Market Simulation Data & Model Validation
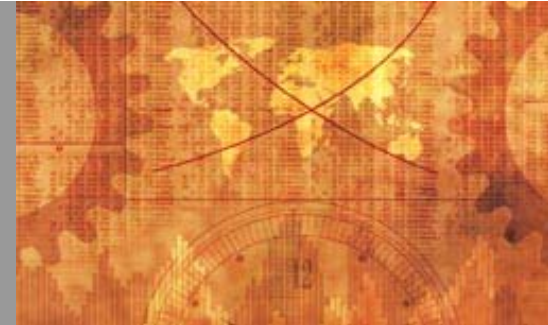
Presentation to SEM Market Participants

NERA
Economic Consulting

How Markets Work™

Agenda

- Description of Project

- Calibration of PLEXOS

- Validation of PLEXOS Input Data

- Observations for the Future

Description of Project

Objectives

- Examine the ability of PLEXOS to produce results that reflect the MSP Software that determines market prices by half hour

- Develop validated PLEXOS database for the October 2008 to September 2009 period suitable for use by the Regulatory Authorities for various purposes including the development of Directed Contract quantities and prices

PLEXOS Calibration

- Actual market results are available from November 1, 2007

- These results provide an opportunity to view the ability of PLEXOS to simulate market operation

- A PLEXOS database was developed using actual load, actual generator availability and actual commercial offers for all thermal units

- PLEXOS results using these data produced SMPs consistent with actual SMPs - that is within 2% averaged over all intervals

- Insight was gained as to impact of PLEXOS settings

PLEXOS Database Development

- NERA began with the validated PLEXOS database developed by KEMA in 2007

- Updated forecast of load, wind and embedded generation were provided by Eirgrid

- Market participants were provided an opportunity to review and update data

- NERA updated the 2007 representation of the availability of Moyle energy

- Fuel and carbon price inputs were developed from forward fuel prices with transport, currency and tax adjustments

Calibration

Calibration of PLEXOS

Objective

- Calibrate PLEXOS vs. actual half-hourly prices from the SEM & recommend required adjustments to settings/ assumptions and/or results

Process

1. Run PLEXOS with actual load and commercial offer data & compare results to actuals

2. Identify reasons for differences

3. Modify assumptions or settings to reduce those differences

4. Go back to Step 1 until results sufficiently calibrated

PLEXOS is Significantly Different than the MSP Software Model

- Examines a longer time frame

- Typically used with availability not known

- While it has a large scale optimization option for unit commitment (MIP) the option is not always feasible to utilize

- Attempts to simulate a full scale optimal unit commitment with approximations (rounded relaxation)
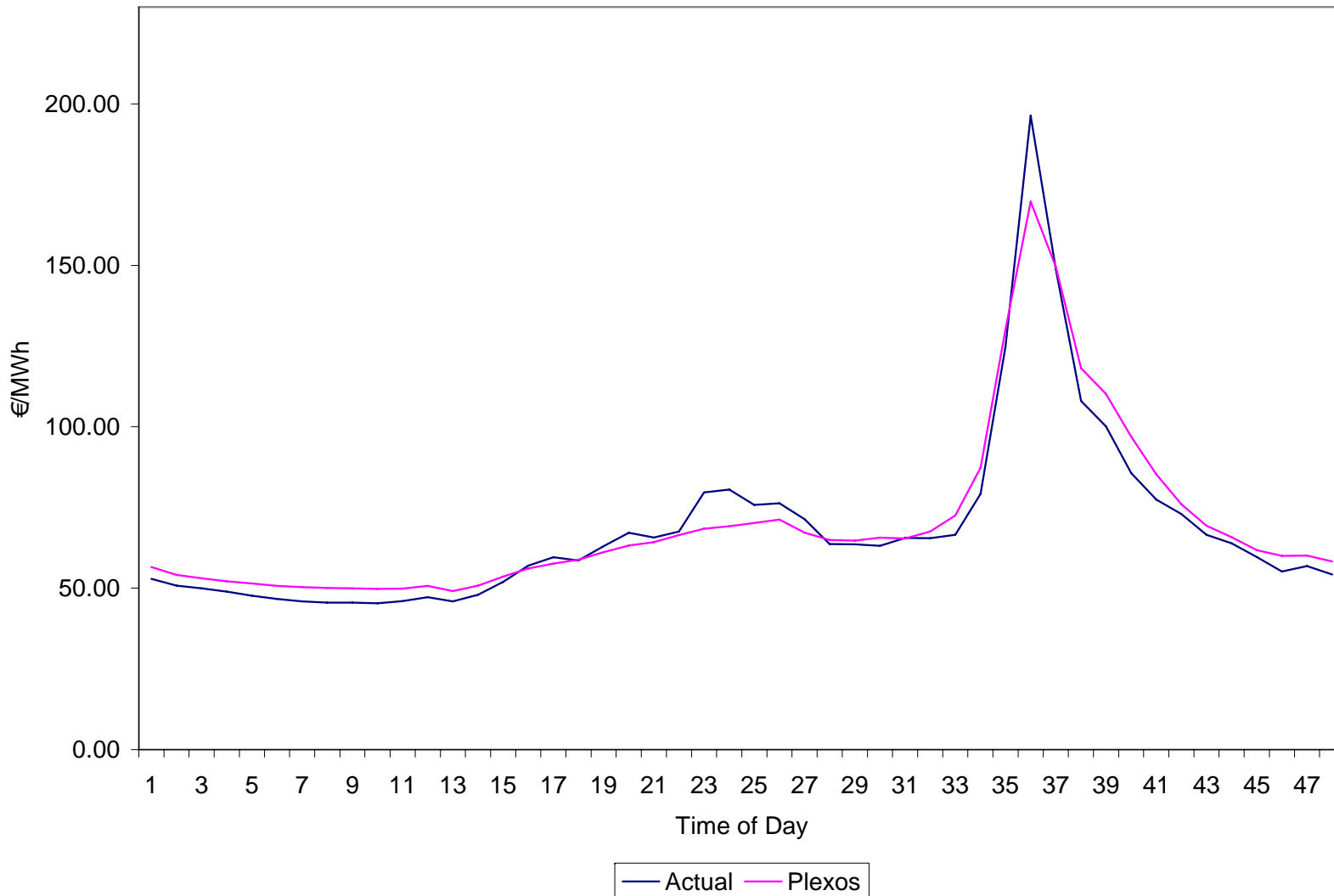
Calibration of PLEXOS

