ENDGAME ECONOMICS

STYLISED MODEL FOR TRANSMISSION ACCESS REFORM

TECHNICAL GUIDE

For The Australian Energy Market Commission

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1. Introduction

1.1. Context

Endgame Economics has been engaged by the Australian Energy Market Commission (AEMC) to develop a stylised Excel model to demonstrate effects on dispatch and market outcomes due to the proposed hybrid model (priority access plus the voluntary congestion relief market). This technical user guide provides guidance on the following:

- overview of the workflow and structure of the model
- explanation of the inputs and outputs.

2. Model infrastructure overview

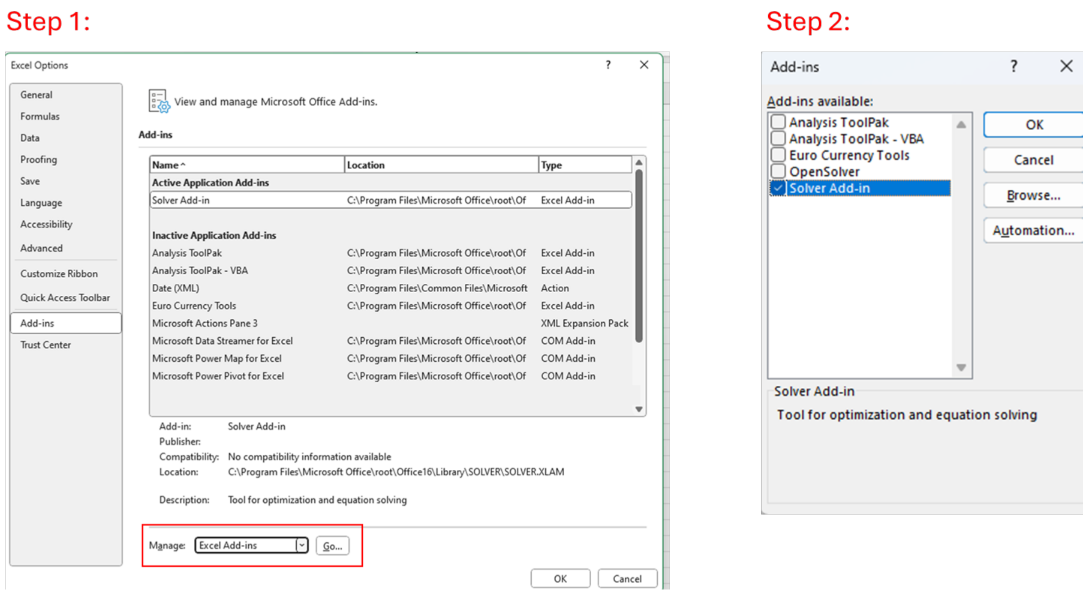
2.1. Setup

Running the model only requires Microsoft Excel and its built-in capabilities:

- solver add-in
- macros.

The Solver Add-in can be enabled by going into **File > Options > Add-ins** and click **Go** after selecting **Excel Add-ins** in the **Manage** Box. In the **Add-ins available** box, select the **Solver Add-in** check box then click **OK**. The dialogue boxes are illustrated in Figure 1 below.

