AIP (PLEXOS) Market Simulation Model Validation Project

Workshop 3 – Final Conclusions

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30 March 2007, Davenport Hotel, Dublin

Agenda for today’s Workshop

1. Introduction to Workshop
2. Overview of project activities since Initial Findings Workshop
3. Review of data validation activity and final conclusions
4. Review of PLEXOS validation work and final conclusions
5. Final steps for Project Completion

Introduction to Workshop

Mike Wilks, Principal Consultant

Introduction to Workshop

- 3rd in a sequence of 3 Project workshops open to all market participants
- Overall aim is to review project activities for data and model validation and to provide an overview of final conclusions
- The two main parts of today's Workshop will be detailed review and discussion of KEMA's data and model validation work undertaken
- Final element of the Workshop will be to outline remaining steps for project completion
- **But (again) first**………some reminders

Reminder: project aims

- This project had two fundamental aims
  - to establish a validated Plexos model of the SEM that is ready to accurately predict prices (i.e. SMP with unconstrained schedule quantities by unit)
  - to achieve the consensus agreement and confidence of market participants in the validated model

Reminder: project activities

- There were 5 required component activities within this project

i. **Validation of model algorithms** against T&SCv1.2 and other relevant associated documents for unconstrained (SMP) model run

ii. In conducting (i), **identification, development and implementation of any required model workarounds** internal (preferably) or external to PLEXOS to ensure a “compliant” simulation model of the SEM

iii. **Validation of modelling assumptions** such as operating regime of Moyle and pumped storage; modelling of forced outages; treatment of TLAFs; definition of legitimate SRMC components etc

iv. **Validation of model input data** – primarily validation of generator technical data but also reviewing other input data such as demand and wind data,

v. **Participant inclusion** – a key thread running throughout the project to ensure best outcome for the above. The primary focus of engagement was regarding model data and assumptions but KEMA will also encouraged comments on model algorithms.

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Reminder - activities not covered by this Project

- We were not cross-validating PLEXOS against the ABB model
- We were not reviewing or seeking to change the draft T&SC (using v1.2 as the baseline for model validation)
- We were not validating transmission data and assumptions – our review only related to the unconstrained PLEXOS model of the SEM (using the PLEXOS 4.896 R3 release version as baseline)
- We were not validating Uplift Option D rules/results
- We were not addressing capacity payments and their calculation
- **This Project does not represent a validation of any SEM market price forecast**

Outline of Project Activities since Initial Findings Workshop

Mike Wilks, Principal Consultant

Outline of Project activities since Initial Findings Workshop

- 2nd Data Questionnaires
  - Providing clarification and addressing some issues which had been identified
  - Varying degrees of further data revision by market participant
- Bilateral dialogue
  - To resolve some misunderstandings and associated data inconsistencies and/or data anomalies or issues
- 2nd round of bilateral meetings
  - 4 parties visited
  - Again very productive and helped to resolve some outstanding data issues
- Preparation of Draft Reports for data and model validation
  - Submitted to the RAs for review and feedback before finalisation after today

Review of Data Validation activity and final conclusions

Dave Lenton, Senior Consultant

Agenda – Data Validation

1) Recent process for updating Generator Technical Data

2) Major changes to data

3) Issues raised on Generator Technical Data

   – SRMC Update
   – Consistency of submission
   – Technical or Commercial Parameters
   – Other clarifications
   – Changes to Forced Outage Rates
   – What is unconstrained

4) Update on other data parameters

Process to date

- 5 March - Revised spreadsheet sent to all market participants
  - Specific list of questions
  - Response due by 12 March (mixed response)
  - Offer of follow up meeting if required
- 20 March - Discussions with market participants in Belfast
- 21 March - Discussions with market participants in Dublin

- 5 March to 29 March - Bilateral email and phone dialogue

Major changes I

- Ballylumford change in Heat Rates to reflect LHV
- A number of other generators changing No Load/Start Up to reflect LHV
- Increase in Start Up Energy for some CCGTs
- Large reduction in Huntstown 1 Start Up Energy
- Use of alternative proxy (DBP) for some Huntstown 2 data
  - Dublin Bay Power considered most appropriate

Major changes II

- Significantly revised Aughinish data
  - Values heat separately from the power
  - Allows Thermal Efficiency to reflect station performance
- Revisions to higher incremental heat rates for Kilroot
- Decrease in Min Up Times and Min Down Times
- Changes in Run Up Rates and Ramp Rates
- Receipt of VOM data for most generators

Short Run Marginal Cost position

- Key discussions point with market participants
- **RAs have specified Bidding Principles rather than rules**
  - Looking for consistency across portfolio and time
  - Consistency not necessarily required across participants
- Participants to decide what items to include and how to cost
- Need to consider whether this will be acceptable to the market monitor
- Two previous excluded items that should be included are:
  - Transmission Loss Factors to increase price (day/night issue)
  - Variable Operation and Maintenance Cost (€/MWh)

Short Run Marginal Cost update

- Variable Operations and Maintenance Figures
  - Provided for most generators with a mixture of €/Start and €/MWh
  - Where not available suggest using similar plant rather than omission
- Transmission Loss Adjustment Factors
  - Recommendation included with day/night time weighted average
  - Will also be included in Uplift Calculations automatically by Plexos
  - 2007 data available and used for testing
- Gas Capacity and SRMC
  - Still being discussed by RAs
- Inclusion of Additional Costs in Technical Parameters
  - Option taken by 1 market participant
  - KEMA have checked explanation of approach taken

Consistency of submissions

- KEMA are seeking confirmation that participants have interpreted the parameters in the same way. Key areas of concern
  - Start Up Energy
    - Energy required to bring the Unit to 0 MW
  - No Load
    - Energy per hour the unit would require to maintain 0 MW
  - Calculation of Heat Rate
    - Rate at which fuel is consumed to generate electrical power
    - Higher Heating Value/Lower Heating Value

Example I – Start Up Energy - CCGT

Unit ID	Unit Name	Max capacity	Start up Energy (GJ) Cold	Start up Energy (GJ) Warm
DBP	Dublin Bay Power	415	7700	2600
HNC	Huntstown	335	20000	10000
HN2	Huntstown Phase II	391	20000	10000
MRT	Marina CC *	112.29	50	50
NW4	Northwall Unit 4	163	80	80
PBC	Poolbeg Combined Cycle	480	2000	2000
TE	Tynagh	404	2811	1633
B31	Ballylumford CCGT 31	240	50	50
B32	Ballylumford Unit 32	240	50	50
B10	Ballylumford Unit 10	103	50	50