- Poor initial results using 2007 settings

- Correction to MSL filter

- Use of cold, warm and hot starts the largest issue

- Rounded relaxation settings & MIP analysed in detail

- Alternative peaker MSLs investigated

- Alternative treatments of Moyle investigated

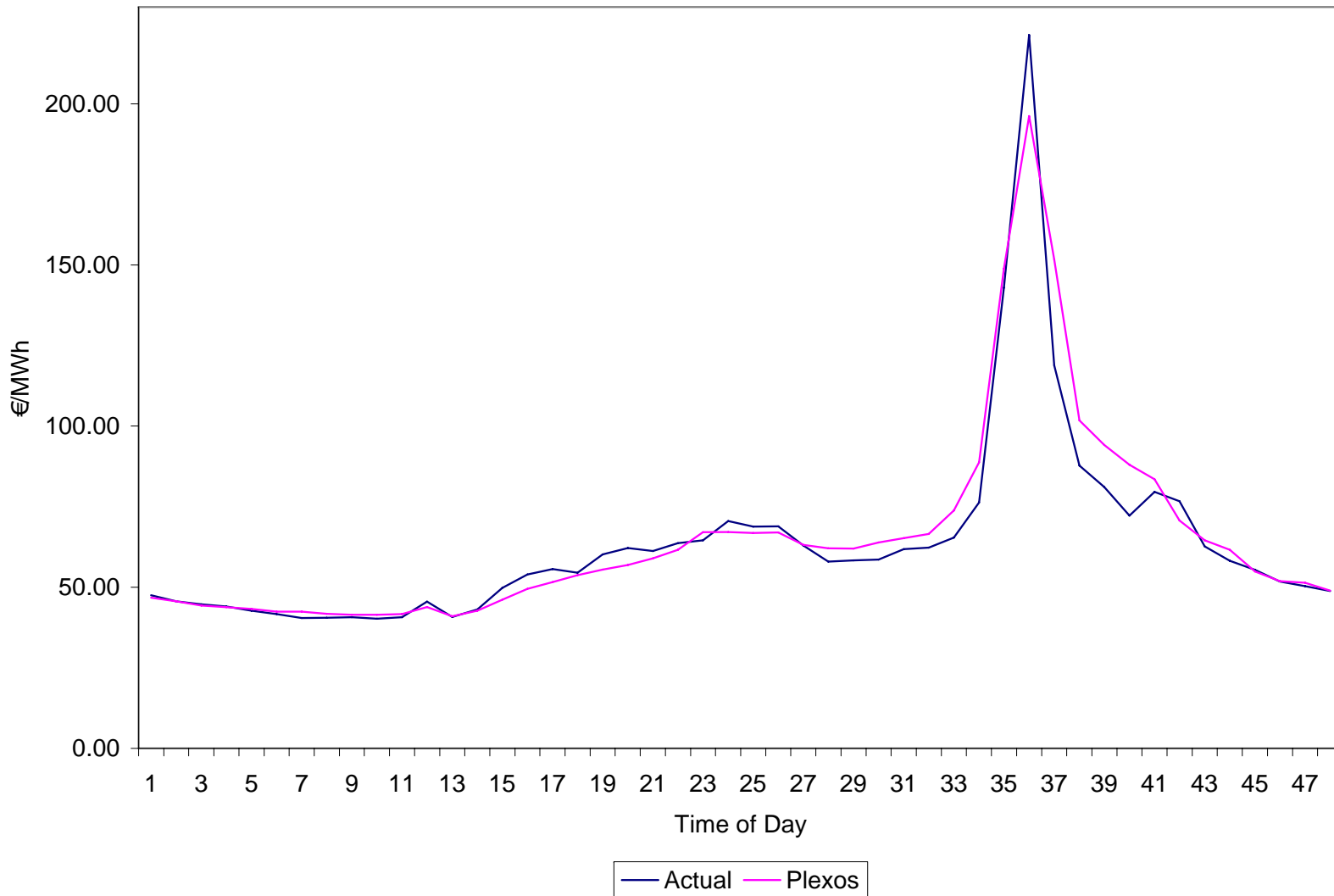- Final results are acceptably well calibrated

