ISO new england

memo

To: NEPOOL Participants Committee Working Session

From: Market Development

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Subject: Modelling Equivalence of FCEM and ICCM

Introduction

The Pathways to the Future Grid study explores potential market frameworks that will help the region achieve clean energy goals. As part of this process, Analysis Group (AGI) will model a forward clean energy framework and a net carbon pricing framework to compare their expected market outcomes to a "status quo" framework where there are no substantial changes to the region's markets and states continue using bilateral contracts to achieve their policy objectives. In previous meetings and materials, stakeholders and the ISO have discussed whether AGI should model a forward clean energy market that is integrated with the capacity market or model a forward clean energy market that is conducted separately from the capacity market.[1]

Under an integrated clean capacity market (ICCM) construct, resources would submit a single offer for the forward sale of both capacity and clean energy, while in a separate forward clean energy market (FCEM) resources would first participate in a forward market for clean energy before submitting offers in a subsequent forward market for capacity. While both frameworks would require significant work to translate the high-level concepts into fully developed designs, the ISO views the ICCM as having particularly complex design and implementation challenges, given the added difficulties associated with jointly procuring two distinct products through a single auction.[2] Nonetheless, the ISO feels that AGI's modeling can simulate outcomes from a high-level ICCM framework, which will provide stakeholders with some insight about its theoretical application.

This memo considers potential differences between the FCEM and the ICCM concepts, with a focus on how these approaches may be similar or different in the context of the modeling efforts that are part of the Pathways to a Future Grid study. In particular, given AGI's proposed modelling structure and the

[1] See the "Scoping" document for the FCEM, located here: https://nepool.com/wp-content/uploads/2021/03/1a-FCEM-Scoping-Memo_vfinal.pdf

[2] While the ISO cannot fully evaluate the work or implementation challenges that may arise under an ICCM design that has not yet been established, we imagine that, at a minimum, the ICCM would likely add significant complexity to the FCM process. For more information on the ICCM, see the "Evaluation of an Integrated Forward Clean Energy Market," located here: https://nepool.com/wp-content/uploads/2021/03/NPC_FG_20210318_Supplemental-1.pdf

corresponding model inputs and assumptions, the memo concludes that the two approaches should produce identical awards and compensation. This result holds because the model makes two key assumptions: i) under an FCEM, resources account for their expected capacity revenue when formulating their competitive clean energy offers, and ii) that these expectations are accurate (i.e., the *expected* FCM prices are the same as the *actual* prices.) Based on this finding, it does not appear critical for the region to choose between an FCEM and an ICCM for the distinct purpose of finalizing the straw forward clean energy framework to be modeled.[3]

The memo begins by describing some of the key assumptions for the following examples. The memo next considers a numerical example that demonstrates awards, prices, and total compensation to resources in a hypothetical ICCM. The memo follows with a similar numerical example for a FCEM with the same assumptions and resource parameters as the ICCM example. The numerical examples show that the FCEM and ICCM will yield identical awards, prices, and total revenue for each resource, given the aforementioned assumptions. The memo concludes with a discussion of AGI's model mechanics and how their assumptions compare to those employed in these examples. It finds that because the assumptions listed in the memo's first section mirror AGI's model structure, the memo's numerical examples are consistent with the model output we would expect from AGI under equivalent conditions.

Given that AGI's expected modelling results can be viewed as consistent with either the FCEM or the ICCM, the ISO does not believe it is necessary for the region to pick one over the other for the purpose of studying a straw forward clean energy framework. The ISO welcomes stakeholder feedback on this issue and looks forward to further discussion.

Key Assumptions and Parameters for Numerical Examples

This section lists the key assumptions for the numerical examples in the subsequent section. Note that these assumptions reflect those AGI will make in their modelling efforts.

Assumption 1: Resources submit offers for capacity and clean energy based on their missing money, where their missing money is defined as the revenue they would need to receive, in addition to that from the energy and ancillary service markets, to recover their costs.[4]

Assumption 2: The markets for renewable energy certificates (RECs) and clean energy certificates (CECs) are competitive, so that the marginal resource recovers its missing money, but no more. In practice, if the REC or CEC markets were not competitive and the marginal resource recovered more than their missing money, we would expect additional resources to enter the markets to profit themselves. As more resources enter the markets, we would expect that competition would increase until the marginal

[3] While the modelling efforts are unlikely to detect differences between the FCEM and the ICCM, there will likely be important differences in practice. As a result, if the region decides to pursue a forward clean energy framework, further consideration of the pros and cons of an FCEM versus an ICCM, as well as additional design details, will be necessary. Moreover, we will seek to provide qualitative information on these differences to help inform the region before it proceeds further into developing potential proposals.

