IASM1920T-1

Interim Auction Solution Methodology

This Interim Auction Solution Methodology provides information relating to Section M.6 of the Capacity Market Code for the Capacity Auction for the Capacity Year 2019/2020, which is expected to be held on 13th December 2018. The auction will be referred to within this document as the 2019/2020 T-1 Capacity Auction.

In accordance with D.1 of the Capacity Market Code, the Capacity Year commences at 23:00 on 30th September 2019 and ends at 23:00 on 30th September 2020. The Capacity Year will be referred to in this document as the 2019/2020 Capacity Year.

All information set out in this document relates solely to the 2019/2020 T-1 Capacity Auction.

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1 Background

The Capacity Market for Ireland and Northern Ireland centres around annual Capacity Auctions that take place approximately four years in advance of delivery (T-4 auction) and approximately one year in advance of delivery (T-1 auction). These auctions match offers from Participants in respect of their Capacity Market Units against a Demand Curve set by the Regulatory Authorities. The auction is combinatorial in nature as it seeks to maximise Net Social Welfare subject to satisfying various constraints including inflexibility constraints (where offers are can be all or nothing) and Locational Capacity Constraints (where a certain predetermined quantity of capacity must clear in particular areas of Ireland and Northern Ireland).

In the short term, in line with the SEM Committee decision SEM-16-081[1], the Capacity Market Code (in M.4 and M.6) provides for the interim solution of Option B, which entails any capacity secured to meet constraints being additional to that which clears in the unconstrained auction. Option B shall apply to all transitional, T-4 and T-1 auctions until such time as the SEM Committee instructs the System Operators to implement Option D. The clearing of any marginal inflexible offer or alternative higher priced offers based on Net Social Welfare will be made after any offers cleared to meet locational constraints have been selected, and the additional capacity selected for locational reasons will be taken into account in the Net Social Welfare calculation. In the medium term, also in line with the SEM Committee decision SEM-16-081, the Capacity Market Code (in F.8.5.1) provides for the enduring solution of Option D, a combinatorial optimisation approach, subject to activation of this enduring approach (in sections M.4 and M.6).

Prior to the implementation of Option D, the methodology for clearing offers to satisfy the Locational Capacity Constraints and inflexibility constraints on the basis of Net Social Welfare is based on Option B. This is referred to here as the Interim Auction Solution Methodology as it combines M.4 (Interim Auction Solution) and M.6 (Alternative Auction Solution Methodology) of the Capacity Market Code. M.4 relates to offers that are cleared based on the unconstrained auction used in the determination of the price and M.6 relates to the rules-based alternative to a mixed integer programming approach that is used to deal with inflexibility constraints and locational capacity constraints.

The Interim Auction Solution Methodology begins with Interim Auction Solution described under M.4 of CMC, where all offers scheduled in the determination of the Auction Clearing Price are cleared, except for a Price Setting Offer that is Inflexible. Then the Interim Auction Solution Methodology clears additional “out of merit” offers only to serve locational capacity constraints and to address “lumpiness” (i.e. inflexible offers that exceed the quantity required).

The Interim Capacity Auction Methodology is subject to a set of requirements in M.6.1.7 of the Capacity Market Code. In particular, in accordance with M.6.1.7.(d), the Interim Auction Solution Methodology, “shall provide for limits, specified by the System Operators, on the number of combinations of solutions for Inflexible price-quantity pairs the subject of Capacity Auction Offers considered … so as to allow the methodology to reach a solution within the Allowed

[1] https://www.semcommittee.com/sites/semcommittee.com/files/media-files/SEM-16-081%20CRM%20Locational%20Issues%20Decision%20Paper.pdf

Timeframe". Under the Interim Auction Solution Methodology described here, when seeking to maximise Net Social Welfare, a subset of inflexible offers not cleared is considered (rather than all inflexible offers not cleared) in order to ensure that the auction can solve within the Allowed Timeframe.

The Interim Auction Solution Methodology set out in this document implements the requirements of the Capacity Market Code set out in F.8 as modified by the Interim Auction Solution set out in M.4 and the Alternative Auction Solution Methodology set out in M.6.

2 Interim Auction Solution Methodology

2.1 Initial Clearing

In accordance with M.4.1.6 (which applies), all offers scheduled in accordance with section F.3 - Determination of the Auction Clearing Price shall be cleared, except for a Price Setting Offer that is Inflexible.