Calibration of PLEXOS

SMP Comparison: November 2007 - February 2008
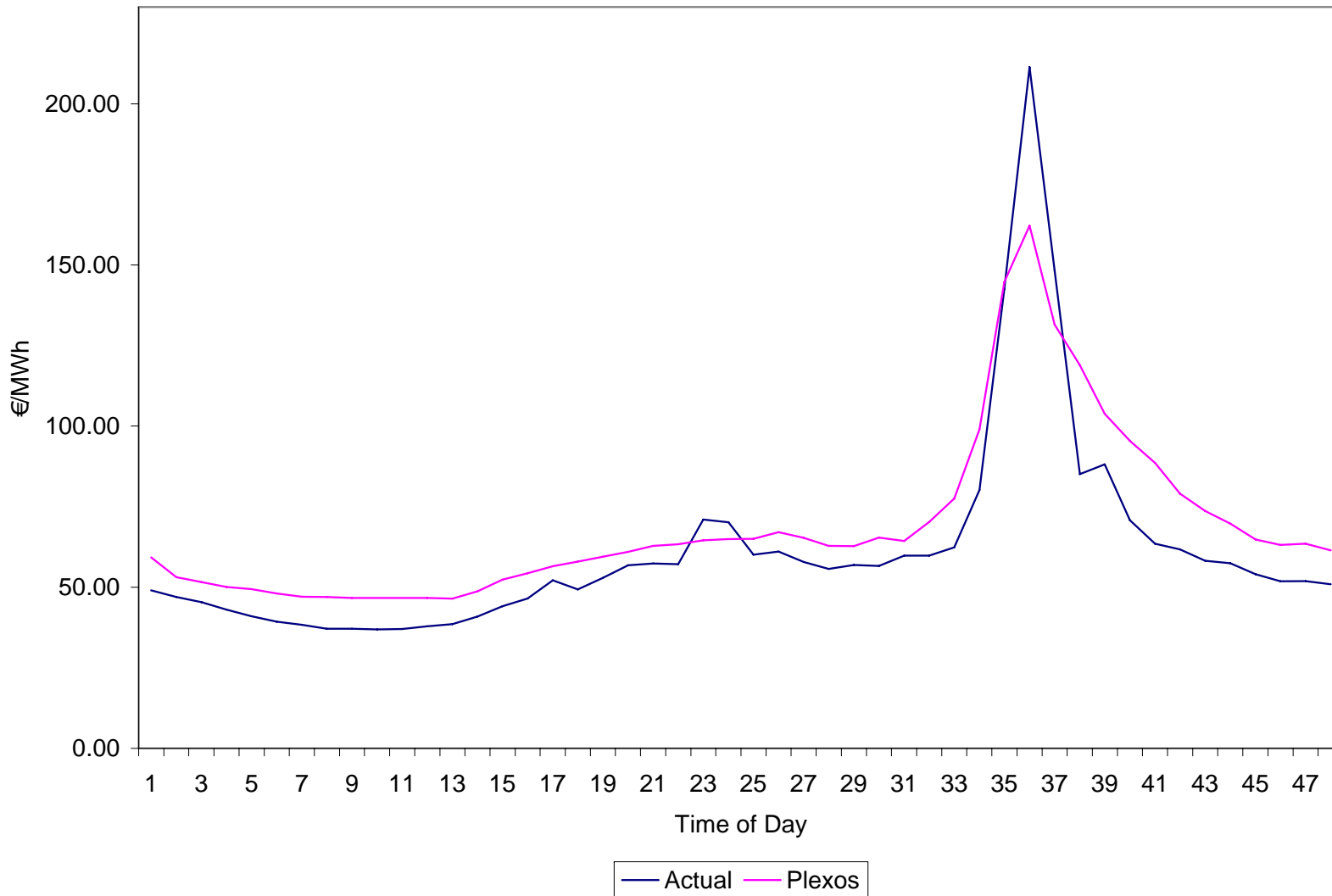
Calibration of PLEXOS

