Addendum: A Generic Approach to Implementing Non-Priced GHG-Reduction Programs in Western Day-Ahead Market Designs.

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Introduction

This addendum paper is a follow on to the earlier white paper *"A Zonal Approach to Implementing Non-Priced GHG-Reduction Programs in a Zonal Day Ahead Market*", referred to in this paper as the *Zonal Approach* paper. The additions are:

- This addendum adopts a more generic approach which could be adapted to either the Markets+ Zonal dispatch model, or the EDAM Resource-Specific model, without depending upon specific characteristics of either model, such as the Unspecified Resources pathway of the Markets+ Zonal model. It uses a simple "assignment" of generation to serve the GHG Zone, much like "deeming" in the Resource Specific approach and Specified Resources in the Zonal approach. The Unspecified Resources pathway can be thought of as an additional generator with a pre-specified emissions rate, i.e., the default GHG hurdle rate for the pathway.

- This addendum uses a more simplified version of determining which generators are assigned to the GHG Zone, which eliminates the need to specifically identify any imports out of the GHG zone.

- This addendum identifies the possibility of a dispatch solution in which not all generators would recover their bid costs, creating an uplift situation. It identifies mitigation strategies that would eliminate the necessity of an uplift payment.

- Two new examples have been added that are simplified and illustrate the dispatch logic more clearly than in the *Zonal Approach* paper.

Emissions Constraint

As in the earlier *Zonal Approach* paper, the backdrop is a load-serving entity (LSE) that is subject to a GHG-reduction program of the variety:

- The annual (or longer) electricity to meet the LSE load must meet an average GHG emissions that is X% less than a historical baseline GHG emissions. X increases over time.

- The annual (or longer) electricity generation to serve the LSE load must meet an average GHG emissions of Y mtons per mwh.

The LSE with the GHG-reduction program will be referred to as the GHG Zone; everything else as the non-GHG Zone.

As with the Resource Specific model and with the Zonal model's Specified Resources, the dispatch model used here will assign specific generators, or portions thereof, to be serving the GHG Zone. This allows the computation of the average emissions of the generation serving the GHG Zone. We will say that the generators, or portions thereof, that are serving the GHG zone are "assigned" to the GHG Zone.

This does not preclude the Zonal model's use of the Unspecified Resource path, which could simply be considered another generator with a specific emissions rate, i.e., the default GHG emission rate of the Zonal model, which is assigned to serving the GHG Zone.

As with the Zonal Approach paper, the core concept is to introduce an emissions constraint:

$$\sum_{i \epsilon Assigned} D_i * E_i \leq max\_emissions$$

Where:

Assigned = set of generators, or portion thereof, assigned to the GHG Zone

D_i = Dispatch of Generator i (mwh), or portion thereof. assigned to the GHG Zone .

E_i = emission rate (mton/mwh) of Generator i.

max_emissions = maximum emissions (mtons) permitted for the GHG Zone in this dispatch interval.

The Shadow Price: the Marginal Carbon Allowance Cost

The shadow price of the Emissions Constraint is the total cost increase to the market if the max_emissions were lowered by one mton. It is measured in dollars per mton and represents a "proxy" GHG allowance price. Interestingly, if this value is used to dispatch the market, treating the GHG Zone as if it were a cap-and-trade zone, it will not necessarily produce a dispatch which does not exceed the max_emissions value. It will generally produce a dispatch result with higher emissions for the GHG Zone, but it can produce a dispatch result with lower emissions for the GHG Zone, though at a higher cost.

The Marginal GHG Cost

A marginal GHG cost is computed as the shadow price of the constraint which requires the GHG Zone load to be met by sufficient generation, as shown below.

$$\sum_{i \epsilon Assigned} D_i = GHG\ Zone\ load$$

Reference Pass

Depending upon the specifics of the market offers, a possible dispatch result could transfer a large amount of higher-emitting generation in the GHG Zone to the non-GHG Zone, and simultaneously transfer a large amount of lower-emitting generation from the non-GHG Zone to the GHG Zone; in effect, a large swap of resources between the GHG Zone and the non-GHG Zone. Even though the GHG Zone has passed an emissions sufficiency test, this "swapping" of resources would likely not meet the intention of the GHG-reduction program and would exacerbate leakage.