Revised Start Up Energy

Unit Name	Max capacity	Start up Energy (GJ) Cold	Start up Energy (GJ) Warm	Start up Energy (GJ) Hot
Dublin Bay Power	415	6930	2340	
Huntstown	343	9545	4947	1732
Huntstown Phase II	401	7000	2500	1200
Marina CC *	112.29	50	50	50
Northwall Unit 4	163	80	80	80
Poolbeg Combined Cycle	480	3000	2500	2000
Tynagh	373	2811	1633	1144
Ballylumford CCGT 31	240	5800	1900	1000
Ballylumford Unit 32	240	5800	1900	1000
Ballylumford Unit 10	103	1800	750	500
Coolkeeragh CCGT	404	5220	3024	1080

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Start Up Energy Issues for CCGTs

- Start Up when GT and ST synchronises
- Issue in that some generation is produced before ST synchronises
- For most generators the production is small enough to be ignored
- Significant for some multi-shaft CCGTs
- Decided that placing costs of synchronisation in Start Up Energy rather than Run Up Rates was the “least bad” solution
- Start Up Energy for Huntstown 2 linked to similar CCGTs rather than Huntstown 1
- Discussion with ESB on Moneypoint, but quantity believed to be credible

Thermal Efficiencies

		Rev 1	Rev 1	Rev 2	Rev 2
Unit ID	Unit Name	Heat Rate MSG	Heat Rate Full Output	Heat Rate MSG	Heat Rate Full Output
DBP	Dublin Bay Power	49.74%	57.87%	48.15%	56.99%
HNC	Huntstown	44.67%	48.52%	48.03%	52.89%
HN2	Huntstown Phase II	44.74%	51.33%	49.24%	54.82%
MRT	Marina CC *	35.58%	40.76%	35.58%	40.76%
NW4	Northwall Unit 4	37.39%	42.48%	37.39%	42.48%
PBC	Poolbeg Combined Cycle	45.42%	52.34%	45.42%	52.34%
TE	Tynagh	48.75%	56.09%	47.51%	54.78%
B31	Ballylumford CCGT 31	35.88%	46.00%	39.86%	51.11%
B32	Ballylumford Unit 32	35.88%	46.00%	39.86%	51.11%
B10	Ballylumford Unit 10	43.75%	47.23%	48.61%	52.47%
CPS CCGT	Coolkeeragh CCGT	48.91%	53.99%	48.91%	53.99%

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Technical or Commercial parameters

- Concern that some of the parameters may be based on contractual issues not technical limits
- RAs indicated that data should be true technical performance
- Key parameters where this applies are:
  - Min Down time
  - Min Up Time
  - Start up and No Load

Example - Min Up and Down Times

		Rev 1	Rev 1	Rev 2	Rev 2
Unit ID	**Unit Name**	**Min Up Time (hrs)**	**Min Down Time (hrs)**	**Min Up Time (hrs)**	**Min Down Time (hrs)**
B4	**Ballylumford Unit 4**	4.00	7.00	4.00	7.00
B6	**Ballylumford Unit 6**	4.00	7.00	4.00	7.00
B31	**Ballylumford CCGT 31**	10.00	8.00	4.00	2.00
B32	**Ballylumford Unit 32**	10.00	8.00	4.00	2.00
B10	**Ballylumford Unit 10**	10.00	8.00	6.00	4.00
BGT1	**Ballylumford GT1**	1.00	1.00	1.00	1.00
BGT2	**Ballylumford GT2**	1.00	1.00	1.00	1.00
CPS CCGT	**Coolkeeragh CCGT**	1.00	8.00	6.00	3.50
CGT8	**Coolkeeragh GT8**	1.00	1.00	1.00	1.00

Other issues resolved

- A number of small issues were resolved after bilateral discussions
  - Submission of non monotonically increasing heat rates
  - Ensuring Max Capacity equals the final capacity point
  - Matching Min Stable Capacity with first capacity point
  - Winter/Summer capacity for CCGTs
  - Introduction of some new Start Up Energy rates
  - Modification of some ramping rates

- No generators indicated any Emissions Constraints for modelling

- Grid Code Compliance has been noted as an issue, but is not for this project to resolve

Remaining issue - Forced Outage Rates

- ESB increased Forced Outage Rates in Revision 1
  - KEMA received historic Forced Outage data on 27th March
  - Increased Forced Outage Rates justified for Great Island, Tarbert 3-4, Poolbeg 1-2
  - Poolbeg 3 should be increased to 40% Forced Outage Rate reflecting historical performance
  - Sufficient evidence not presented to justify increase in Moneypoint, Poolbeg CCGT or Aghada (and recent history conflicts)
  - Apparent missing evidence for Tarbert 1 and Tarbert 2
  - ESB to produce additional evidence by end Monday 2 April

What is unconstrained?

- **Interconnector**
  - Limited to 400 MW transferred to Ireland
  - Transmission Entry Capacity (TEC) limited to 80 MW in Scotland
- **Pumped Storage**
  - No requirements in T&SC to reserve water for black start
  - Ancillary Services outside unconstrained schedule
  - Limit on upper reservoir should not be included in unconstrained schedule
- **Peat Plants**
  - Principle that ROI customers should pay costs for ROI social policies
  - Interpreted as Peat Stations needing to be must run in Unconstrained schedule

Current position on Generator Technical Data

- Generator technical data set (except Forced Outage Rates and an issue on treatment of Poolbeg CCGT units) now essentially complete

- Believe it represents a credible set of technical performance data
  - within accepted degrees of freedom
  - based on submission by generators not audits
  - consistent with indicated operational intentions
  - consistent with international benchmarks

- Some generators indicated best figure based on current understanding of plant's performance
  - accept may change for uncommissioned plant
  - accept may change for "overhauled" plant

Demand

- Forecast independently by System Operators

- Both Jurisdiction’s data is calculated from actual 2005 data

- KEMA checking consistency of approach
  - Includes all network losses
  - Demand Side Management schemes assumed to continue
  - Demand supplied from Embedded generation (mainly wind and CHP) is included

- No direct Demand Side Participation data has been validated for inclusion in the modelling

Wind

- Wind Series for 3 regions produced by EirGrid will be published
- Based on historic figures of availability from 60 wind farms
- Wind capacity sourced from published information from Eirgrid and SONI
  - Will be checked against input files for Capacity

Fuel Prices

- KEMA have worked on data from EirGrid by Ilex
  - Gas prices have changed considerably since September
  - Low range forecasts now seem appropriate
  - Includes consistent set of BETTA prices
  - Includes parameters for transport, carbon calculations, excise etc
- Fuel prices for key runs should be from transparent sources
- Discussions with RAs indicate following data sets are likely
  - Gas – ICE Futures for Gas – Heren Report
  - Coal – Forward prices for Argus Daily Coal International
  - LSFO and Gasoil – Platts
  - Carbon Prices – London Energy Brokers Association