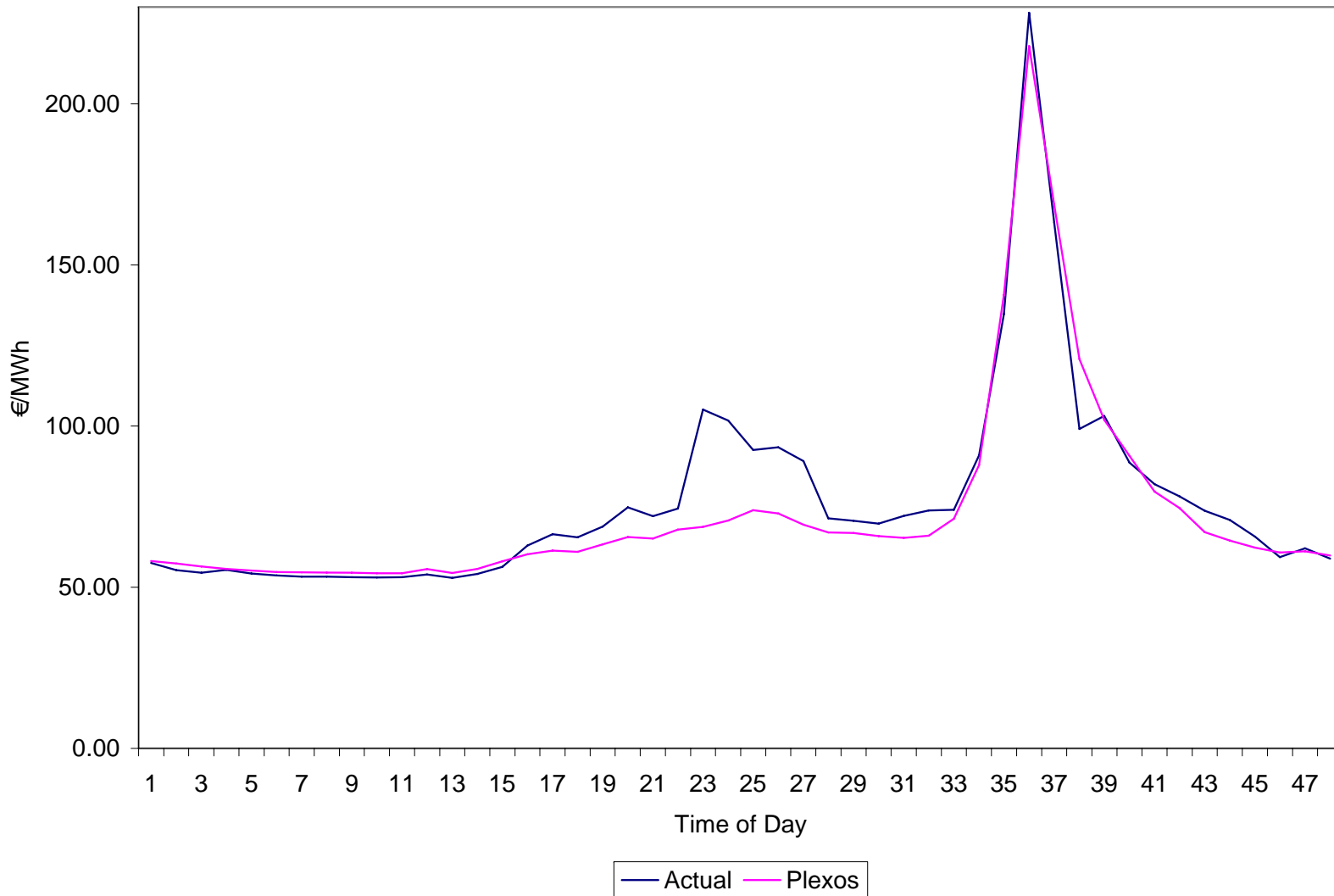## SMP Comparison: November 2007

Calibration of PLEXOS

SMP Comparison: December 2007

Calibration of PLEXOS

SMP Comparison: January 2008

Calibration of PLEXOS