[4] This is a simplifying assumption and generalizes to cases where resources submit offers based on the maximum of their missing money and the "common value component", or the expected opportunity cost of taking on a forward position.

resources earn no profit. Note that this is a natural extension of Assumption 1: if resources submit offers to recover their missing money, the marginal resource will recover its missing money and earn no profits.

Assumption 3: Resources offer to sell the entirety of their clean energy and capacity capability forward. For example, if a clean energy resource expects to produce 3,000 MWh of clean energy for each MW of capacity during the delivery year, they will offer to sell this entire 3,000 MWh of clean energy in the forward markets. We make this assumption because, in equilibrium, we expect the forward clean energy price to equal the expected clean energy price in the delivery period, so that resources cannot profit from selling some of their clean energy in the spot market rather than the forward market.

Assumption 4: Resources submit fully rationable (i.e., non-lumpy) offers for capacity. This is a simplifying assumption to make the examples easier to follow.

Assumption 5: Resources have perfect foresight, so that they can exactly predict the capacity clearing price, their capacity award, their real-time energy profits, their clean energy production, etc.

Assumption 5 is an important modeling assumption that may not hold in practice, as it is likely that actual capacity prices will differ from those expected by resources when formulating the clean energy offer prices. However, it is consistent with the model framework that AGI will employ in the pathways efforts. Without this assumption, we might observe divergent outcomes between the ICCM and the FCEM, particularly when the resources have different beliefs about the expected capacity prices.[5]

Key Parameter Values for the Numerical Examples

The following numerical examples consider market outcomes for four resources. More specifically, the examples consider how the resources offer to sell their capacity and clean energy in a FCEM and an ICCM, and the resulting awards, prices, and compensation in each framework. The examples show that each framework results in the same awards and prices so that the resource's total compensation is identical in both the FCEM and the ICCM.

Table 1 below lists parameter values for the four resources included in this memo's numerical examples. Note that the parameter values are held constant across the two examples so that the results are comparable. Row [1] contains each resource's missing money per MW. This represents the revenue they would need to recover from capacity or clean energy to be economical. Row [2] contains their maximum capacity award, which is the maximum quantity of capacity the resource can sell in a FCM or an ICCM. Row [3] lists each resource's expected clean energy production during the delivery year. Row [4] sets the CSO demand at 1,200 MW and Row [5] sets the clean energy demand at 3,000,000 MWh. Note that we assume vertical demand curves, for simplicity, but the results generalize to sloped demand curves as well.

[5] While it may not be possible to fully eliminate this divergence, there may be mechanisms that would tend to reduce this divergence by decreasing the uncertainty of the price for the second product and ensuring that there are retrading opportunities for both products after the primary auction. If the region chooses to pursue a forward clean energy framework, further consideration of these mechanisms may be worthwhile when evaluating the relative merits of an FCEM versus an ICCM.

Table 1. Resource Parameters for Numerical Examples					
		Non-Clean 1	Clean 1	Clean 2	Clean 3
[1]	Missing Money Per MW	$60,000/MW	$160,000/MW	$150,000/MW	$200,000/MW
[2]	Max Capacity Award	1,000 MW	300 MW	300 MW	300 MW
[3]	E[Clean Energy]	-	6,000 MWh/MW	3,000 MWh/MW	7,000 MWh/MW
[4]	CSO Demand	1,200 MW			
[5]	Clean Energy Demand	3,000,000 MWh			

Numerical Example: Integrated Clean Capacity Market

With an ICCM, capacity and forward clean energy are procured simultaneously in one forward auction. Resources submit a single $/MW offer to provide both clean energy and capacity, where their offer includes a "clean energy parameter" that defines the quantity of forward clean energy they would need to sell per unit of capacity. In effect, the clean energy parameter "binds" a resource's capacity award with their clean energy award, so that a resource's capacity award cannot be increased without also increasing the resource's clean energy award by their clean energy parameter.[6]

For example, suppose that Clean 2 submits an offer of $150,000/MW into the ICCM with a clean energy parameter of 3,000 MWh/MW (equal to their expected clean energy production from Table 1). This offer suggests that they would need to be paid at least $150,000/MW to be awarded both 1 MW of CSO and 3,000 MWh of forward clean energy. If Clean 2 is awarded a MW of CSO, they must also be awarded 3,000 MWh of forward clean energy.