Figure 1: Dialogue boxes for enabling solver add-in



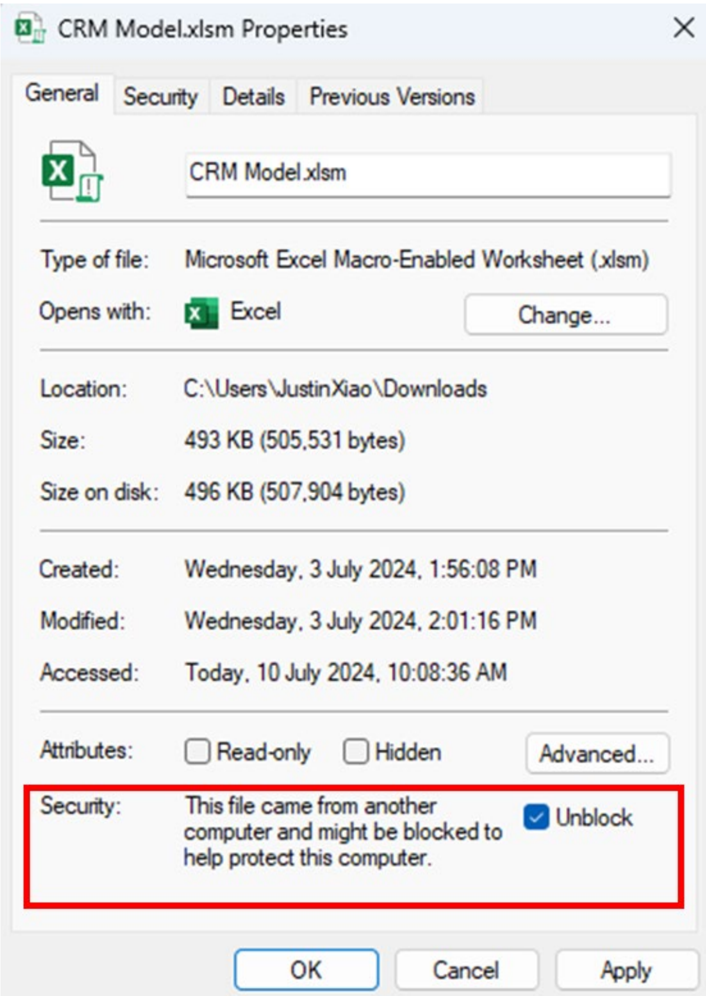
Macros can be enabled by clicking **Enable Content** on the security warning banner after opening the Excel workbook or trying to run a macro (Figure 2).

Figure 2: Security warning on macros

Macros can be flagged as a security risk and will be blocked from enabling on the Excel workbook itself (Figure 3). It can be unblocked by ticking the Unblock box in file properties (Figure 4).

Figure 3: Security risk on macros

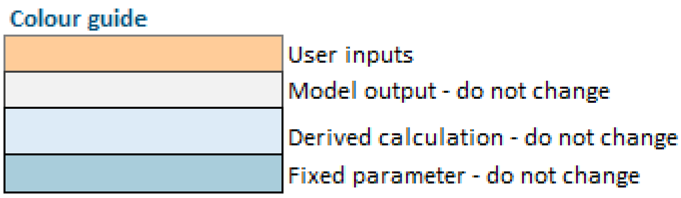
Figure 4: Excel workbook properties dialogue



2.2. Colour guide

A colour guide is used to distinguish cells that is user modifiable from other cells. As shown in Figure 5, users are allowed to modify cells in tan. It is important to note that modifying cells other than the intended ones might result in the model being broken.

Figure 5: Colour guide of the model



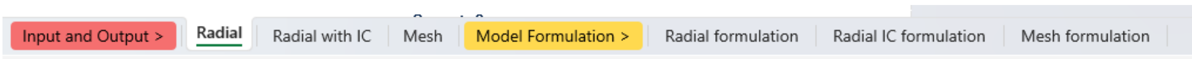
2.3. Workbook structure

The Excel workbook consists of two major parts (Figure 6):

- inputs and outputs – user modifiable parameters and dispatch outcomes
- model formulations – backend formulations based on user inputs.

Each topology is contained in a separate sheet within each part.

Figure 6: Sheets in the Excel model

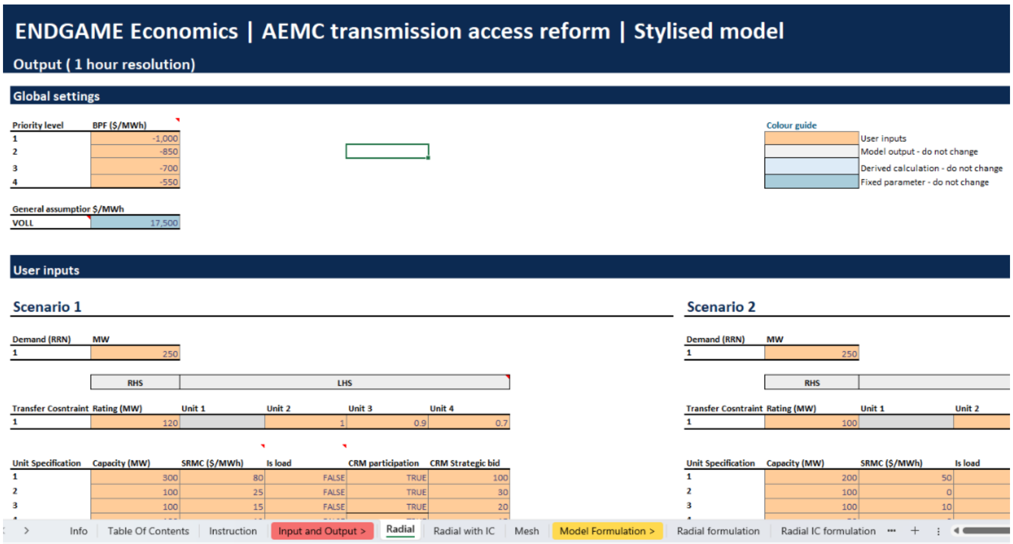


Model formulation sheets contain the final formulation going into the Solver Add-in. This includes the objective function, variables as well as the constraints. It is important to note that the formulation sheets are strictly not for user modification as they relay information from the inputs and outputs sheet automatically to the backend automatically.