SMP Comparison: February 2008
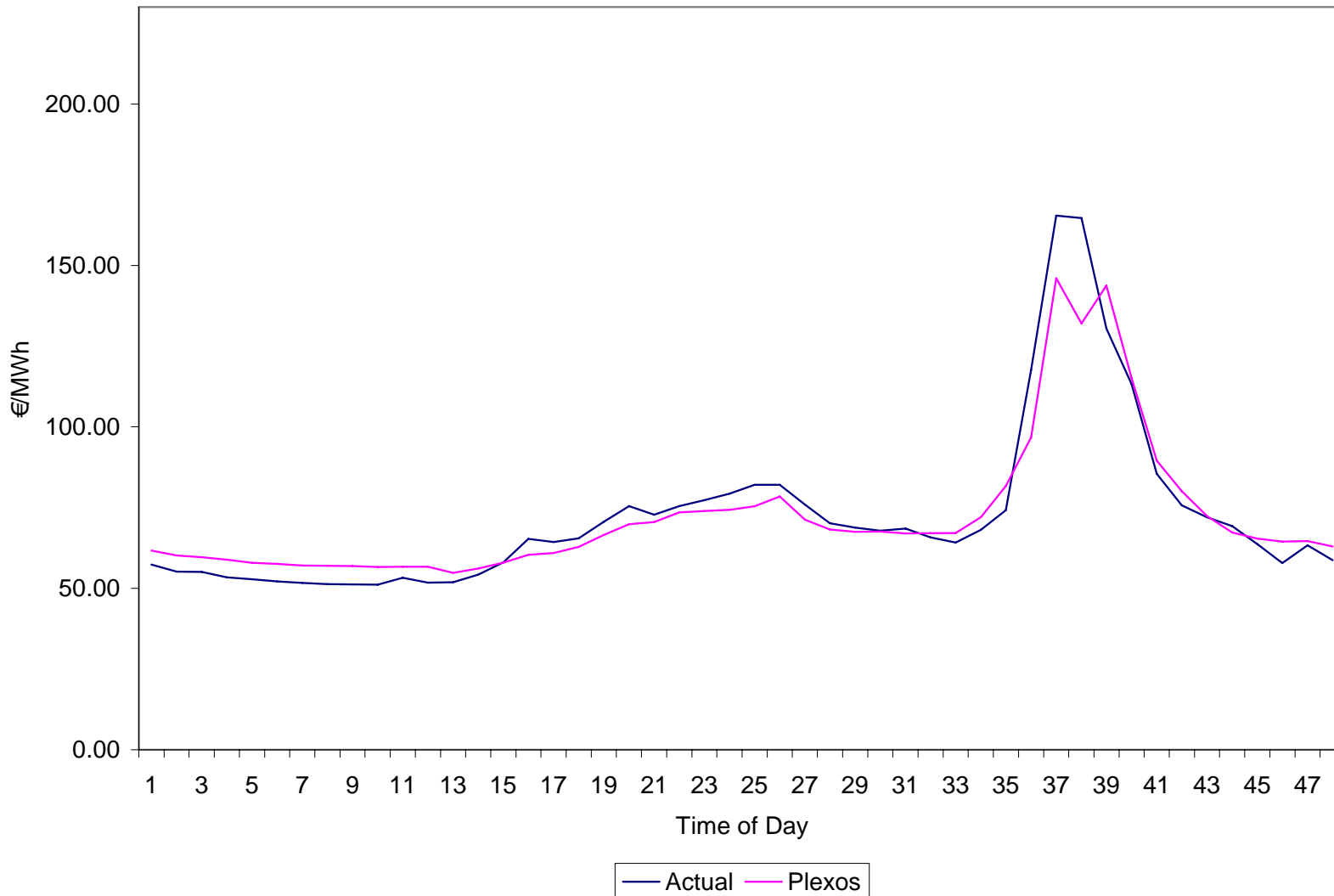
Calibration of PLEXOS

SMP Comparison: Week 7

Calibration of PLEXOS
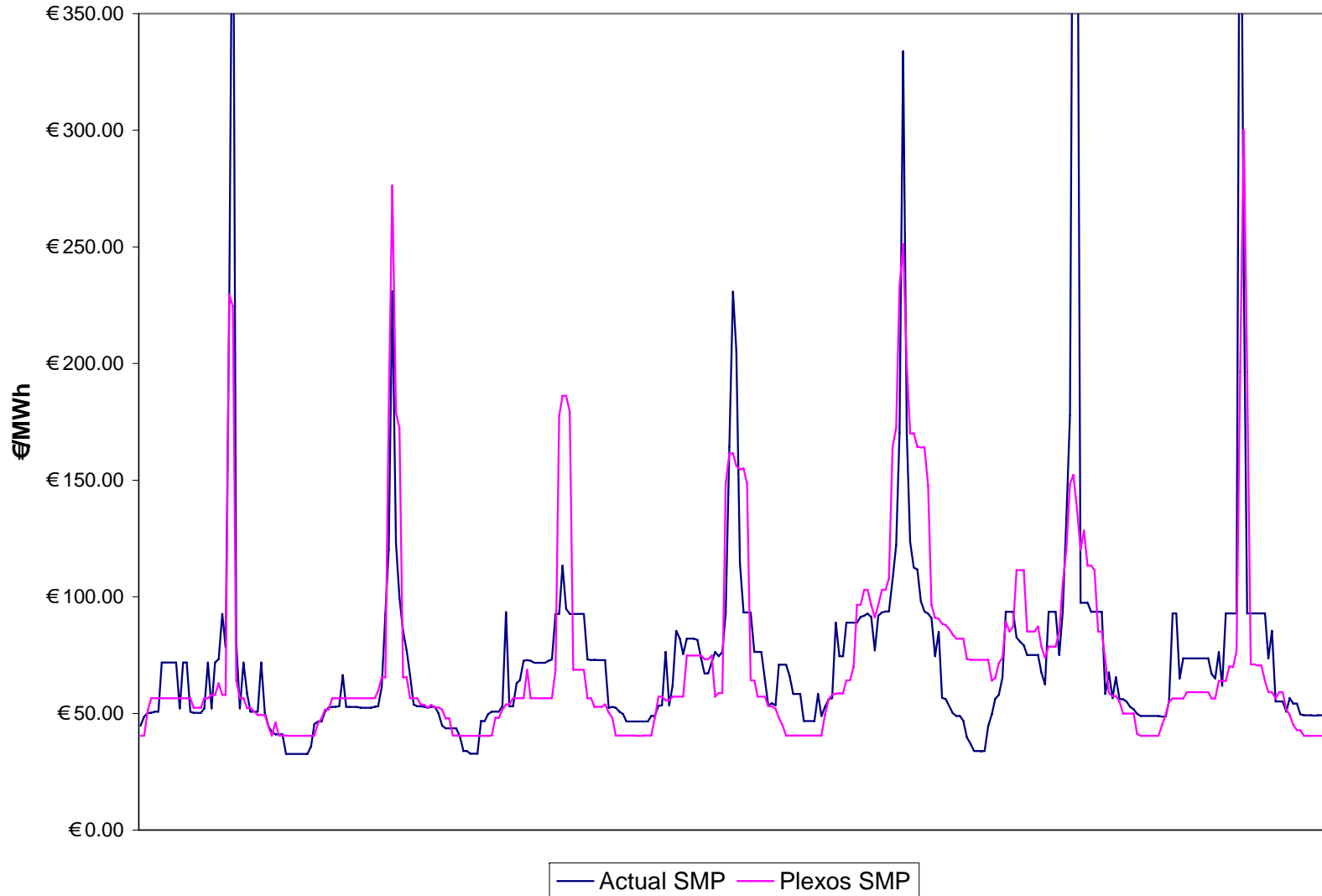
SMP & Shadow Price Comparison