To avoid this situation, we run an initial dispatch, called the Reference Pass, which disallows assignment of resources in the non-GHG Zone to serving the GHG Zone. A Second Pass is then run which allows assignment of resources to the GHG Zone, but limits transfers from the GHG Zone to the non-GHG Zone to no more than the UEL of each generator minus the Reference Pass dispatch. In a sense, this is saying that the generators in the GHG Zone can only transfer "excess" generation to the non-GHG Zone if it is economic to do so.

Scheduling Coordinator (SC)

The SC sets the maximum emissions for each dispatch interval in the Day-Ahead Market. It is assumed that the SC does so subject to guidelines and limitations set through a sanctioned process, such as a state regulatory proceeding in the case of a state-regulated utility, or an open, self-run proceeding as in the case of public or federal power. The procedure would presumably be informed by the GHG-reduction program's requirements for the current compliance period.

It is most likely that the maximum emissions would be established for different seasons and peak versus non-peak hours, depending on the characteristics of the market. The Emission Constraint can be effectively turned off by setting it to a very high value, e.g., 99999 multiplied by the load.

To avoid a potential infeasibility problem, the SC must submit a set of offers in the market that could meet the maximum emissions set by the SC, in the absence of any market transfers into the GHG Zone. In other words, the LSE cannot lean on the market to provide it with low-emissions generation that it does not possess itself. The purpose of the market is to allow the LSE to meet the maximum emissions at lowest possible cost.

Uplift Situations

A possible issue that can occur with the Emissions Constraint method is the occurrence of an "uplift situation". An uplift situation occurs when the bids and offers to the market are such that the dispatch algorithm must dispatch a generating unit in the GHG zone whose bid cost is higher than the LMP (energy + GHG marginal costs) of the GHG zone. This means that payments to the affected generator(s) based on the LMP will not cover their bid costs. To ensure that the generator's bid cost is recovered, the difference between the generator's bid cost and the generator's LMP payment would have to be recovered through an additional payment, called an uplift payment. However, revenue from the LSEs based on the LMP would be insufficient to cover the uplift payment, so an additional out-of-market assessment must be made against the LSEs by some allocation protocol. Uplift situations are generally considered undesirable since they represent an economically inefficient solution and are unpredictable expenses for the LSEs. Typically, uplift events happen in unusual market situations in which the market operator must take extraordinary measures to ensure reliability.

The Emissions Constraint methodology can sometimes produce an uplift situation. There are, however, strategies that can be employed to avoid an uplift situation if an Emissions Constraint causes an uplift situation.

Strategy 1. Treating the GHG Zone as though it is a cap-and-trade zone when an uplift situation occurs.

If the Emissions Constraint method produces an uplift situation, the market could be re-dispatched with the GHG reduction zone being treated as if it were a cap-and-trade zone with the carbon marginal allowance cost from the Emissions Constraint Pass being used as the CO2 allowance price. This would also require the Reference Pass to be rerun since the results would be different using the carbon marginal allowance price instead of the Emissions Constraint.

Under this strategy, there is no requirement for generators to purchase allowances, there are no allowances to be purchased. Rather, the marginal carbon allowance price is used only to determine dispatch and set marginal costs.

Strategy 2. Do not enforce the Emissions Constraint when an uplift situation occurs.

If the Emissions Constraint produces an uplift situation relatively infrequently, then an acceptable strategy would be to run the dispatch again but not enforce the Emission Constraint.

Both strategies will, on average, produce dispatch results in which the emissions target for the GHG zone is exceeded. However, since compliance is annual, or longer, this would likely be manageable if uplift situations occur relatively infrequently.

To test the frequency of uplift situations and the impact on emissions and costs in the GHG zone, a Monte Carlo simulation was run over 12,500 scenarios to assess the frequency of an uplift situation and the impact on emissions and costs. The scenarios were first run through the Emissions Constraint algorithm (the “Emissions Constraint run”). If that run produced an uplift situation, then the carbon marginal price produced in the Emissions Constraint run was used in a second run where the GHG zone is treated as a cap-and-trade zone (the “cap-and-trade run”). Lastly, the scenario was run a third time in which the Emission Constraint was not enforced (the “no Emission Constraint run”).