Table 2 below contains the resource offers, awards, prices, and total revenue in the ICCM, given the parameter values in Table 1.

Table 2. Resource Offers, Awards, Prices, and Revenue in ICCM						
			Non-Clean 1	Clean 1	Clean 2	Clean 3
[1]	ICCM Offers		$60,000/MW	$160,000/MW	$150,000/MW	$200,000/MW
[2]	Clean Energy Parameter		-	6,000 MWh/MW	3,000 MWh/MW	7,000 MWh/MW
[3]	CSO Award		728.6 MW	300 MW	0 MW	171.4 MW
[4]	CSO Price		$60,000/MW	$60,000/MW	$60,000/MW	$60,000/MW
[5]	Clean Energy Award		-	1,800,000 MWh	0 MWh	1,200,000 MWh
[6]	Clean Energy Price		-	$20/MWh	$20/MWh	$20/MWh
[7]	Total Revenue	=[3]*[4]+[5]*[6]	$43,714,800	$54,000,000	$0	$34,285,200

Rows [1] and [2] define the offer parameters for the resources. Row [1] provides the $/MW offer for each resource. These offers represent the amount of money the resources would need to be paid to sell 1 MW of CSO and the accompanying forward clean energy defined by their clean energy parameter, displayed in

[6] Stakeholders have questioned whether it would be possible for some resources to sell only clean energy in an ICCM. While submitting "clean energy only" offers in an ICCM is not considered in this memo, the ICCM (and AGI's model) can likely be modified to accommodate such offering behavior.

Row [2]. Note that the offers in Row [1] equal each resource's missing money in Table 1 Row [1]. Because Non-Clean 1 does not provide clean energy, they do not submit a clean energy parameter and their offer only represents the minimum amount they would need to be paid to sell capacity. In these examples, Non-Clean 1 would need to be paid $60,000/MW for capacity.

Row [3] lists CSO awards. Clean 1 clears for their entire capability because, as we will see, they are infra-marginal for clean energy and their capacity award is bound to their clean energy award by their clean energy parameter. Clean 3 is awarded 171.4 MW of capacity, but they are not marginal for capacity, as Non-Clean 1 can provide capacity more cheaply than Clean 3. Indeed, Clean 3 is awarded capacity because, when they sell capacity, they also sell clean energy that contributes to meeting the clean energy demand.

Row [4] lists the CSO clearing price. Non-Clean 1 is marginal for capacity and sets the CSO price at $60,000/MW. To see how this price is determined, consider an incremental increase in the installed capacity requirement of 1 MW, without a corresponding increase in clean energy demand. The least-cost way to meet this increment is to increase Non-Clean 1's CSO award by 1 MW, at a cost to the system of $60,000. Thus, Non-Clean 1 sets the CSO clearing price at $60,000/MW.

Note that Clean 2 does not clear for capacity despite the fact that their offer is less than Clean 3's offer (See Row [1]). While Clean 2 submits a lower-priced capacity offer, their clean energy parameter is also much smaller than Clean 3's and so they contribute less to clean energy demand. From the perspective of the optimization problem, Clean 3's additional contributions to clean energy demand per MW outweigh their increased cost, and so they are awarded capacity and clean energy positions ahead of Clean 2.

Row [5] lists the forward clean energy awards. Clean 1 is infra-marginal for clean energy and so clears for their entire capability, 1,800,000 MWh. Because they clear their entire clean energy capability, they also clear for their entire capacity capability. Clean 3 is awarded 1,200,000 MWh of forward clean energy to meet the remaining clean energy demand.