GB generator bid prices

- Rational generator should bid net of Uplift and capacity
- Four stage process
  - i) Prediction of prices in the UK
  - ii) Prediction of the costs of purchasing Interconnector capacity
  - iii) Prediction of Capacity payments
    - Will require some modelling of capacity pots
  - iv) Prediction of Uplift received by Moyle user
    - Iterative process with capacity adjusted prices

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Options for sourcing GB price data

- Forward Curve for peak/off peak for 2008
- Convert Forward Curve into EFA shapes using historical data
- Commission model of BETTA prices
- Use Spark Spread movement to adjust forward curve for peak/off peak movements
- Choice will depend on timescales, objectives, required accuracy and range of sensitivities considered etc

Generator Outages

- Data available for some not all generators
- Plan is to roll forward outage schedule created for 2007
- KEMA are check for major outages that impact on this schedule and against data that has been submitted

Review of Plexos Model Validation activity and final conclusions

Adrian Palmer, Senior Consultant

Model Validation – outline of discussion

1. Introduction
2. Commercial offers
3. Technical offers
4. Special cases
5. Unit Commitment
6. Shadow prices
7. Uplift
8. PLEXOS configuration
9. Conclusions

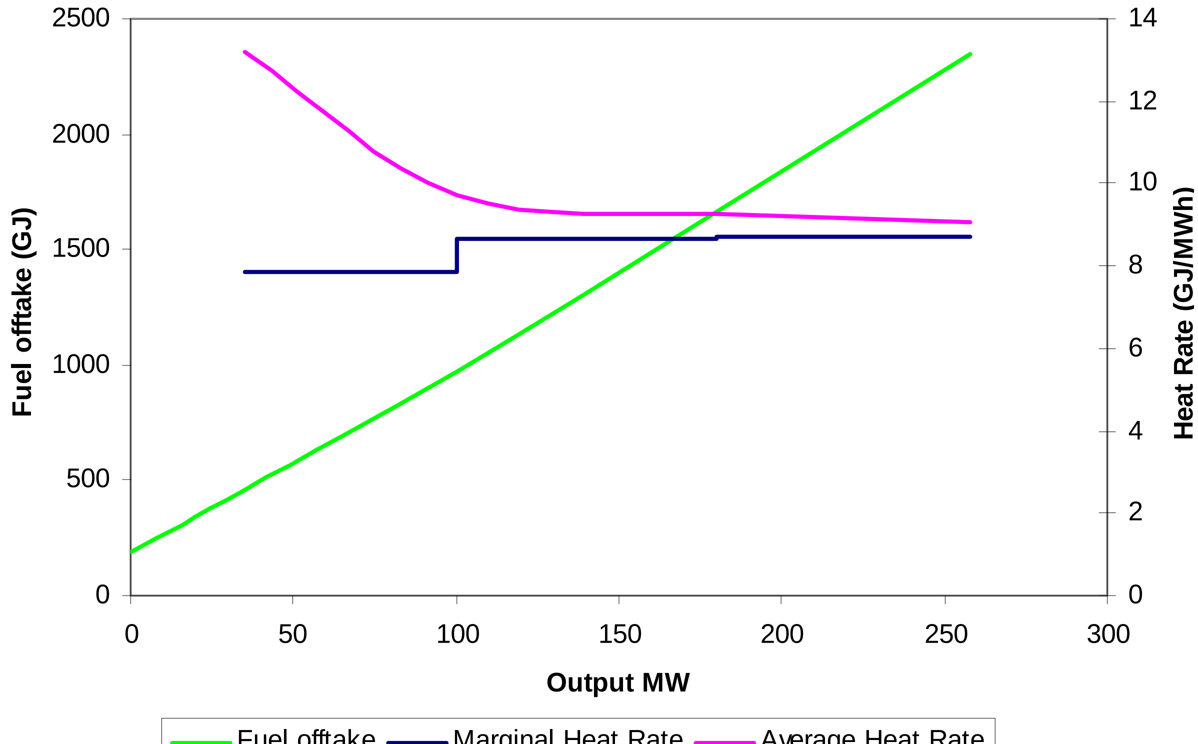
Introduction

- SEM baseline for comparison: T&SC v1.2
- PLEXOS releases: 4.896 R3 (Feb), 4.894 R2 (Jan)
  - New release 4.898 R5 available this week
- Starting data set: AIP Loop 2 “Central”
- PLEXOS online help: www.plexos.info

Commercial Offers: Heat Rates

- Generators have submitted no load costs and incremental heat rates
- Input heat rate step functions utilised directly by PLEXOS in determining marginal heat rate functions and SRMCs
- AD1 example:

Property	Value	Units	Band
Min Stable Level	35	MW	1
Max Capacity	258	MW	1
Heat Rate Base	187.17	GJ/hr	1
Load Point	35	MW	1
Heat Rate Incr	7.86	GJ/MWh	1
Load Point	100	MW	2
Heat Rate Incr	7.86	GJ/MWh	2
Load Point	180	MW	3
Heat Rate Incr	8.64	GJ/MWh	3
Load Point	258	MW	4
Heat Rate Incr	8.72	GJ/MWh	4