The Emissions Constraint run produced an uplift situation about 3.5% of the time. The cap-and-trade and no Emissions Constraint runs never produced an uplift situation.

Figure 1 shows the impact on emissions and settled costs when an uplift situation occurs in the Emissions Constraint run. In both the cap-and-trade run and the no Emissions Constraint run, emissions and settled costs increased in the mitigation strategy compared to the Emissions Constraint run, including the uplift costs in the Emissions Constraint case.

It is a policy question as to which mitigation strategy to employ, or even to accept the uplift situation when it occurs since, on average, it appears to cost consumers less than the mitigation strategies.

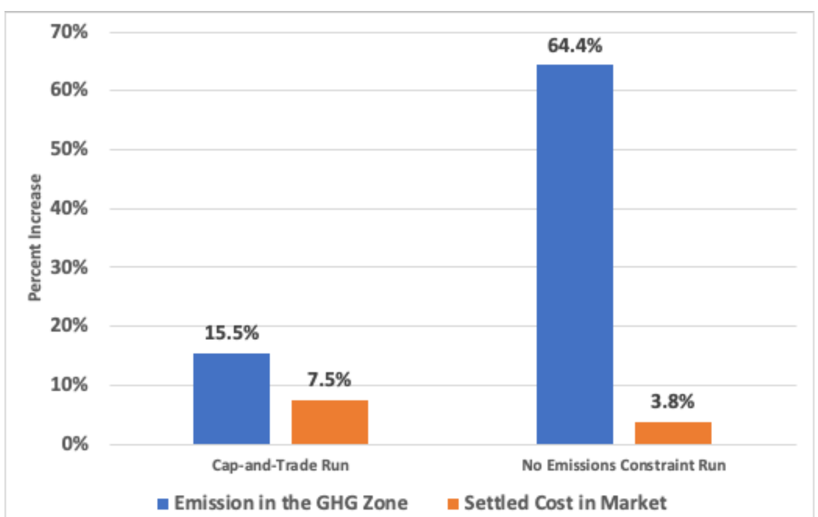

Figure 1: Percent Increase over the Emission Constraint Run

Examples

The two examples provided here assume two Zones – a GHG Zone called A which has a GHG-reduction requirement, and the non-GHG Zone called B. Both have a load of 500 mwh. There are seven generators, three in Zone A and four in Zone B.

The GHG zone has set a maximum emissions rate of 0.3 mtons/mwh for the dispatch interval, which means no more than 150 mtons of emissions produced by generation assigned to A.

The examples assume that each Zone is resource sufficient based on internal generation, i.e., neither Zone depends upon external resources for resource sufficiency. This is not a requirement of the Emissions Constraint method, but rather is done here for simplicity. Likewise, the GHG Zone is emissions sufficient based on internal generation, i.e., the internal generation portfolio offered to the market has an average portfolio emissions rate at or below 0.3 mtons/mwh. Meeting Emissions Constraint sufficiency with only internal generation is not a requirement of the Emissions Constraint method but is done here for simplicity.

Example 1: No Uplift Situation.

This scenario shows the Emissions Constraint mechanism without creating an uplift situation. Table 1-1 shows the scenario: the type, Upper Economic Limit (UEL), emissions rate and bid price for each generator.

Table 1-1: Scenario Setup

GEN #	Zone	Type	Emissions Rate (mtons/mwh	UEL mwh	Bid $/mwh
1	A	HY	0.00	144	$57
2	A	HYB	0.29	125	$26
3	A	CC	0.42	383	$42
4	B	SO	0.00	8	$24
5	B	CC	0.51	204	$32
6	B	SO	0.00	52	$30
7	B	CO	1.14	389	$44

CC = Combined Cycle SO = Solar HY = Hydro CO = Coal HYB = Hybrid

Scenario B7XH

Table 1-2 shows the Reference Pass and Second Pass dispatch results. The Reference Pass disallows assignments of generation from B to A. In the Second Pass, assignment to A of generators in B, or portions thereof, is permitted, but transfers from A to B are limited to the UEL minus the Reference Pass. In the Second Pass, there were 110 mwh transferred from Generator 3 in Zone A to Zone B, which was the maximum permitted transfer from Generator 3. In the Second Pass, Generator 1 was dispatched down 60 mwh, and that was made up by assigning 60 mwh from Generators 4 and 6. The Second Pass produced 149.93 mtons of emissions, just under the maximum of 150 mtons.