Row [6] lists the forward clean energy price. Clean 3 is the marginal resource for the forward clean energy positions and sets their price at $20/MWh. To see how this price is determined, consider an incremental increase in the forward clean energy demand of 1 MWh, without a corresponding increase in CSO demand. To meet this additional 1 MWh demanded, Clean 3 must be awarded an additional $\frac{1}{7000}$ MW of CSO, costing the system $\frac{1}{7000} * \$200{,}000 = \$28.57$. Because Clean 3 clears for an additional $\frac{1}{7000}$ MW of CSO, however, Non-Clean 1's CSO award can be decreased by $\frac{1}{7000}$ MW, saving the system $\frac{1}{7000} * \$60{,}000 = \$8.57$. The total change in system costs is thus $28.57-$8.57 = $20, and so the forward clean energy price is $20/MWh.

Finally, Row [7] lists the total revenue to each resource. Because Non-Clean 1 cannot sell clean energy, their total revenue is equal to their capacity revenue: $60,000/MW * 728.6 MW = $43,714,800. For the clean resources, their total revenue is the sum of their capacity revenue and their clean energy revenue. Clean 3's total revenue, for example, is their capacity revenue ($60,000/MW * 171.4 MW = $10,285,200) plus their clean energy revenue ($20/MWh * 1,200,000 MWh = $24,000,000), for a total of $34,285,200. Note that Clean 3's per MW revenue is their total revenue divided by their capacity award, $\frac{\$34{,}285{,}200}{171.4\ MW} =$

$\$200{,}000/MW$. That is, Clean 3 is paid their offer for their capacity and clean energy, and so they exactly recover their missing money. This is consistent with Assumption 2, the competitive markets assumption, as it indicates that the marginal resource for clean energy does not earn infra-marginal profits.

Numerical Example: Forward Clean Energy Market

In a market where forward clean energy is purchased in advance of the capacity market, clean resources submit offers to sell clean energy in the FCEM and then subsequently submit offers in the FCM. That is, unlike the ICCM which has one optimization that solves for both capacity and clean energy awards, the FCEM has two sequential optimizations, the first for clean energy and the second for capacity. As a result, resources know their forward clean energy awards and revenue before they submit offers for capacity in the FCM. This section considers 1) clean resource's offers into the FCEM, 2) the resulting forward clean energy awards and prices given those offers, 3) the resource's CSO offers in the capacity market, given the awards and prices in the FCEM, and, finally, 4) the capacity prices and awards in the FCM.

Resource Offers in the FCEM

Clean resources submit offers into the FCEM that reflect the missing money they would need to recover to enter the market or remain in operation. However, the calculus associated with this decision differs from that in the ICCM because clean energy and capacity are awarded in separate auctions. While resources seek to recover their missing money via payments for their clean energy and capacity (as they do in the ICCM), they now must determine their competitive FCEM offers before the capacity market price has been determined. Thus, when submitting their FCEM offers, the resources do not know how much of this missing money would be recovered via the sale of capacity. [7]

However, we assume that these resources have perfect foresight regarding the capacity clearing price when developing their clean energy offers (consistent with Assumption 5.) As such, resources set their clean energy offers as the remaining missing money that they must recover, net of their future capacity revenues. Table 3 below displays the clean resource's FCEM offers.

Table 3. Clean Resource Offers in FCEM

			Clean 1	Clean 2	Clean 3
[1]	Missing Money		$160,000/MW	$150,000/MW	$200,000/MW
[2]	E[Capacity Price]		$60,000/MW	$60,000/MW	$60,000/MW
[3]	E[Clean Energy Production]		6,000 MWh/MW	3,000 MWh/MW	7,000 MWh/MW
[4]	FCEM Offer	=([1]-[2])/[3]	$16.67/MWh	$30.00/MWh	$20.00/MWh

Row [1] contains each resource's missing money, where this value does not account for their expected capacity revenue. In other words, the values in Row [1] are the quantity of money the resources need to recover through both capacity and clean energy revenue. For example, Clean 3 needs to be paid $200,000 for each MW of capacity they sell *and* the clean energy they expect to produce with that capacity. Note that values in Row [1] above are the same as those in Row [1] of Tables 1 and 2.

[7] The results illustrated in this example would still hold if the order of the markets were reversed, so that the FCM occurs before the FCEM and where resources would develop their capacity offer prices using the expected clean energy price.