In accordance with section F.8.3 - Determination of the Auction Clearing Price and paragraphs M.4.1.3 to M4.1.5 (which apply), where a tie exists for the Price Setting Offer, the offers will be scheduled in the following order of priority: Clean, higher Net Social Welfare, lower Maximum Duration and finally randomly.

2.2 Locational Capacity Constraints

Figure 1 illustrates a set of offers that contribute to satisfying a Locational Capacity Constraint. Some of these offers are already cleared by the Initial Clearing Process. The following process is applied to identify a set of feasible solutions involving different combinations of inflexible offers to be considered further.

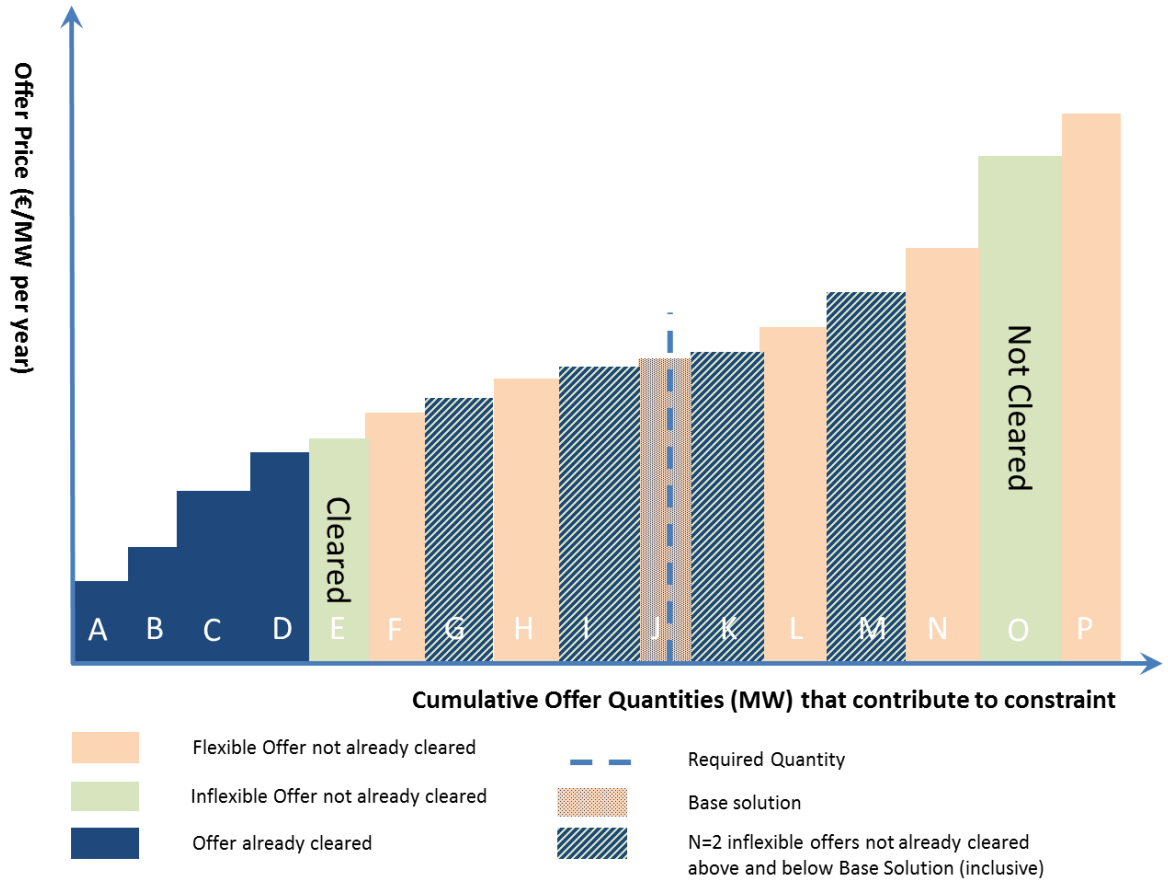

Figure 1 - Identifying feasible solutions based on subset of inflexible offers not cleared for N=2

For each Locational Capacity Constraint that is not satisfied, the following steps are followed for all feasible solutions already determined in that Locational Capacity Constraint:

1. Determine the base solution (the marginal offer that meets the requirements of the constraint when inflexibility constraints are relaxed). In Figure 1, this is offer J, which is a flexible offer. This can also be an inflexible offer.

2. Where two or more offers have the same price (i.e. there is a tie), schedule offer pairs in the following order: clean, flexible, quantity (lesser quantities first), duration (shorter durations first), random.