Table 1-2: Dispatch Results

GEN #	Reference Pass		Second Pass	
	Dispatch	Assigned To A	Dispatch	Assigned To A
1	102	102	42	42
2	125	125	125	125
3	273	273	383	273
4	8	0	8	8
5	204	0	204	0
6	52	0	52	52
7	236	0	186	0
Total	**1000**	**500**	**1000**	**500**
Emissions	**523.01**	**149.93**	**511.68**	**149.93**

The marginal energy cost (MEC) is $44 per mwh. This is because if there were one more mwh of load in the market, it would be filled by Generator 7 at a cost of $44. The marginal GHG cost is $13. This is because if there were one mwh of load transferred from Zone B to Zone A, this would result in Generator 1 dispatching up one mwh at a cost of $57, and Generator 7 dispatching down one mwh at a savings of $44, for a total cost of $13 per mwh.

The marginal carbon allowance cost is $39 per mton. This is because if the Emissions Constraint maximum were reduced by 1 mton to 149 mtons, or a rate of 0.298 mtons/mwh, this would cause Generator 1 to dispatch up by 3 mwh at a cost of $171, and Generator 7 to dispatch down by 3 mwh at a savings of $132, for a total cost of $39 per mton.

The LMP for Zone A is $57 per mwh ($44 plus $13). The LMP for Zone B is $44. We can see that all dispatched generators will have their full bid cost recovered through their respective Zone's LMPs. Tables 1-3 shows the settlement.

Tables 1-3: Generation and Load Settlement

GEN #	Energy Payment	GHG Payment	Uplift Payment	Total Payment
1	$1,848	$546	$0	$2,394
2	$5,500	$1,625	$0	$7,125
3	$16,852	$3,549	$0	$20,401
4	$352	$104	$0	$456
5	$8,976	$0	$0	$8,976
6	$2,288	$676	$0	$2,964
7	$8,184	$0	$0	$8,184
Total	**$44,000**	**$6,500**	**$0**	**$50,500**

Zone	LMP Payments	Uplift Payments	Total Payments
A	$28,500	$0	$28,500
B	$22,000	$0	$22,000
Total	**$50,500**	**$0**	**$50,500**

Example 2: An Uplift Situation

This scenario illustrates an uplift situation and applying a third pass to mitigate the uplift payment, by treating Zone A as if it were a cap-and-trade zone.

Table 2-1: Scenario Setup

Gen #	Location	Type	Emission Factor mtons/mwh	Energy Bid mwh	Energy Bid $
1	A	CC	0.44	293	$38
2	A	CC	0.48	65	$37
3	A	HY	0	293	$55
4	B	GT	1.54	57	$38
5	B	CC	0.49	429	$27
6	B	GT	1.41	64	$44
7	B	SO	0	102	$27

CC = Combined Cycle   GT = Gas Turbine HY = Hydro SO = Solar

Scenario XIMS

Table 2-2 shows the Reference Pass and Second Pass dispatch results.

Table 2-2: Dispatch Results

GEN #	Reference Pass for Second Pass		Second Pass	
	Dispatch	Assigned To A	Dispatch	Assigned To A
1	282	282	285	285
2	54	54	65	51
3	164	164	62	62
4	0	0	57	0
5	429	0	429	0
6	0	0	0	0
7	71	0	102	102
Total	**1000**	**500**	**1000**	**500**
Emissions	**360.21**	**150**	**454.59**	**149.88**

The marginal energy cost (MEC) is $38 per mwh. This is because if one more mwh of load is added to the system it will cause Generator 1 to dispatch up by one mwh at a cost $38, and this one mwh will be assigned to Zone A, and 1 mwh of Generator 2 will be unassigned to Zone A (and transferred to B) which neither increases nor decreases cost to the system.