Within the inputs and ouputs tab, user modifiable cells are coloured in yellow (see Figure 7) under:

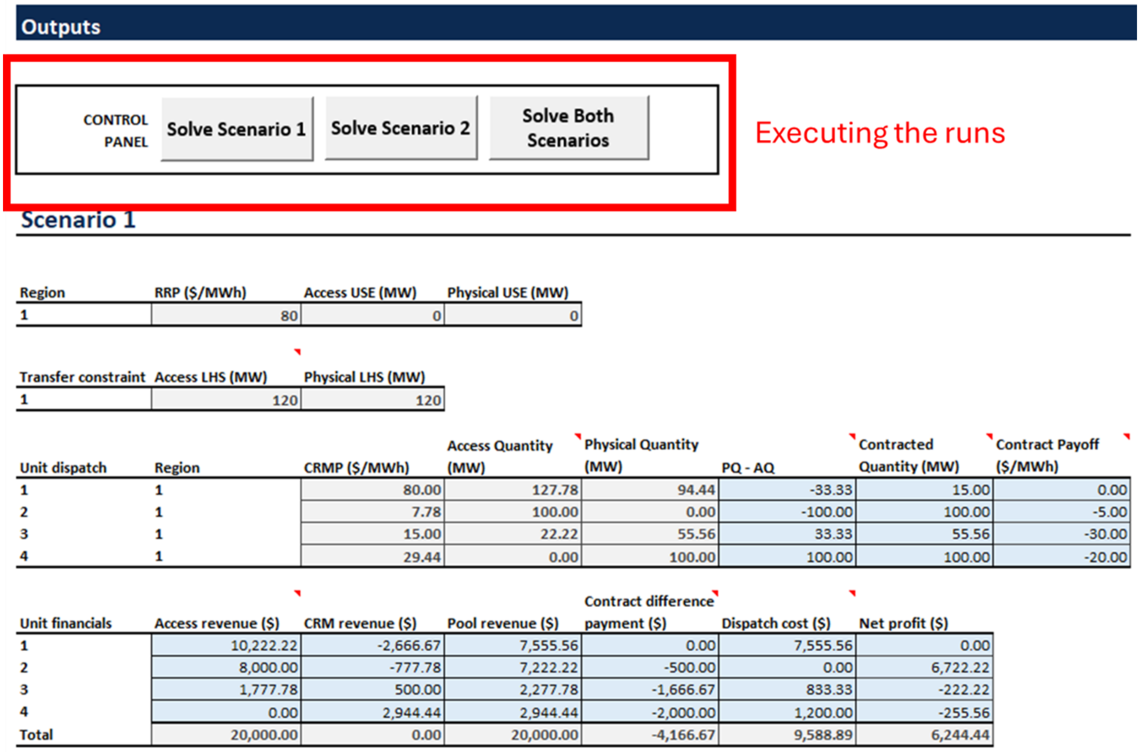
- global settings – applies to both scenarios
- user inputs – scenario specific parameters.

Figure 7: User modifiable sections



Simulations are executed by a set of buttons under the Outputs section. The dispatch results and prices are summarised in the tables below the execution control panel (Figure 8).