- Overall SMP calibration is reasonable and no systematic bias warranting an adjustment of results was found

- PLEXOS shadow price is low

- PLEXOS uplift is high

- The effects are more-or-less offsetting even on a half hourly basis

- The cause is over-commitment by PLEXOS

- Over-commitment by PLEXOS appears to be systematic

Over Commitment Requires Modelling Adjustments

- MSL filter removes impact on uplift of many units scheduled in PLEXOS at minimum stable load which does not happen in MSP Software

- Use of warm start cost only avoids significant overstatement of SMP as a result of very high uplift values

- Higher rounded relaxation tolerance can improve backcast results by reducing over-commitment. However,

  – In forecast mode higher rounded relaxation tolerance led to high instances of unserved energy.

  – For this reason, the middle RR level of 5 is recommended in forecast modelling and was used in NERA's final backcast calibrations.

Calibration of PLEXOS

SMP Comparison: Use of 3 start states
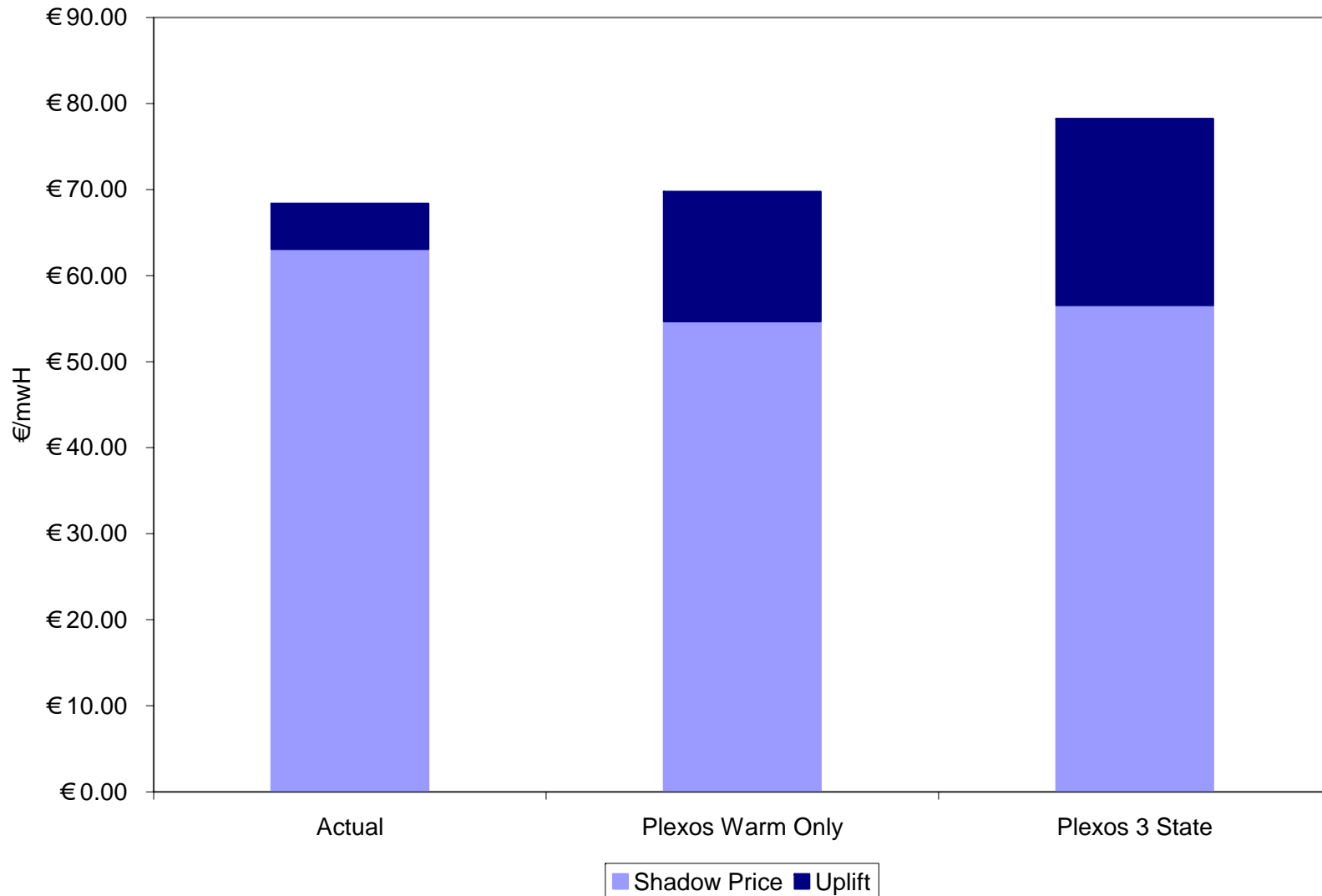
Calibration of PLEXOS