Row [2] contains the expected capacity price. By Assumption 5, each of the resources perfectly predicted the capacity price at $60,000/MW. (We will see in subsequent tables that the capacity clearing price in the FCM is indeed $60,000/MW, meaning each resource's expectations about this price is correct.)

Row [3] contains their expected clean energy production per MW, which is identical to the clean energy parameter the resources submitted as part of their offers in the ICCM example above. (See Assumption 3 in the first section.)

Finally, Row [4] contains each resource's per MWh offer. For each resource, they subtract their expected capacity revenue from their missing money (Row [1] – Row [2]), as they expect to recover this revenue via the capacity market and therefore do not include it in their clean energy market offers. They then divide the remaining missing money by their expected clean energy production per MW (Row [3]). This is the missing money they need to recover for each MWh of clean energy that they deliver, and therefore reflects their competitive clean energy market offer price.

FCEM Awards, Prices, and Revenue

Given the offers in Table 3 above, Table 4 contains the awards, prices, and revenue to each clean resource in the FCEM. As in the case of the ICCM, total demand for clean energy is equal to 3,000,000 MWh.

Table 4. Resource Awards, Prices, and Revenue in FCEM					
			Clean 1	Clean 2	Clean 3
[1]	FCEM Offer		$16.67/MWh	$30/MWh	$20/MWh
[2]	Clean Energy Award		1,800,000 MWh	0 MWh	1,200,000 MWh
[3]	Max Clean Energy Award		1,800,000 MWh	900,000 MWh	2,100,000 MWh
[4]	Clean Energy Price		$20/MWh	$20/MWh	$20/MWh
[5]	FCEM Revenue	=[2]*[4]	$36,000,000	$0	$24,000,000

Each resource's FCEM offer is listed in Row [1], for convenience. Row [2] contains each resources clean energy award and Row [3] contains their maximum clean energy capability. Note that Clean 1 clears for their entire capability and so are infra-marginal.

The forward clean energy clearing price is listed in Row [4]. Clean 3 is the marginal resource and sets the price at $20/MWh. To see how we arrive at this price, consider an incremental increase in forward clean energy demand of 1 MWh. To meet this increase in clean energy demand, Clean 3's forward clean energy award is increased by 1 MWh at a cost to the system of $20. As a result, Clean 3 sets the forward clean energy price at $20/MWh. Note that the forward clean energy price is the same here as in the ICCM example, and in each case, it is set to Clean 3's incremental cost of supplying a MWh of clean energy (Row [5] of Table 2.) This will be important when we compare the two frameworks.

The total FCEM revenue for each resource is listed in Row [5]. Their total revenue is the product of the forward clean energy clearing price ($20/MWh) and their FCEM award, listed in Row [2].

Clean 3's CSO Offers after the FCEM

Now that the FCEM has been run and forward clean energy awards have been assigned, the FCM is conducted. Each resource will submit offers into the FCM that seek to recover any outstanding missing money while accounting for their revenue from the FCEM. Table 5 below lists only Clean 3's offer, for brevity.

Table 5. Clean 3's CSO Offer after FCEM

			Clean 3
[1]	Missing Money		$200,000/MW
[2]	E[Capacity Award]		171.4 MW
[3]	Maximum Capacity Award		171.4 MW
[4]	FCEM Revenue		$24,000,000
[5]	FCEM Revenue Per E[MW of CSO]	=[4]/[2]	$140,000/MW
[6]	Missing Money Less FCEM Revenue	=[1]-[5]	$60,000/MW
[7]	CSO Offer	=[6]	$60,000/MW

First, note that Clean 3 was awarded 1,200,000 MWh of forward clean energy in the FCEM. Because Clean 3 sold 57 percent of its forward clean energy capability (1,200,000 MWh out of a possible 2,100,000 MWh), we also assume that it seeks to sell 57 percent of its capacity capability, which as illustrated in Row [2] of Table 5 is 171.4 MW.[8] As a simplifying assumption, we assume that Clean 3 submits only one offer with a maximum award of 171.4 MW, as shown in Row [3].[9]

Clean 3 thus submits their CSO offer to recover the missing money associated with this 171.4 MW of capacity that was not recovered in the FCEM. To do so, Clean 3 incorporates the FCEM revenue it received, which totals $24,000,000. Given that its total missing money on this block of capacity is $34,284,000 (its missing money in Row [1], $200,000/MW, times its maximum offered capacity, 171.4 MW), it must recover the remaining $10,284,000 via the FCM. When this remaining missing money is translated into a $/MW value by dividing it by 171.4, it comes to $60,000 per MW. Thus, in order to recover the missing money on this 171.4 MW of capacity, Clean 3 offers its capacity at $60,000/MW.