Figure 8: Ouputs section



Region	RRP ($/MWh)	Access USE (MW)	Physical USE (MW)
1	80	0	0

Transfer constraint	Access LHS (MW)	Physical LHS (MW)
1	120	120

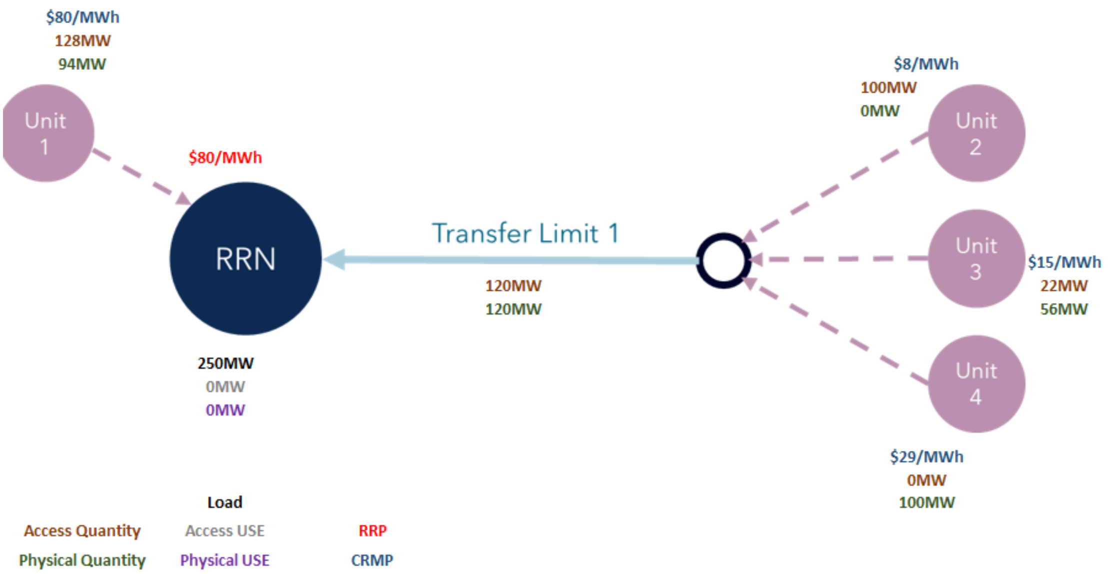
Unit dispatch	Region	CRMP ($/MWh)	Access Quantity (MW)	Physical Quantity (MW)	PQ - AQ	Contracted Quantity (MW)	Contract Payoff ($/MWh)
1	1	80.00	127.78	94.44	-33.33	15.00	0.00
2	1	7.78	100.00	0.00	-100.00	100.00	-5.00
3	1	15.00	22.22	55.56	33.33	55.56	-30.00
4	1	29.44	0.00	100.00	100.00	100.00	-20.00

Unit financials	Access revenue ($)	CRM revenue ($)	Pool revenue ($)	Contract difference payment ($)	Dispatch cost ($)	Net profit ($)
1	10,222.22	-2,666.67	7,555.56	0.00	7,555.56	0.00
2	8,000.00	-777.78	7,222.22	-500.00	0.00	6,722.22
3	1,777.78	500.00	2,277.78	-1,666.67	833.33	-222.22
4	0.00	2,944.44	2,944.44	-2,000.00	1,200.00	-255.56
Total	20,000.00	0.00	20,000.00	-4,166.67	9,588.89	6,244.44

A graphical diagram of the dispatch results is also illustrated under the output summary tables for both stages of the dispatch (Figure 9).

Figure 9: Graphical diagram for dispatch outcomes

Scenario 1



3. User inputs

The parameters of user inputs include:

- Bid Price Floor (BPF) for each priority level
- nodal demand
- unit specification
- participation (TRUE or FALSE) in the Congestion Relief Market (CRM)
- bidding strategy and financial contract
- line rating limit
- transfer limit constraint contribution coefficients by relevant units (Radial networks only).

3.1. Global settings

Global settings apply to both scenarios in the chosen topology.

In this case, it sets the Bid Price Floor (BPF) of each priority level. By convention, priority level of 1 should have the most negative BPF and it should be less negative as the levels go up.

The Value of Lost Load (VOLL) is a fixed parameter of $17500/MWh in line with the 2024-2025 market price cap released by the AEMC[1].

[1] See: 2024-25 market price cap now available | AEMC

3.2. Unit specification

The information of each unit has accounted for include (Figure 10):

- capacity (MW)
- whether the unit is a dispatchable generator or load
- SRMC ($/MWh) – this is equivalent to the willingness to pay for dispatchable load
- the participation status of the unit in CRM.

Figure 10: Unit properties

Unit Specification	Capacity (MW)	SRMC ($/MWh)	Is load	CRM participation
1	300	80	FALSE	TRUE
2	100	25	FALSE	TRUE
3	100	15	FALSE	TRUE
4	100	12	FALSE	TRUE

Note that other properties such as ramp rates and their associated constraints have not been included in the stylised model for simplicity. In practice if a tethered CRM were implemented, the difference between a unit's access and physical dispatch would be limited by its ramping constraints.