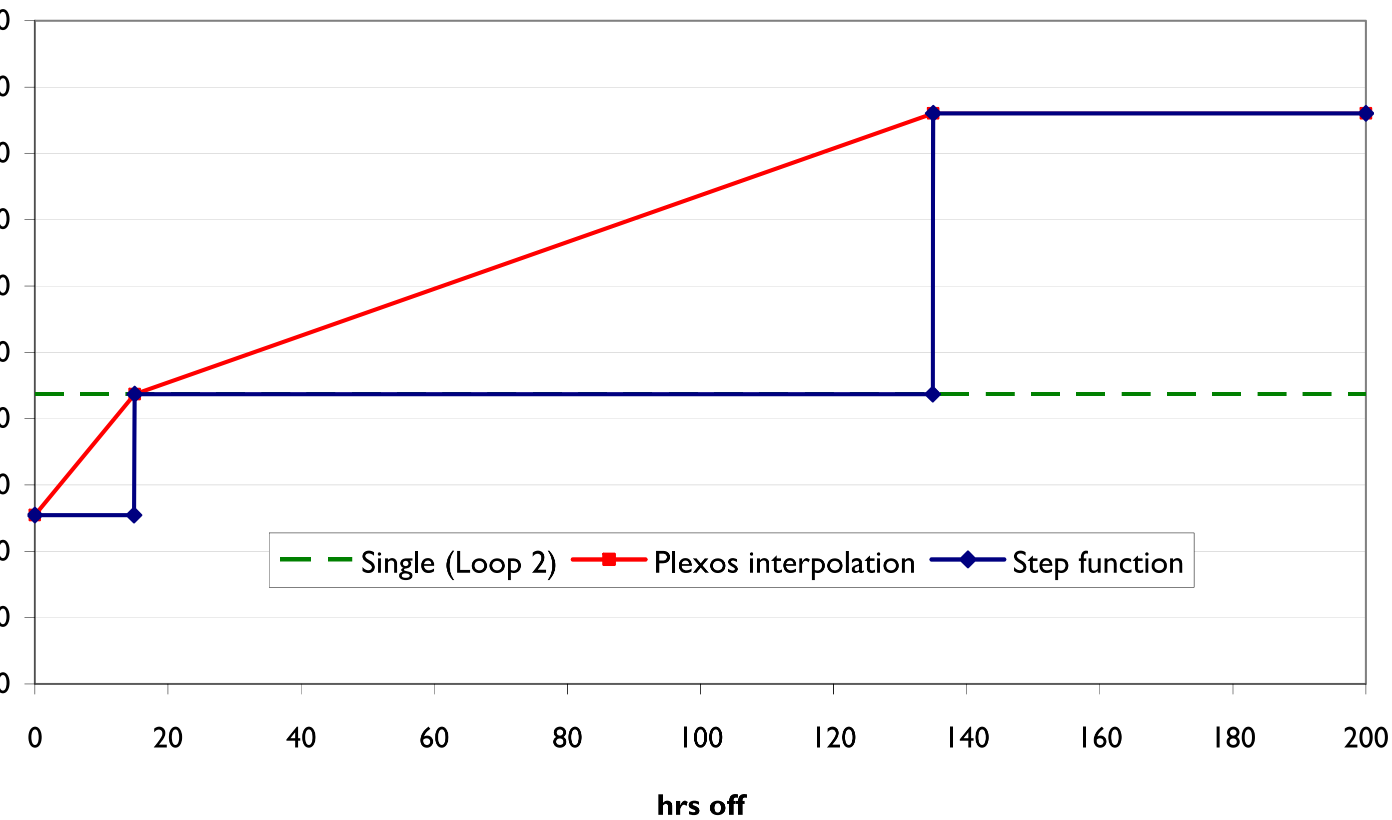


Commercial Offers: SRMC

- **SRMC = Fuel Price × Marginal Heat Rate + VOM Charge**
- Validated PLEXOS reported SRMC at multiple load points
- Tests ranged from modelling single generators (e.g. AD1) to checking hourly SRMCs in annual all-island runs

Period	Demand (MW)	Shadow Price (€/MWh)	Marginal Heat Rate (GJ/MWh)	Generator SRMC (€/MWh)	Average Heat Rate (GJ/MWh)	Generation Cost (€k)	Average Cost (€/MWh)
1	35	67.75	7.86	67.75	13.21	95.63	113.85
2	95	67.75	7.86	67.75	9.83	193.2	84.74
3	105	74.48	8.64	74.48	9.68	210.27	83.44
4	175	74.48	8.64	74.48	9.26	335.39	79.85
5	185	75.17	8.72	75.17	9.23	353.34	79.58
6	255	75.17	8.72	75.17	9.09	479.62	78.37
7	260	300	8.72	75.17	9.09	485.04	77.73

Commercial Offers: Start Costs



- Investigated modelling multiple warmth states
- Hot / warm / cold step function to mimic T&S
- Material impact on Up in our base (RR) run
- Annual average prices

Start Cost Model	SMP €/MWh	Uplift €/MWh	Shadow Price €/MWh	Relative PLEXOS run time
Single: Warm only	61.08	6.97	54.12	1.00
Multiple: Interpolation	67.05	13.12	53.93	2.02
Multiple: Step function	66.67	12.77	53.90	1.77

Technical Offers

- Validated that key constraints not violated
  - Minimum stable level (MSL), ramp rates, minimum on/off times, time-profiled minimum and maximum availability
- Some T&SC technical parameters not currently modelled in PLEXOS
  - Dwell times, soak times, synchronous start times, warmth-state dependent run-up (& ramp?) rates
  - Have not examined data for these parameters or confirmed how they would be handled in EPUS
  - But would not typically expect these constraints to be relevant / material for ex-post modelling at hourly resolution

Technical Offers: Run-up

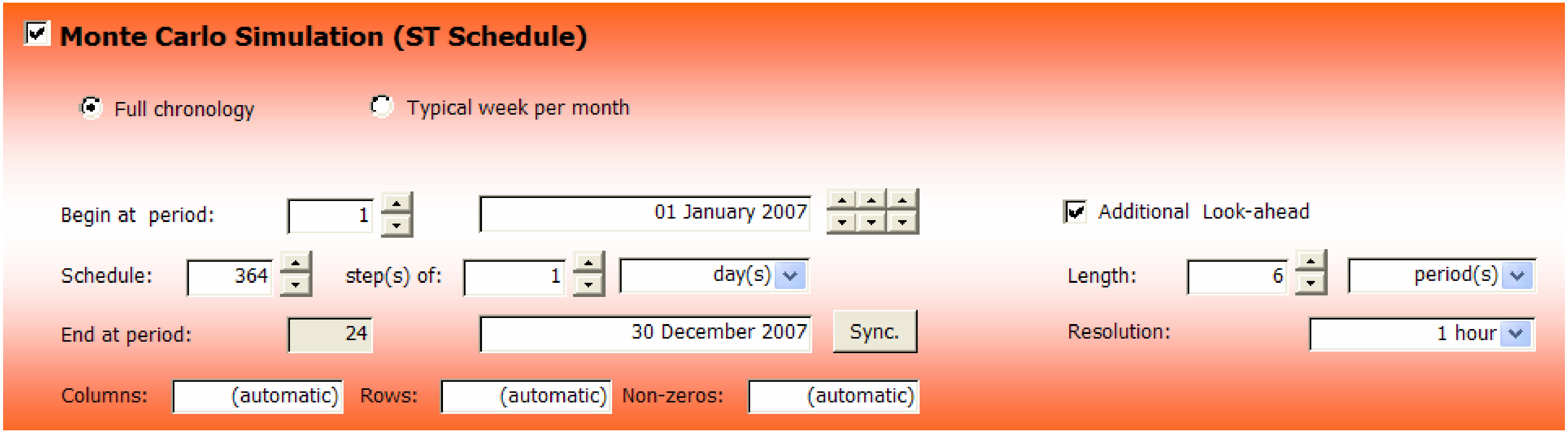
- Option to model run-up to MSL in PLEXOS
- Recommend default setting of not modelling unit run-up
  - Our tests suggested that modelling run-up leads to Uplift and scheduling anomalies in current PLEXOS release (e.g. plant running below MSL able to set Uplift)
- Our understanding is that EPUS does not model dispatch below MSL