Key Takeaway: For Clean 3's 171.4 MW of offered capacity, they only need to be paid $60,000/MW to recover their missing money because they also recovered some of their missing money in the FCEM.

Total Revenue to Resources Via the FCEM and FCM

Once the FCEM has been run and resources have received their forward clean energy awards, a separate FCM will be run to procure the region's capacity. Table 6 contains each resource's CSO offer and award, the CSO clearing price, and their total revenue across both the FCEM and the FCM.

[8] In any example, for the FCEM outcome to be an equilibrium, the clean resources have to recover missing money on the entirety of the capacity they would need to support their forward clean energy positions.

[9] In practice, Clean 3 may submit another offer block at a higher price for its remaining capacity that did not sell clean energy, where this second block may be priced at $200,000/MW to reflect the fact that all of their missing money per MW would need to be recovered by capacity revenue.

Table 6. Resource Awards, Prices, and Revenue in FCM after FCEM						
			Non-Clean 1	Clean 1	Clean 2	Clean 3
[1]	CSO Offer		$60,000/MW	$40,000/MW	$150,000/MW	$60,000/MW
[2]	CSO Award		728.6 MW	300 MW	0 MW	171.4 MW
[3]	CSO Price		$60,000/MW	$60,000/MW	$60,000/MW	$60,000/MW
[4]	FCM Revenue	=[2]*[3]	$43,714,800	$18,000,000	$0	$10,285,200
[5]	FCEM Revenue		-	$36,000,000	$0	$24,000,000
[6]	Total Revenue	=[4]+[5]	$43,714,800	$54,000,000	$0	$34,285,200

Each resource's CSO offer is listed in Row [1]. Note that Clean 3's offer has a maximum award of 171.4 MW. This quantity of capacity will result in enough clean energy to satisfy their forward obligation. Note also that Clean 1 submits an infra-marginal offer of $40,000/MW. Clean 1 has received sufficient revenue in the FCEM that they are price-takers in the FCM.

Row [2] lists each resource's CSO award. Clean 1 is infra-marginal for capacity and sells their entire capability. Clean 3 also sells their entire offered capability of 171.4 MW.[10] Non-Clean 1 satisfies the rest of the capacity demand, providing 728.6 MW of CSO.

Row [3] contains the CSO price. Non-Clean 1 is marginal for capacity and sets the capacity clearing price at $60,000/MW. To see how this price is determined, consider an incremental increase in the installed capacity requirement of 1 MW, without a corresponding increase in the clean energy bids. The least-cost way to meet this increment is to increase Non-Clean 1's CSO award by 1 MW, at a cost to the system of $60,000. Thus, Non-Clean 1 sets the CSO clearing price at $60,000/MW.

Row [4] provides each resources FCM revenue, defined as the CSO price (Row [2]) times their CSO award (Row [3]). Row [5] pulls each resources FCEM revenue from Table 4 Row [4]. Finally, Row [6] provides each resource's total revenue, defined as their FCM revenue (Row [4]) plus their FCEM revenue (Row [5]).

Comparison of Awards, Prices, and Total Revenue Between ICCM and FCEM

Table 7 below lists the CSO and clean energy awards and prices, as well as total revenue for each resource under both frameworks. As illustrated by comparing the ICCM and FCEM results, the awards, prices, and revenues are equivalent for each of the four resources between the two cases. Thus, in these examples and any examples with Assumptions 1-5, there is no difference between market outcomes under an ICCM and an FCEM.

[10] While the example assumes that Clean 3 submits the same offer as Non-Clean 1, Clean 3 is willing to accept Non-Clean 1's offer as the clearing price and so would likely submit an offer just below Non-Clean 1's offer. Thus, as a simplifying assumption, we assume that Clean 3 clears before Non-Clean 1.

