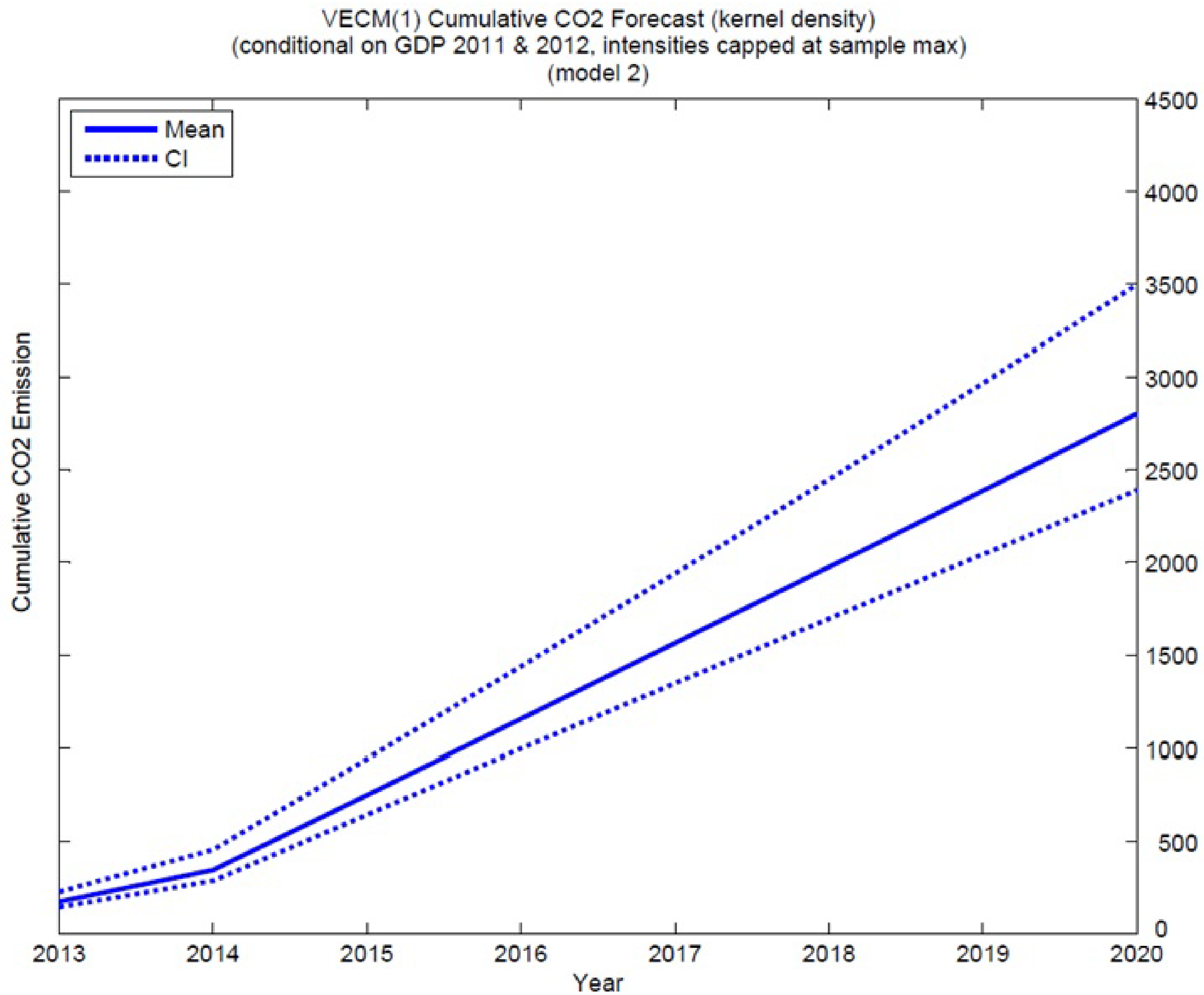
Figure 4c
Estimated Business-As-Usual Emissions

(GHG Ratios to Other Factors Bounded Above at Maximum)



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Supply of Abatement

Table 1: Potential Emissions Reductions from Complementary Policies

Category	**Measure**	**Average Annual Reductions**	**Years Under Cap**	**Total Aggregate Reductions**
Complimentary Measures	20% and 33% RPS	7.8 – 12.4 MMT	2013 – 2020	62.4 – 98.8 MMT
	Auto Standards	9.3 – 16.2 MMT	2015 – 2020	74.2 – 129.8 MMT
	LCFS	0 – 10.3 MMT	2015 – 2020	0 – 61.9 MMT
	Energy Efficiency	0 – 3.4 MMT	2013 – 2020	0 – 27 MMT
	Other transport	0 – 1.5 MMT	2015 – 2020	0 – 12.4 MMT
Low-price Responses	Offsets	9.4 – 17.4 MMT	2013 – 2020	75 - 139 MMT
	Reshuffling	15 – 45 MMT	2013 – 2020	120 – 360 MMT
Price-Responsive (at $50/ton)	Gasoline		2015 - 2020	13.4-26.7 MMT
	Natural Gas		2015 - 2020	18.5-35.8 MMT
	Electricity		2013 - 2020	15-25 MMT
Totals				**378.5 – 916.4**