Special Cases: Hydro & Pumped Storage

- Hydro optimised subject to monthly energy targets (daily constraint decomposition from MT Schedule)
- Tested materiality of MSL / ramp constraints on hydro units and MSL / min pump load and rough running range constraints on pumped storage

Scenario	Pumped storage			Hydro		Unserved energy (MWh)	Infeasibilities
	MSL	Min Pump Load	Rough Running Range	MSL	Ramps		
BASE: relax PS & Hydro dynamic constraints	N	N	N	N	N	0	None reported
PS MSL & min pump constraints on	Y	Y	N	N	N	12	Multiple days
PS all constraints on	Y	Y	Y	N	N	78	Multiple days
Hydro MSL & ramp constraints on	N	N	N	Y	Y	935	None reported
PS & Hydro all constraints on	Y	Y	Y	Y	Y	1,423	Multiple days

Unit Commitment: ST Schedule



- Objective function consistent with T&SC:
  - *Minimise production cost (incrementals, no load, start) over optimisation horizon*
- Base model configured per T&SC
  - Daily optimisation step, 06:00 start, 6 hour look-ahead
  - But hourly trading period approximation

Unit Commitment: Look-ahead

- Inter-day “edge effects” reported in AIP Loop 2 results due to 06:00 start and no look-ahead
- Configurable look-ahead feature now available in PLEXOS
- Tested sensitivities with 0 and 24 hour look-ahead periods
  - Annual average prices:

Look-ahead Period	SMP €/MWh	Uplift €/MWh	Shadow Price €/MWh	Relative PLEXOS run time	Unserved Energy MWh
6 Hours [Base]	61.08	6.97	54.12	1.00	0
24 Hours	59.43	5.38	54.05	1.41	8
None	69.47	12.74	56.73	1.03	9425

  - *Caveat: Start-cost carry-forward for SEM Uplift is a function of look-ahead period!*

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Unit Commitment: Trading Period

- Tested materiality of hourly trading period approximation by re-runnin PLEXOS at half-hourly resolution:
  - Retained average hourly load, wind, BETTA profiles
  - Anticipated to see some differences due to dynamic constraints (e.g. binding ramp rates for MP over ½ hour)
- Model run more than doubled but immaterial price impact
  - Annual average prices:

Trading Period	SMP €/MWh	Uplift €/MWh	Shadow Price €/MWh	Relative PLEXOS run time
Hourly	59.93	5.81	54.12	1.00
Half-Hourly	59.71	4.97	54.74	2.45

Shadow Prices: Sense Check

- Stack model developed to sense check PLEXOS shadow prices
  - Supply stack based on full load SRMC
  - Ignores plant dynamic constraints, no-load & start costs
  - Seasonal average prices broadly consistent with PLEXOS:

CENTRAL	Stack Model SRMC Price			PLEXOS Shadow Price		
€/MWh	All	Peak	Off-peak	All	Peak	Off-peak
All	51.86	58.86	47.96	54.12	61.89	49.80
Summer	42.30	47.46	39.46	45.23	51.23	41.92
Winter	65.40	74.76	60.11	66.80	76.88	61.12

LOW	Stack Model SRMC Price			PLEXOS Shadow Price		
€/MWh	All	Peak	Off-peak	All	Peak	Off-peak
All	38.75	43.98	35.83	40.57	47.36	36.80
Summer	33.58	36.87	31.77	36.27	41.49	33.39
Winter	46.07	53.89	41.65	46.71	55.61	41.71