3. Where available, select next N inflexible offers not cleared above base solution (inclusive). Where available, select next N inflexible offers not cleared below base solution (inclusive). These offers represent the subset of inflexible offers not cleared to be considered further[2]. Where a tie exists, the approach in step 2 applies. In Figure 1, N=2 and the subset of offers to be considered is G, I, K and M.

4. Inflexible offers not cleared below this subset are cleared. Inflexible offers not cleared above this set remain not cleared. In Figure 1, offer E is cleared and offer O remains not cleared on this basis.

5. Determine allowed solutions for every combination of subset of inflexible offers not cleared subject to offers on same CMU being scheduled in order. Based on offers set out in Figure 1, 16 combinations of the four inflexible offers are possible. They are G, I, K, M, GI, GK, GM, IK, IM, KM, GIK, GIM, GKM, IKM, GIKM and "none".

6. For each allowed solution, schedule allowed flexible offers not cleared in order of increasing price as required to cover any remaining shortfall. Based on offers set out in Figure 1, combination GIKM would not require any flexible offers to be schedule, whereas the combination of none of the inflexible offers would require F, H, J, L and N (partially).

7. Check feasibility of allowed solution: (a) it meets the Required Quantity and (b) it does not exceed the Required Quantity by more than an entire offer quantity. Based on offers set out in Figure 1, all combinations would be feasible.

8. Record feasible solutions to take forward to processing next step of auction.

Repeat for all Level 2 Locational Capacity Constraints and then for all Level 1 Locational Capacity Constraints.

[2] Where the base solution is flexible, this subset would be comprised of 2N inflexible offers not cleared. Where the base solution is inflexible, this subset would include the base solution and would therefore be comprised of 2N-1 inflexible offers not cleared.

2.3 Inflexibility Constraints and Final Solution

Once a set of feasible solutions that satisfy all the Locational Constraints has been identified, associated offers are cleared for each feasible solution and the Net Social Welfare of each feasible solution is calculated.

For each feasible solution, if the Price Setting Offer is an inflexible offer not cleared, an approach similar to Section 2.2 is applied to determine if the Net Social Welfare can be improved as follows:

1. Determine the base solution as the inflexible Price Setting Offer.
2. Where available, select next N inflexible offers not cleared above base solution (inclusive). These offers represent the subset of inflexible offers not cleared to be considered further. Where a tie exists, the approach in step 2 applies.
3. Inflexible offers not cleared above this set remain not cleared.
4. Determine allowed solutions for every combination of subset of inflexible offers not cleared subject to offers on same CMU being scheduled in order.
5. For each allowed solution, schedule allowed flexible offers not cleared in order of increasing price where they increase the Net Social Welfare of the allowed solution.
6. The feasible solution is updated with the allowed solution with greatest Net Social Welfare. Where there is no allowed solution with a greater Net Social Welfare, the feasible solution is not updated.

The final solution is the feasible solution (updated accordingly as set out above) with the highest Net Social Welfare from the set of feasible solutions identified in section 2.2 (as modified by this section). Where there is a tie between scheduled offers in the final solution in accordance with F.8.4.6 of the Capacity Market Code, the relevant offers are cleared in accordance with F.8.4.7 of the Capacity Market Code.

3 Auction Parameters

3.1 Allowed Timeframe

In accordance with paragraph F.8.5.2 of the Capacity Market Code, F.8.5.2:

The “Allowed Timeframe” shall be 24 hours from the program run being initiated or such shorter period as is determined from time to time by the System Operators.

The Allowed Timeframe for the 2019/2020 T-1 Capacity Auction is 24 hours.

3.2 Number of Inflexible Offers Not Cleared considered (N)

The value of N to be applied in the 2019/2020 T-1 Capacity Auction is N=5. This represents a reasonable trade-off between reaching an optimal solution and solving the auction within the allowed timeframe of 24 hours, which is the maximum permissible under the Capacity Market Code. The rationale for these values is set out in following section.

It should be noted that the Interim Auction Solution Methodology is designed to handle all potential combinations of offer data. Therefore, it has to cater for all Locational Capacity Constraints being binding and large numbers of inflexible offers. It is quite possible, however, that fewer inflexible offers are submitted, that the auction clears on a flexible offer and that the Locational Capacity Constraints are satisfied on the basis of the unconstrained auction. Nevertheless, it is necessary to provide for less probable outcomes to ensure that the auction process is robust.