3.3. Treatment of load and generation

User inputs for load and generation are both to be positive. The outputs and model backend will convert load to negative as needed.

This implies that dispatched load will have a non-positive value in dispatch quantity, and it makes outgoing payment if its pool revenue or contract difference payment is negative. A negative dispatch cost implies receiving payment.

3.4. Bidding and contracts

The model allows the user to choose different representative bidding strategies. To demonstrate the impact of the priority level on dispatch outcomes, the relevant options include:

- BPF – adjusted by the assigned priority level
- SRMC.

Similarly, there are two bidding strategies for the CRM stage:

- strategic – using user specific set of bids
- SRMC.

The relevant columns for selecting strategies and their assigned values are shown in Figure 11.

Figure 11: Relevant columns for setting bidding strategies

Sets SRMC bid values | Sets Strategic bid values

Unit Specification	Capacity (MW)	SRMC ($/MWh)	s load	CRM participation	CRM Strategic bid
1	300	80	FALSE	TRUE	100
2	100	25	FALSE	TRUE	30
3	100	15	FALSE	TRUE	20
4	100	12	FALSE	TRUE	15

Unit Bidding	Priority level	Access run bidding strategy	CRM bidding strategy	Access run bid ($/MWh)	CRM bid ($/MWh)
1	1	SRMC	SRMC	80	80
2	1	BPF	SRMC	-1000	25
3	2	BPF	SRMC	-850	15
4	4	BPF	Strategic	-550	15

Sets BPF bid values | Strategy selection | Final bid values

The model allows each unit to have one financial contract for settlement with the dispatch outcomes (Figure 12). There are three types of contracts:

- Power Purchase Agreements (PPA)
- swap contract
- cap contract.

Contract volume and strike prices are to be specified to calculate the contract difference payment along with the dispatch outcomes. This is explained in more details in section Model outputs.

Note that cap contracts should have a strike price of $300/MW/hr, however this can be varied to test a range of financial outcomes.

Figure 12: Fiancial contracts input

Unit Contracts	Type	Volume (MW/hr)	Strike price ($/MW/hr)
1	Cap	15	100
2	Swap	100	75
3	PPA	100	50
4	PPA	100	60

3.5. Transfer limit representation

The Radial and Radial with IC topologies have a set of constraints which directly limit the total dispatch from a group of units (Figure 13). Closely aligned with the current NEMDE setting, this representation of transfer limit allows the user to directly test the impact of constraint coefficients by abstracting away from detailed configurations of the local network.

Figure 13: Transfer limit constraint specification for radial networks

	RHS	LHS			
Transfer Cosntraint	Rating (MW)	Unit 1	Unit 2	Unit 3	Unit 4
1	120		1	0.9	0.7

Users can specify the LHS coefficient of each relevant unit under the "LHS" header. The RHS value is the transfer rating. In this case, the constraint is formulated as:

$$Coeff_2 \cdot Dispatch_2 + Coeff_3 \cdot Dispatch_3 + Coeff_4 \cdot Dispatch_4 \leq Rating$$

Note that the coefficients will be converted to negative for dispatchable load in the backend of the model. This means that all input coefficients should be positive, including for dispatchable load.

The inter-regional interconnector in the Radial with IC topology is explicitly modelled with a line rating. It sets the upper limit on export/import capacity between the region reference nodes of the two regions (Figure 14).

Figure 14: Line rating input on export and import limit

Line	Rating (MW)
1	90

For the Mesh topology, the nodes of the network and its associated intra-regional lines are all explicitly modelled in the similar way as the interconnector. In addition, the flows are governed by solving DC-Linearised power flow equations. This means that the total flow from one node to the other will be split between all available paths. All lines are assumed to have the same susceptance of -10, indicating that they have the same tendency to flow.

Interconnector loss is not modelled in this exercise. This is due to the need to use binary variables to prevent non-physical losses, which significantly increase the complexity and limit of the built-in Excel Solver Add-in. Intra-regional losses are also not modelled for simplicity.

Another implication of the abstraction in the Radial topologies is that all demand in the region will be located at its respective region reference node. Due to its explicitness, the Mesh topology expresses the demand at any node instead.

4. Model outputs

4.1. Regional and nodal summaries

The output section produces a summary result of each region (Figure 15). This includes:

- RRP ($/MWh) – the price at the region reference node in the access run
- access/physical USE – the amount of Unserved Energy (USE) at each stage of the dispatch.