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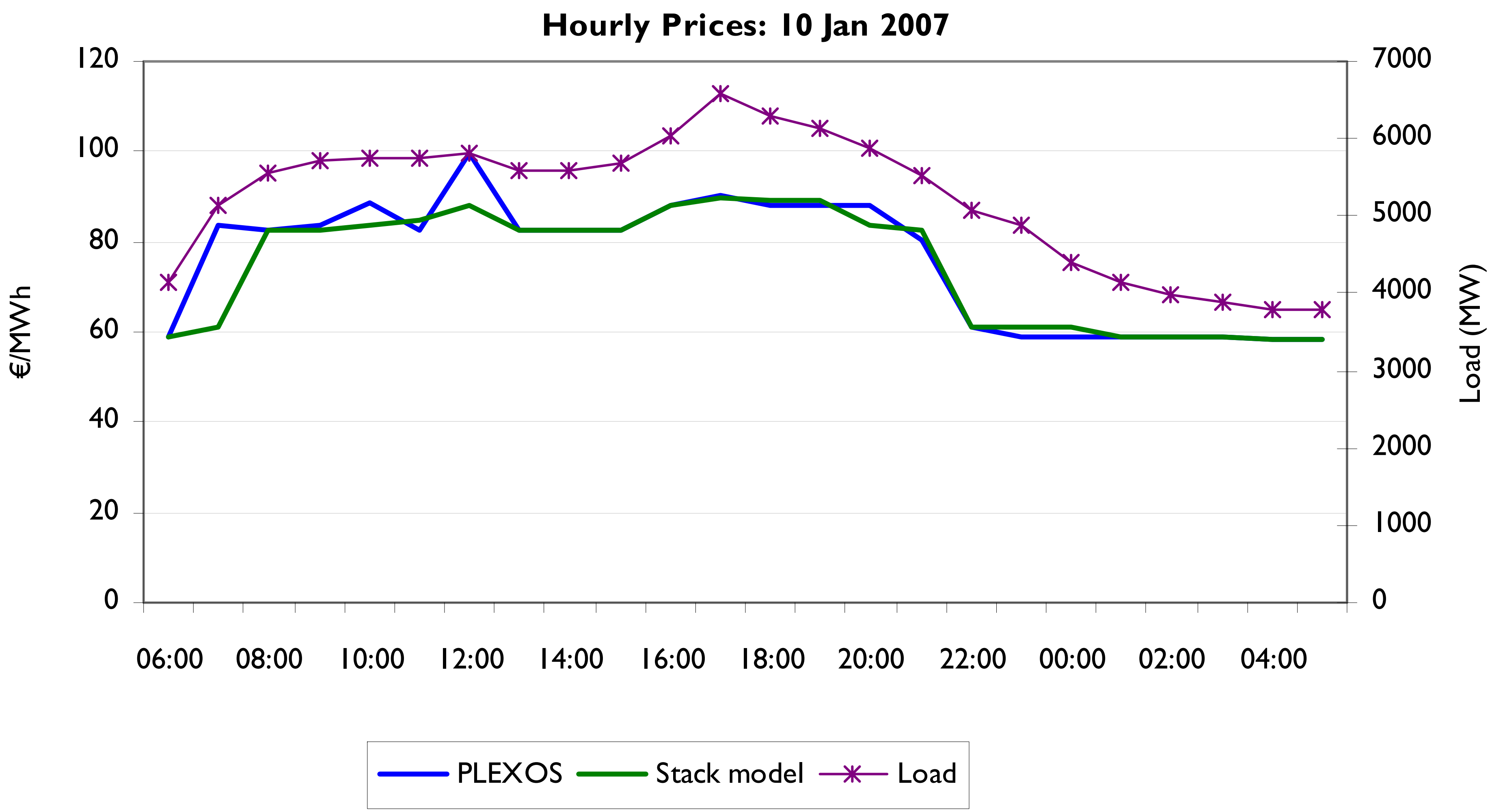
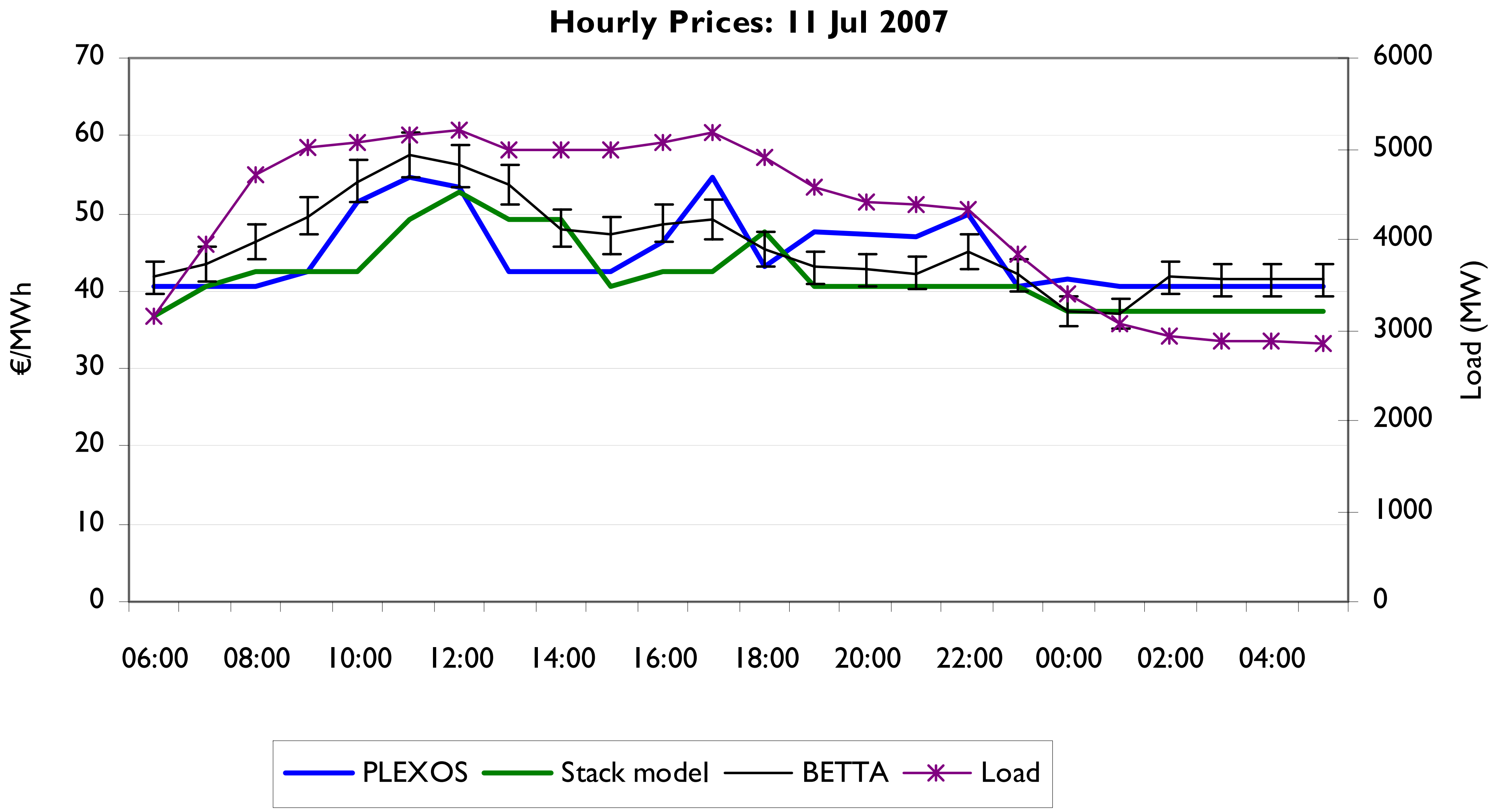
Shadow Prices: Sense Check

- Representative winter weekday:



Shadow Prices: Sense Check

- Representative summer weekday:



PLEXOS Shadow Prices

- PLEXOS determines shadow prices automatically as part of the optimisation solution

Δ (Objective Function) / Δ (Demand)

  - Not calculated ex-post by identifying "marginal" plant
- PLEXOS shadow price often equal to a generator SRMC but a given price can involve multiple generators over multiple periods
  - Analysis of annual RR run:

BASE (RR)	
Generator SRMC	*65.9%*
Moyle marginal	*28.8%*
Other (delta)	*5.2%*

PLEXOS Shadow Prices

- Analysed instances of plant running when SRMC above shadow price
  - Typically due to plant running @ MSL
  - Some oil plant has binding ramp rates in starting data set

BASE (RR)	# of Periods					
Condition	**Total**	**Coal**	**Gas**	**Oil**	**Distillate**	**Peat**
Running (total generating hours)	*184,966*	*42,674*	*73,522*	*1,734*	*114*	*10,729*
Running when SRMC > shadow price:	*7,225*	*1,471*	*3,252*	*562*	*69*	*1,871*
& when @ MSL	*6,997*	*1,471*	*3,252*	*355*	*69*	*1,850*
& when @ ramp limit	*207*	-	-	*207*	-	-
(delta)	*21*	-	-	-	-	*21*

- Plant @ MSL not always prevented from setting shadow price
  - 1,088 instances in above run

Uplift: Discrepancies

- SEM Uplift algorithm in PLEXOS release 4.896 R3 based on May-06 Uplift paper, AIP-SEM-60-06
- Some discrepancies identified with T&SC v1.2:

1. “Price takers” and Cost Objective Function
2. “Price takers” and Cost Recovery Constraint
3. Start cost carry forward formula

Uplift: Discrepancies

- Some discrepancies identified with T&SC v1.2:

1. "Price takers" and Cost Objective Function
    - *Not relevant with proposed* ***α*** *= 0*
2. "Price takers" and Cost Recovery Constraint
    - *Workaround: remove fuel, no-load and start costs for any thermal "price takers"*
3. Start cost carry forward formula
    - *Anticipate T&SC modifications*

Uplift: Discrepancies (2)

- Further discrepancies identified with T&SC v1.2:

4. Start cost carry forward over multiple days
5. “Rev Min” constraint not currently modelled
6. Incorporating TLAFs in Uplift

Uplift: Discrepancies (2)

- Further discrepancies identified with T&SC v1.2:

4. Start cost carry forward over multiple days
    - *Addressed in new PLEXOS release 4.898 R5 (testing TBC)*
5. “Rev Min” constraint not currently modelled
    - *Immaterial with proposed* ***δ*** *= 5*
6. Incorporating TLAFs in Uplift
    - *Example follows*

Uplift: TLAFs

- Uplift Cost Recovery Constraint:

  SMP x MSQ >= INC x MSQ + NLC + SUC

- But generators actually get paid on a loss-adjusted basis:

  SMP x MSQ x TLAF

- PLEXOS models Cost Recovery Constraint on loss-adjusted basis:

  SMP x MSQ x TLAF >= INC x MSQ + NLC + SUC

- EPUS does not model explicitly loss factors in schedule or Uplift
  - Generators would need to loss-adjust all offer components to ensure break-even :

    SMP x MSQ >= [INC x MSQ + NLC + SUC] / TLAF

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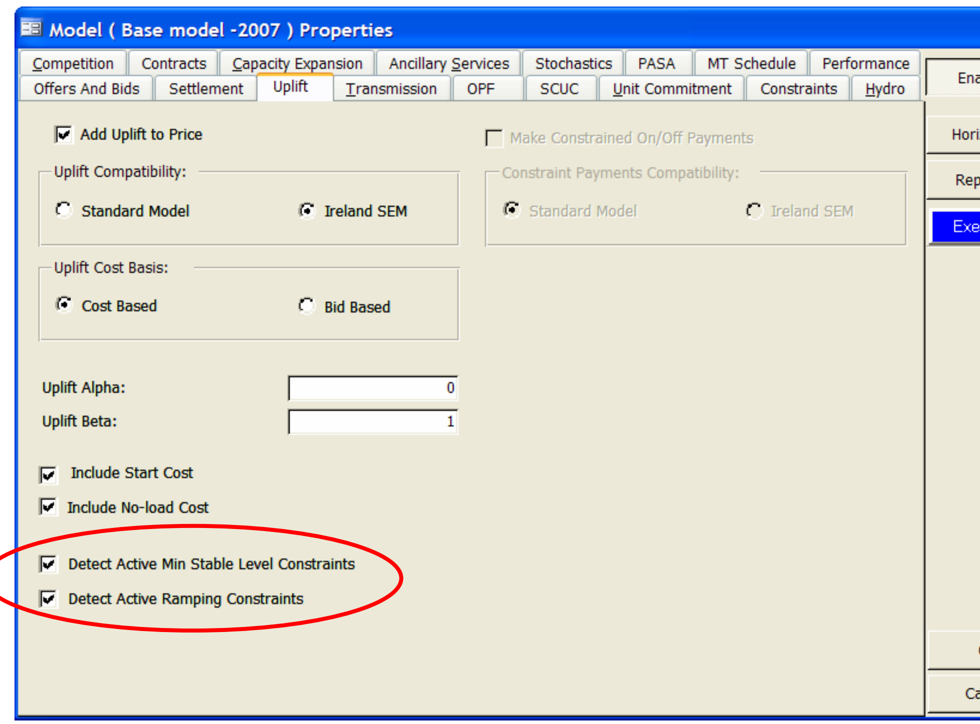
Uplift: TLAFs (2)

- PLEXOS applies TLAF to incremental offers (but not no-load and start costs) in determining schedule
  - Loss-adjusted no-load and start costs could impact schedule
- Potential workaround of manually loss-adjusting all PLEXOS inputs rather than applying built-in TLAF functionality
  - Too impractical for extended timeframe given time-varying TLAFs

Uplift: Testing

- Validated cost recovery constraint being held
- Inspected formulation of Uplift problem in PLEXOS diagnostic files
- Tested start cost carry forward
- Replicated PLEXOS Uplift values for small-scale system
- Tested whether Rev Min constraint binding
- Tested PLEXOS Uplift filters for MSL & ramp constraints



PLEXOS Configuration: Commitment

- Tested alternative PLEXOS unit commitment options
  - RR and MIP consistent with T&SC in respecting integer constrain (e.g. MSL)
  - Annual average prices under base scenario:

PLEXOS Mode	SMP €/MWh	Uplift €/MWh	Shadow Price €/MWh	Relative PLEXOS run time
Mid-Term Only (MT)	n/a	n/a	58.82	0.18
Linear Relaxation (MT + ST LR)	60.02	0.01	60.01	1.23
Rounded Relaxation (MT + ST RR)	61.08	6.97	54.12	1.00
Mixed Integer Program (MT + ST MIP)	62.49	1.32	61.17	41.73