3.3 Rationale for Value Chosen

The reason for adopting the Interim Auction Solution Methodology relates to the tractability of the mathematical problem being solved. Each binding constraint will result in a maximum of 2N inflexible offers not cleared being considered which results in 2^{2N} combinations per binding constraint or $2^{(NBCx2N)}$ where NBC is the number of binding constraints. A binding constraint is one where the constraint gives rise to change in Net Social Welfare and would arise where any of the Locational Capacity Constraints are not satisfied or where the Price Setting Offer is inflexible. Table 1 sets out the values of $2^{(NBCx2N)}$ for different values of N and NBC.

Table 1- Maximum Solutions Considered

Max Solutions Considered		Number of Binding Constraints			
		1	2	3	4
N	3	6.40E+01	4.10E+03	2.62E+05	1.68E+07
	4	2.56E+02	6.55E+04	1.68E+07	4.29E+09
	5	1.02E+03	1.05E+06	1.07E+09	1.10E+12
	6	4.10E+03	1.68E+07	6.87E+10	2.81E+14
	7	1.64E+04	2.68E+08	4.40E+12	7.21E+16
	8	6.55E+04	4.29E+09	2.81E+14	1.84E+19
	9	2.62E+05	6.87E+10	1.80E+16	4.72E+21
	10	1.05E+06	1.10E+12	1.15E+18	1.21E+24
	11	4.19E+06	1.76E+13	7.38E+19	3.09E+26

Table 2 and Table 3 set out theoretical times to solve and memory requirements for the same values of N and NBC. These values represent the maximum requirements and while it is unlikely that these maximums would be reached, it is not possible to predicate with certainty the amount of time required to solve the problem and memory requirements.

Table 2 - Maximum time to solve (hrs) on basis of 500 calculations per solution and 10^9 calculations per second

Max Time to Solve (Hrs)		Number of Binding Constraints			
		1	2	3	4
N	3	2.22E-09	1.42E-07	9.10E-06	5.83E-04
	4	8.89E-09	2.28E-06	5.83E-04	1.49E-01
	5	3.56E-08	3.64E-05	3.73E-02	3.82E+01
	6	1.42E-07	5.83E-04	2.39E+00	9.77E+03
	7	5.69E-07	9.32E-03	1.53E+02	2.50E+06
	8	2.28E-06	1.49E-01	9.77E+03	6.41E+08
	9	9.10E-06	2.39E+00	6.25E+05	1.64E+11
	10	3.64E-05	3.82E+01	4.00E+07	4.20E+13
	11	1.46E-04	6.11E+02	2.56E+09	1.07E+16

Table 3 - Maximum memory requirements (GB) on basis of 20kB per solution

Max RAM requirements (GB)		Number of Binding Constraints			
		1	2	3	4
N	3	1.28E-04	8.19E-03	5.24E-01	3.36E+01
	4	5.12E-04	1.31E-01	3.36E+01	8.59E+03
	5	2.05E-03	2.10E+00	2.15E+03	2.20E+06
	6	8.19E-03	3.36E+01	1.37E+05	5.63E+08
	7	3.28E-02	5.37E+02	8.80E+06	1.44E+11
	8	1.31E-01	8.59E+03	5.63E+08	3.69E+13
	9	5.24E-01	1.37E+05	3.60E+10	9.44E+15
	10	2.10E+00	2.20E+06	2.31E+12	2.42E+18
	11	8.39E+00	3.52E+07	1.48E+14	6.19E+20

These tables clearly demonstrate the need for limiting the value of N and give some guidance on prudent values to adopt. Note: while testing can give some degree of confidence regarding ability to solve the problem within the timeframe, the number of solutions to be considered is quite dependent on the number of binding constraints and on the number of inflexible offers submitted.

There are four constraints to be considered in the 2019/2020 T-1 Capacity Auction:

- L2-1: Greater Dublin Locational Capacity Constraint
- L1-1: Northern Ireland Locational Capacity Constraint
- L1-2: Ireland Locational Capacity Constraint
- Inflexible Price Setting Offer

It is difficult to predict with any degree of certainty which of these constraints will bind; however, it is possible to make reasonable assumptions about whether combinations of them will occur.

Where the Ireland constraint is not satisfied, it is likely that Northern Ireland constraint is satisfied and vice versa. It is possible that both Level 1 constraints are not satisfied as the sum of their Required Quantities exceeds the value of the Demand Curve at a price of Net Cost Of

New Entry (Net CONE) by approx. 170 MW. For both constraints to bind, they both would have to have a combined shortfall of no more than 170MW where the auction price clears at Net CONE (i.e. at the capacity requirement). For prices below Net CONE, the difference between the combined Required Quantities and the Demand Curve reduces (to 0MW at a price of 69,000 €/MW per year). On this basis, it is reasonable to assume that both Northern Ireland and Ireland Locational Capacity Constraints are unlikely to both be binding. This reduces NBC to three. It is not possible to predict with any degree of certainty whether combinations of two are likely.