Figure 15: Regional output summary

Region	RRP ($/MWh)	Access USE (MW)	Physical USE (MW)
1	80	0	0

Apart from the Radial with IC topology, there are only one region and hence the RRP should be identical across all nodes.

The Mesh topology reports CRMP on each node as well.

Figure 16: Nodal output summary

Node	Region	RRP ($/MWh)	CRMP ($/MWh)	Access USE (MW)	Physical USE (MW)
1	1	100	100	0	0
2	1	100	100	0	0
3	1	100	100	0	0
4	1	100	100	0	0
5	1	100	4	0	0
6	1	100	52	0	0

4.2. Dispatch results

For each unit, the following results are recorded (Figure 17):

- CRMP ($/MWh) – the Congestion Relif Market Price of each unit. Note that it is reported on each node for the Mesh topology instead.
- access/physical quantity (MW) – the dispatch in access/physical runs respectively. Dispatchable loads will have non-positive values in these columns
- CRM deviation in physical dispatch from the access dispatch (PQ - AQ)
- dispatch that is contracted – this is based on physical dispatch
- the contract difference payment ($/MWh) – this is based on the RRP.

Figure 17: Unit dispatch results

Unit dispatch	Region	CRMP ($/MWh)	Access Quantity (MW)	Physical Quantity (MW)	PQ - AQ	Contracted Quantity (MW)	Contract Payoff ($/MWh)
1	1	80.00	127.78	94.44	-33.33	15.00	0.00
2	1	7.78	100.00	0.00	-100.00	100.00	-5.00
3	1	15.00	22.22	55.56	33.33	55.56	-30.00
4	1	29.44	0.00	100.00	100.00	100.00	-20.00

Given the scope of the stylised model to maintain simplicity, deviation limits or constraints between PQ and AQ are not enforced. Namely:

- quantity deviation limits – a proposed CRM bidding feature that limits the maximum CRM quantity deviations[2]
- tethering limits - a proposed CRM design feature that constrains the deviation of PQ from AQ during to ramping limits.[3]

[2] Refer to section C.7 of the AEMC's Transmission access reform consultation paper for more information on quantity deviation limits.
[3] Refer to section 7.2.1 of the AEMC's Transmission access reform consultation paper for more information on tethering.

4.2.1. Contracted quantity formula

Cap and swap contract quantity does not depend on physical dispatch – it is simply the volume in the contract input section. For PPA contracts, it is the minimum of the contract volume and physical dispatch.

Dispatchable loads have a non-positive contracted quantity due to the convention of treating load in the model.

4.2.2. Contract payoff value

It is the payoff value per contracted volume. For swap and PPA contracts, this is equivalent to (for every MW in an hour):

$$Payoff = Strike\ price - RRP$$

Cap contracts also follow the above formula when RRP is above the strike price, otherwise it is floored at 0.

4.3. Financials

Financial settlement broken down by components for each unit is also provided in Figure 18.

Figure 18: Financial outputs

Unit financials	Access revenue ($)	CRM revenue ($)	Pool revenue ($)	Contract difference payment ($)	Dispatch cost ($)	Net profit ($)
1	10400	0	10400	0	10400	0
2	8000	-2000	6000	-500	500	5000
3	8000	0	8000	-3000	1500	3500
4	1600	2000	3600	-2000	1200	400
Total	28000	0	28000	-5500	13600	8900

The net profit is calculated by aggregating all the components by:

$$Net\ Profit = Pool\ Revenue + \ Contract\ Difference\ Payment - Dispatch\ Cost$$

4.3.1. Pool revenue stacks

Pool revenue is the net revenue from the access run and the physical run, as illustrated in Figure 19 below.

Figure 19: Pool revenue calculation

$$Pool\ revenue = \boxed{AQ \times RRP} + \boxed{(PQ - AQ) \times CRMP}$$

Access revenue   CRM revenue

A positive pool revenue implies an incoming payment, and a negative pool revenue implies an outgoing payment.

4.3.2. Contract difference payment

Contract difference payment is calculated by multiplying the contract payoff value and the contracted quantity. Namly

$$Contract\ Difference\ Payment = Contracted\ Quantity \times Contract\ Payoff\ Value$$

A positive value implies revenue from contract difference. Likewise, a negative value means it's an outgoing payment.

4.3.3. Dispatch cost

Dispatch cost of a unit is calculated by multiplying the SRMC (willingness to pay for load) with the physical dispatch quantity:

$$Dispatch\ Cost = SRMC \times PQ$$

A negative value implies it is receiving payment.

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