However, the marginal GHG cost is $0 per mwh because if we transfer one mwh of load from Zone B to Zone A, it will cause Generator 1 to dispatch up by two mwh at a cost of $76 and

Generator 4 to dispatch down by two mwh at a savings of $76. The two mwh dispatched from Generator 1 will be assigned to A, and Generator 2 will have one mwh unassigned to A (and transferred to B) which neither increases nor decreases cost to the system.

The marginal carbon allowance cost is $34 per mton. This is because if we reduce the Emissions Constraint to 149 mtons maximum in Zone A, this will cause Generator 1 to dispatch down two mwh at a savings of $76, and Generator 3 to dispatch up two mwh at a cost of $110, for a total system cost increase of $34.

Consequently, the LMP in both Zones is $38 and this causes an uplift situation because Generator 3 cannot recover its bid costs at that price. The uplift amount is the difference between Generator 3's bid cost of $55 and the LMP of $38 times the full dispatch of 62 mwh, which is $1,054.

Table 2-3 shows what the settlement would be if this dispatch solution were to be used. The uplift is assessed against Zone A.

Table 2-3: Settlement with uplift

GEN #	Energy Payment	GHG Payment	Uplift Payment	Total Payment
1	$10,830	$0	$0	$10,830
2	$2,470	$0	$0	$2,470
3	$2,356	$0	$1,054	$3,410
4	$2,166	$0	$0	$2,166
5	$16,302	$0	$0	$16,302
6	$0	$0	$0	$0
7	$3,876	$0	$0	$3,876
Total	**$38,000**	**$0**	**$1,054**	**$39,054**

Zone	LMP Payments	Uplift Payments	Total Payments
A	$19,000	$1,054	$20,054
B	$19,000	$0	$19,000
Total	**$38,000**	**$1,054**	**$39,054**

To eliminate the uplift situation, we can run a Cap-and-Trade Pass treating Zone A as a cap-and-trade zone, by using the carbon marginal cost of $34 per mton from the Second Pass. Table 2-4 shows the dispatch results of the Cap-and-Trade Pass. Note that a new Reference Pass was also run because the results will be different from the Reference Pass for the Emission Constraint Pass.

Table 2-4: Third Pass Dispatch Results

GEN #	Reference Pass for Cap-and-Trade Pass		Cap-and-Trade Pass	
	Dispatch	Assigned To A	Dispatch	Assigned To A
1	293	293	293	293
2	65	65	65	65
3	142	142	40	40
4	0	0	57	0
5	429	0	429	0
6	0	0	14	0
7	71	0	102	102
Total	**1000**	**500**	**1000**	**500**
Emissions	**370.33**	**160.12**	**477.85**	**160.12**

The Cap-and-Trade Pass does not produce a solution that meets the Emissions Constraint of 150 mtons, but it is not unreasonably higher. The marginal energy cost in the Third Pass is $44. This is because if we add one more mwh of load to the market it will cause Generator 6 to dispatch up by 1 mwh for a cost of $44.

The marginal GHG energy cost is $11, because if we transfer one mwh of load from Zone B to Zone A, this will cause Generator 3 to dispatch up by one mwh at a cost of $55 (because it is hydro it does not incur a compliance cost based on the $34 per mton allowance cost) and Generator 6 will dispatch down by one mwh at a savings of $44, for a total system cost of $11.

The LMP for Zone A is therefore $55 per mwh, and the LMP for Zone B is $44 per mwh. This means that the LMPs will now cover the bid costs of all generators. The settlement table for the Cap-and-Trade Pass is shown in Table 2-5.

Table 2-5: Cap-and-Trade Pass Settlement

GEN #	Energy Payment	GHG Payment	Uplift Payment	Total Payment
2	$12,892	$3,223	$0	$16,115
3	$2,860	$715	$0	$3,575
4	$1,760	$440	$0	$2,200
5	$2,508	$0	$0	$2,508
6	$18,876	$0	$0	$18,876
7	$616	$0	$0	$616
Total	$4,488	$1,122	$0	$5,610
Emissions	**$44,000**	**$5,500**	**$0**	**$49,500**

Zone	LMP Payments	Uplift Payments	Total Payments
A	$27,500	$0	$27,500
B	$22,000	$0	$22,000
Total	**$49,500**	**$0**	**$49,500**