SMP & Shadow Price: Nov 2007-Feb 2008 (Actual)

Calibration of PLEXOS

SMP & Shadow Price: Nov 2007-Feb 2008 (PLEXOS)

Calibration of PLEXOS

Base prices Nov-Feb

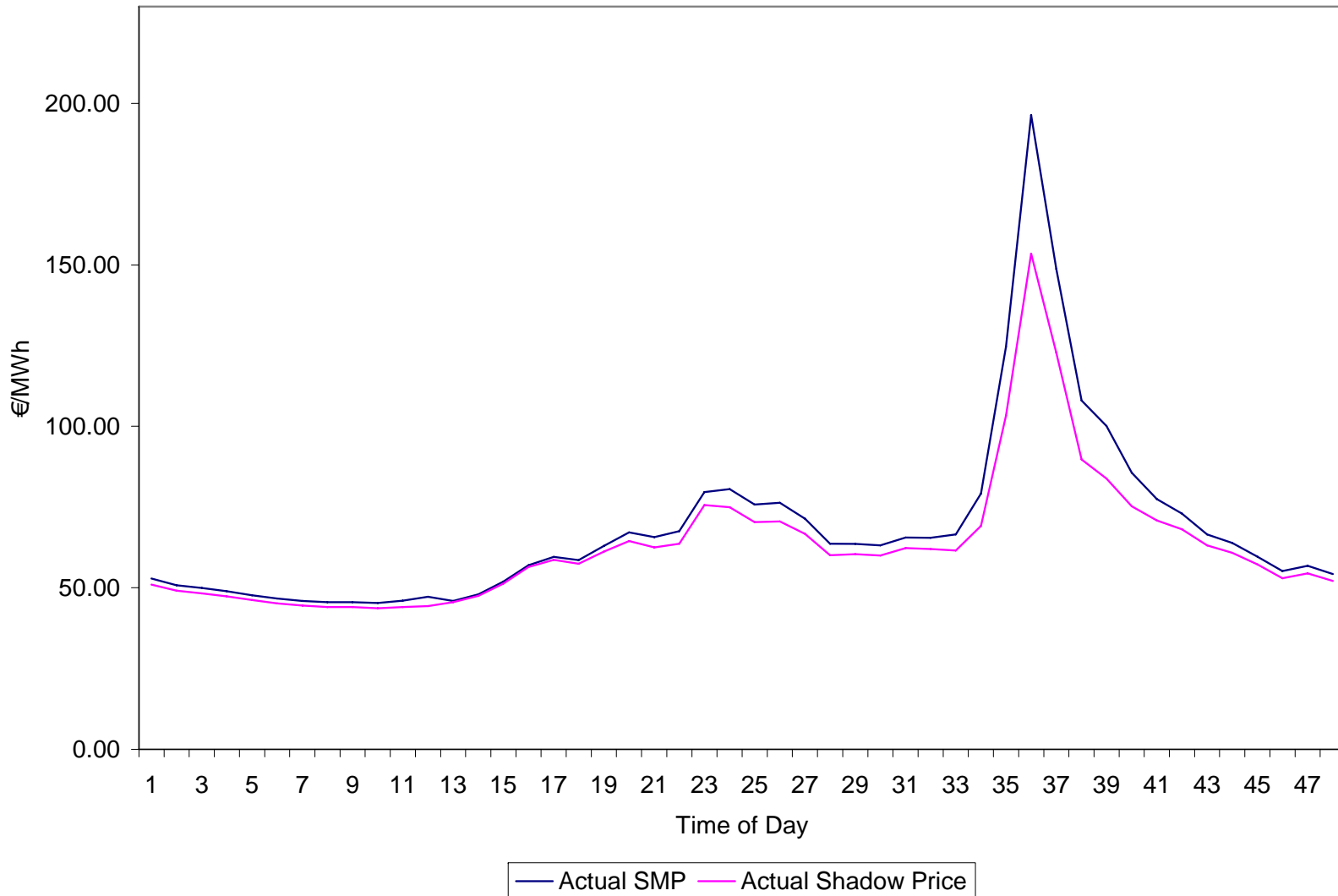