On the basis of NBC=3 and an Allowed Timeframe=24hrs, a value of N=5 is prudent considering that in the presence of NBC=3, N=6 potentially would breach the Allowed Timeframe. Furthermore, while the number of solutions is likely to exceed the number of feasible solutions considerably, it is nevertheless important to consider the memory requirements of the problem in terms of solutions. As can be seen in Table 3, the memory requirements for NDC=3 and N=6 would be of the order of 137 TB. If only 10% of solutions are feasible, it would still require of the order of 137 GB. If we consider, NDC=3 and N=5, the memory requirement would require of the order of 2TB. Again, if we consider that only 10% of solutions are feasible, the requirement is reduced to 2GB.

4 Relevant Capacity Market Code requirements

4.1 Section M.6

In accordance with M.6.1.7 of the Capacity Market Code, the Interim Auction Solution Methodology must reflect the following principles:

(a) **the starting cleared quantity for each priced-quantity pair the subject of a Capacity Auction Offer shall be the minimum value required to be cleared under paragraph F.8.4.4(c) or M.4.1.6 (as applicable);**

In accordance with M.4.1.6 (which applies), all offers scheduled in accordance with section F.3 - Determination of the Auction Clearing Price shall be cleared, except for a Price Setting Offer that is Inflexible. In accordance with section F.8.3 - Determination of the Auction Clearing Price, where a tie exists for the Price Setting Offer, the offers will be scheduled in the following order of priority: Clean, higher Net Social Welfare, lower Maximum Duration and finally randomly (in accordance with paragraphs M.4.1.3 to M.4.1.5).

(b) **the methodology shall, as required, determine additional quantities to clear from price-quantity pairs the subject of Capacity Auction Offers so as to ensure that each Locational Capacity Constraint is satisfied, or if this is not possible, that the shortfall is minimised;**

See approach set out in section 2.2

(c) **if the Price Setting Offer:**

(i) **was Inflexible;**

(ii) **was scheduled because of paragraph F.8.3.3 at a level greater than zero MW and less than its maximum quantity; and**

(iii) **was not required to be cleared to a quantity above zero MW to satisfy sub-paragraph (b),**

the methodology shall determine additional quantities to clear from price-quantity pairs (including the Price Setting Offer's price-quantity pair) the subject of Capacity Auction Offers in place of the quantity scheduled from the Price Setting Offer if this will result in a higher Net Social Welfare under paragraph F.8.4.2;

See approach set out in section 2.3.

(d) **the methodology shall provide for limits, specified by the System Operators, on the number of combinations of solutions for Inflexible price-quantity pairs the subject of Capacity Auction Offers considered under sub-paragraphs (b) and (c) so as to allow the methodology to reach a solution within the Allowed Timeframe;**

Due to the combinatorial nature of this calculation, the number of solutions increases rapidly with N. In order to ensure that the Capacity Auction will solve in the Allowed Timeframe of 24 hours, a value of N=5 has been chosen based on a trade-off between optimality and practicality.

(e) **if a solution can be found within the Allowed Timeframe without imposing the limits described in sub-paragraph (d), then the solution that maximizes the Net Social Welfare under paragraph F.8.4.2 applies; and**

Where all constraints are satisfied by flexible offers, it is possible that the optimal solution can be found within the Allowed Timeframe; however, due to the combinatorial nature of the

calculation, and that we are operating on the basis of the Interim Auction Solution, set out in M.4 of the CMC, where the Price Setting Offer is inflexible or any of the Locational Capacity constraints is not satisfied by the unconstrained solution, it will be necessary to impose the limits described in sub-paragraph (d).

(f) **to reduce solution time, the methodology may exclude exploring combinations of solutions that are likely to be inferior to other combinations of solutions and the exclusion of which will not conflict with the principle in sub-paragraph (e).**

Prior to the implementation of the enduring solution, in most cases, it would not be possible to identify an solution as being optimal (due to the combinatorial nature of the calculation); however, the approach set out here is considered to be more likely to identify more optimal solutions on the basis that solutions based on offer combinations beyond N are more likely to be inferior due to their more expensive price.