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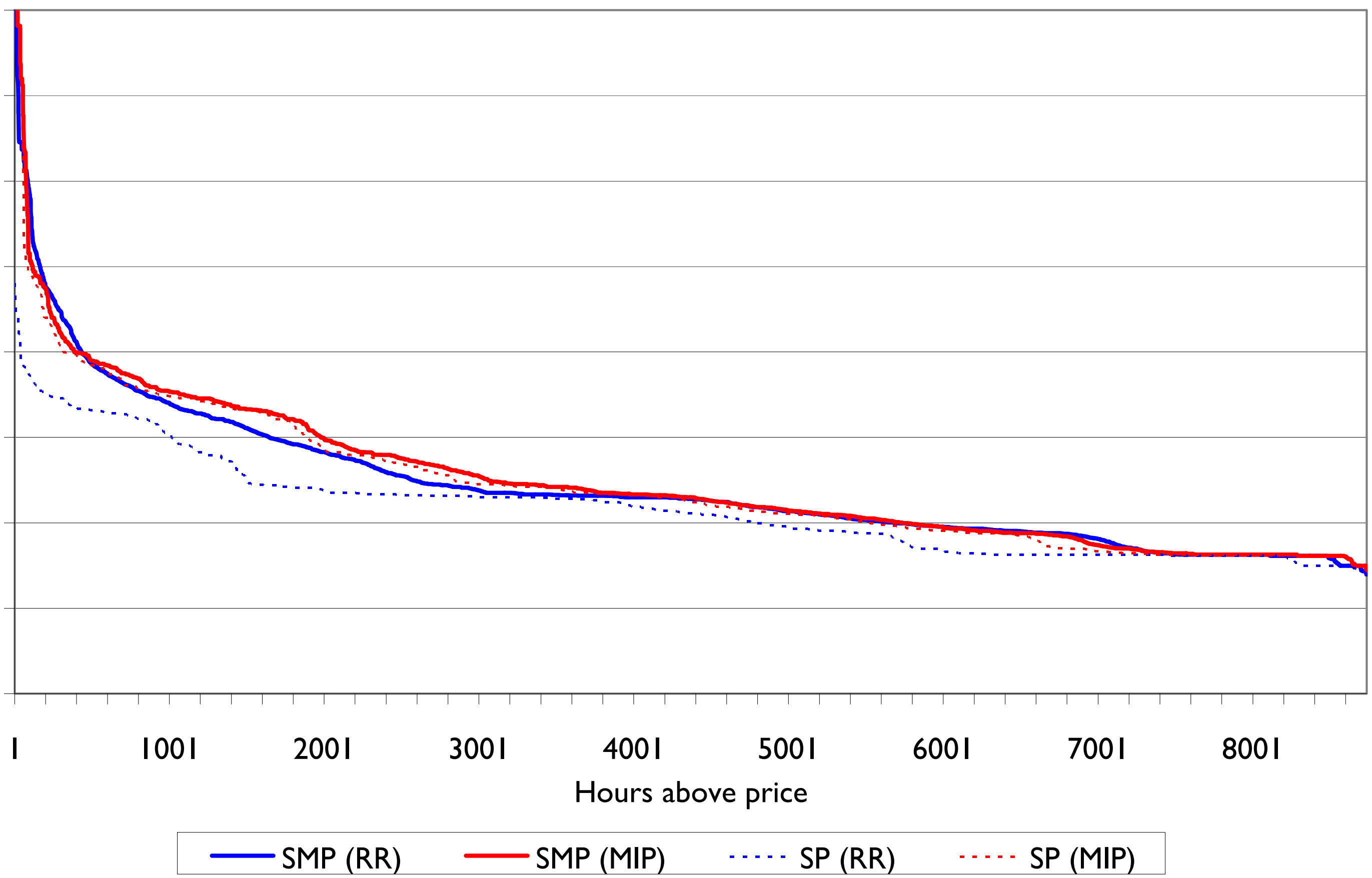
PLEXOS Configuration: Prices



- MIP& RR SMP duration cur medians and percentiles broadly consistent in base scenario
- MIP price spikes typically associated with shadow pric c.f. Uplift in RR
- Price differentials reversed i multiple start costs sensitivi

KEMA

PLEXOS Configuration: Generation

- Generation statistics for base RR and MIP runs:

Plant Type	RR				MIP			
	GWh	% GWh	Gen Hrs	Hrs @ MSL	GWh	% GWh	Gen Hrs	Hrs @ MSL
Coal	10,018.5	26.5%	42,674	2,294	10,001.7	26.7%	41,074	564
Gas	22,804.3	60.3%	73,522	3,390	22,407.2	59.7%	70,793	639
Oil	222.4	0.6%	1,734	373	169.5	0.5%	1,082	25
Distillate	1.6	0.0%	114	83	2.4	0.0%	54	4
Peat	1,085.4	2.9%	10,729	1,945	1,192.0	3.2%	10,444	172
Wind	2,839.0	7.5%	8,733	-	2,839.0	7.6%	8,733	-
Hydro	718.4	1.9%	45,233	-	718.4	1.9%	45,243	-
Hydro PS	143.6	0.4%	2,227	-	188.6	0.5%	3,284	-
Total	**37,833.3**	**100.0%**	**184,966**	**8,085**	**37,518.8**	**100.0%**	**180,707**	**1,404**

  – Net Moyle imports higher in MIP run, offsetting lower gas output

PLEXOS Configuration: RR & MIP

- Both RR and MIP consistent with T&SC in respecting generator technical constraints and (Uplift) cost recovery
- MIP should generally find a more optimal solution than RR but shado prices often less "intuitive"

Shadow Price Analysis	RR	MIP
Generator SRMC	*65.9%*	*31.4%*
Moyle marginal	*28.8%*	*37.5%*
Other (inter-temporal, multi-unit)	*5.2%*	*31.1%*

- Schedules generally show fewer plant operating at MSL under MIP
  - RR schedules still technically feasible per T&SC
  - Uplift MSL filters

PLEXOS Configuration: RR & MIP (2)

- Model run time a key drawback for MIP
  - Typically 25 – 50 times longer than RR
- MIP prices not considered the benchmark for comparing RR results
- Unit commitment choice ultimately depends on study objectives
  - We recommend RR for simulating prices over extended timeframe
  - Faster performance supports scenario analysis for modelling uncertainty of key price drivers

Conclusions

- PLEXOS does support commercial offers, technical offers, unit commitment and Uplift in accordance with SEM T&SC v1.2
- Identified a number of discrepancies / issues for discussion and resolution with Elan Consulting / Drayton Analytics:
  - Currently testing new PLEXOS release 4.898 R5 to test resolution of Uplift start cost carry forward issue
  - No issues judged to be material with proposed workarounds
- Conclude that PLEXOS is a suitable tool for simulating SEM prices
  - RR recommended option for multiple scenario annual pricing studies

Last steps for Project completion

Mike Wilks, Principal Consultant

Final steps after this Workshop

- Draft final Data Validation and Model Validation Reports have been provided to the RAs for review – these will be completed in next coupl of weeks following this Workshop
- KEMA will hold final Handover meetings within the RAs in this timeframe
- Before then will resolve the few outstanding issues highlighted by KEMA today and revisit a few other issues if and as required following discussion with and feedback from participants today
- Now anticipate that public versions of the Final Reports and reviewed data will be made available mid-late April by the RAs

Final Thoughts

- The project has been intense and challenging due to the timeframes and issues BUT productive and enjoyable
- We hope we have provided further confidence to market participants i the robustness of Plexos for market modelling by the RAs
- We hope we have provided a robust baseline set of input data and modelling assumptions which can be used as the basis for the further required modelling as part of the subsequent Loop 3 and Directed Contract exercises
- We hope we have identified any issues which need to considered and addressed appropriately going forward within SEM policy and/or modelling
- Finally, we have welcomed the active participation and cooperation of all market participants and the TSOs….THANK YOU