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Three Abatement Scenarios

- Low Availability:
  - 475 MMT from comp. and low price policies
  - Medium price response
- Medium Availability:
  - 583 MMT from comp. and low price policies
  - Low price response
- High Availability:
  - 710 MMT from comp. and low price policies
  - Medium price response

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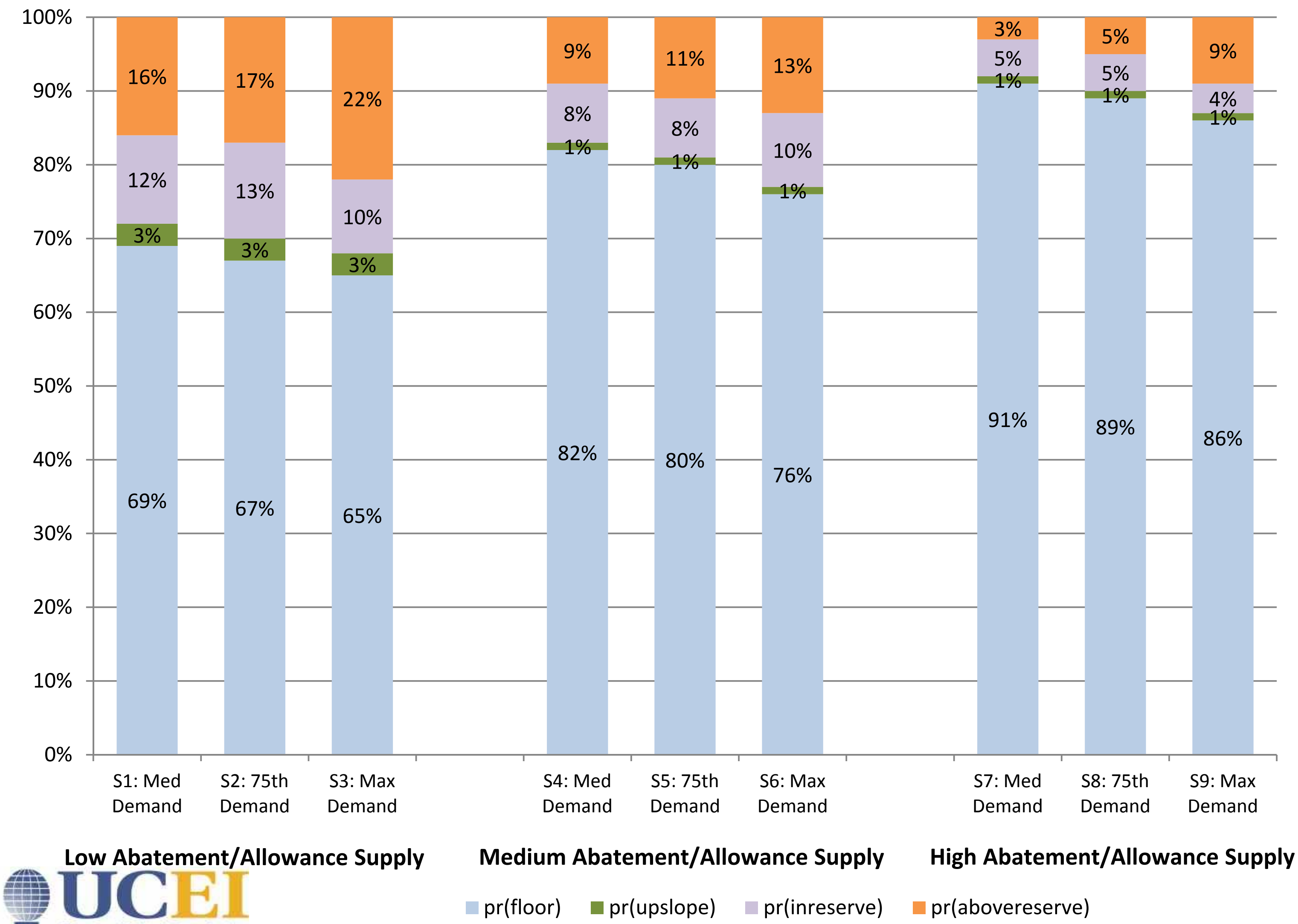
Figure 5
Allowance Price Probabilities by Scenario



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Conclusions from Modeling

- Very skewed distribution of possible prices
  - "fat" tails on low and high prices
  - Steeper abatement curves and fatter tails on expected emissions magnify this effect
- Expected prices less informative about risks of extreme prices than for normal distributions
- Without banking, ``width'' of the segments from the abatement supply curve narrow
  - Prices would not be the same every year
  - Probability of extreme prices in any given year increase

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Policy Implications

- Small, but real chance of reaching and exhausting allowance reserve before 2021.
  - Specific policies to respond to potential exhaustion of reserve are needed. CARB is working on these.
- Allowance revenues could fall well below previous forecasts.
  - Floor price most likely outcome
  - Lower sales at the floor price
- Prices could be volatile as market updates to new information
  - Small swings in BAU or abatement could lead to large prices swings