Table 7: Awards, Prices, and Total Revenue Comparison

		Non-Clean 1	Clean 1	Clean 2	Clean 3
[1]	ICCM CSO Award	728.6 MW	300 MW	0 MW	171.4 MW
[2]	FCEM CSO Award	728.6 MW	300 MW	0 MW	171.4 MW
[3]	ICCM CSO Price	$60,000/MW	$60,000/MW	$60,000/MW	$60,000/MW
[4]	FCEM CSO Price	$60,000/MW	$60,000/MW	$60,000/MW	$60,000/MW
[5]	ICCM Clean Energy Award	-	1,800,000 MWh	0 MWh	1,200,000 MWh
[6]	FCEM Clean Energy Award	-	1,800,000 MWh	0 MWh	1,200,000 MWh
[7]	ICCM Clean Energy Price	$20/MWh	$20/MWh	$20/MWh	$20/MWh
[8]	FCEM Clean Energy Price	$20/MWh	$20/MWh	$20/MWh	$20/MWh
[9]	ICCM Total Revenue	$43,714,800	$54,000,000	$0	$34,285,200
[10]	FCEM Total Revenue	$43,714,800	$54,000,000	$0	$34,285,200

Key Takeaway: Table 7 shows that, given the assumptions listed in the first section, the ICCM and FCEM will yield identical outcomes for each resource. Under an FCEM, resources incorporate their future capacity revenue when determining how much missing money they must recover by selling clean energy forward. When these capacity revenue predictions are accurate, as we assume in the above examples, we get equivalent results under an FCEM or an ICCM.

Analysis Group's Model Framework

Analysis Group's modeling efforts determine the resource mixes under i) a forward clean energy framework, ii) a net-carbon pricing framework, and iii) a "status quo" framework. As part of this effort, AGI's model will make assumptions that are generally consistent with those employed in the above examples. Specifically, the model used to simulate market outcomes will assume the following: i) the markets for RECs and CECs are competitive, ii) resources submit offers to sell clean energy based on their clean energy production in the delivery period, iii) resources submit fully rationable offers for capacity and clean energy, and iv) resources have perfect foresight about future prices and awards in all markets when making entry/exit decisions.

Digging deeper into the modelling details, the capacity expansion model that will be used to determine the resource mix in each framework conducts a single, global optimization that considers each resource's costs and solves for the lowest cost set of resources that meet a series of constraints. In this case, the model will include constraints corresponding with i) capacity demand, ii) renewable energy demand, or renewable portfolio standards, and iii) clean energy or carbon emissions abatement demand. As such, this modelling approach does not clearly distinguish between a sequential FCEM and a simultaneous ICCM because it is equally consistent with either i) an ICCM where capacity and clean energy awards are determined simultaneously, as in the first example, or ii) a FCEM where resources correctly forecast capacity prices when formulating their clean energy offers, as in the second example. Thus, given these assumptions, this modeling approach is consistent with either an FCEM where resources correctly internalize the actual capacity price when formulating their clean energy offer price, or an ICCM where clean energy and capacity are procured jointly.

Conclusion

Using two numerical examples, this memo demonstrates that a FCEM and an ICCM will yield identical pricing, awards, and total revenue to resources under assumptions that mirror Analysis Group's modelling approach. Specifically, in an ICCM, capacity and clean energy are procured simultaneously in one optimization problem. In an FCEM, clean energy and capacity are procured separately in two sequential optimization problems. When determining their clean energy offers in an FCEM, resources will make predictions about the amount of revenue they will receive in the capacity market. If these predictions are accurate, then the same resources will sell the same quantity of capacity and clean energy at the same prices in a FCEM as in an ICCM, leading both approaches to produce equivalent results.

AGI's model output for the "forward clean energy framework" can thus be viewed as broadly consistent with either a FCEM or an ICCM. As a result, the ISO proposes that it is not necessary for stakeholders to choose one framework over the other at this time. Rather, the model results can be interpreted as representing both a FCEM and an ICCM. If the region chooses to pursue a clean energy framework, the region may wish to further consider the tradeoffs between a FCEM and an ICCM, including those that are not fully captured in the modeling during the pathways efforts.