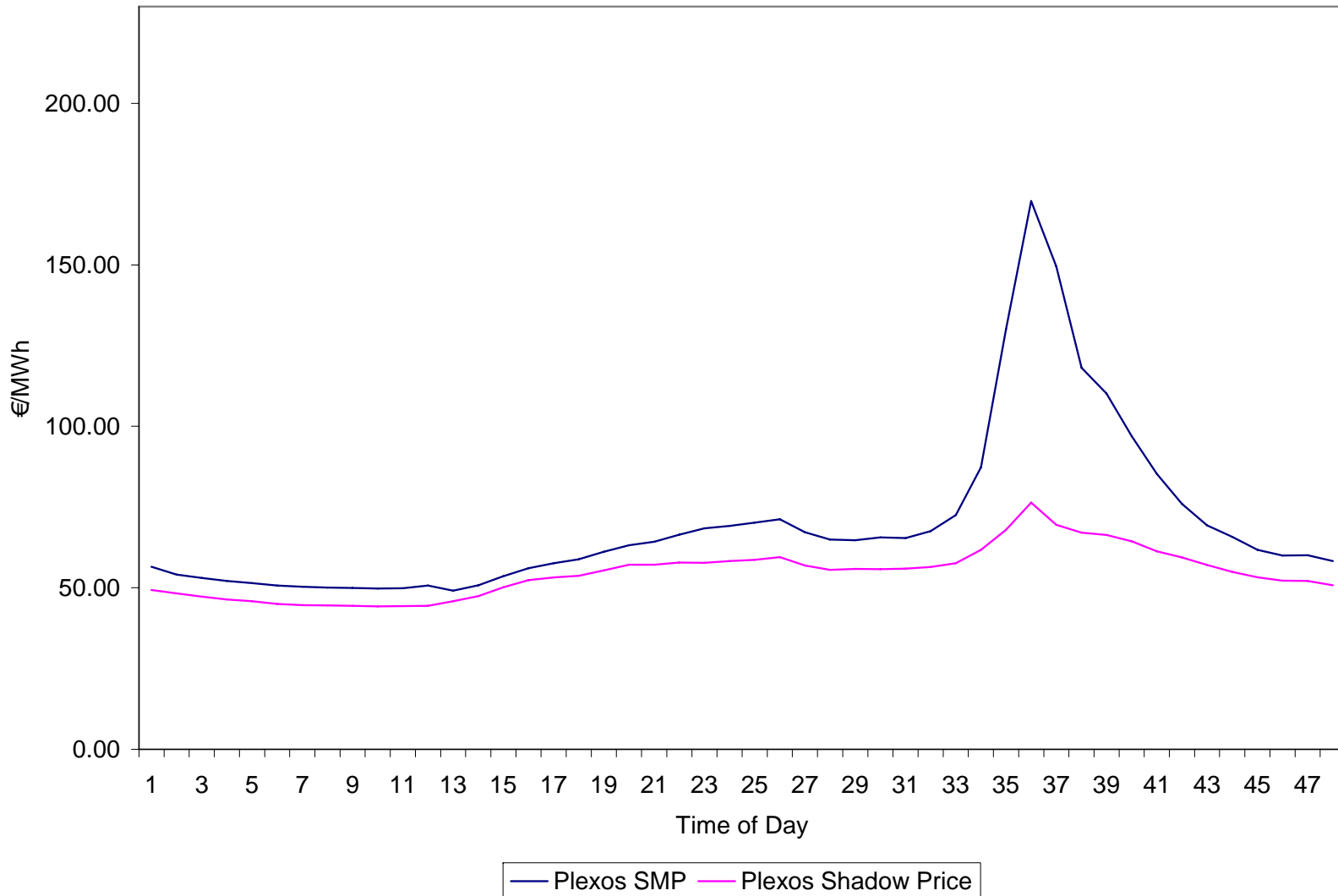|	Sh. Price	Uplift	SMP
Actual	€ 63.08	€ 5.28	€ 68.36
PLEXOS	€ 54.68	€ 15.06	€ 69.74
Variance	(€ 8.40)	€ 9.78	€ 1.37

Mid prices Nov-Feb

	Sh. Price	Uplift	SMP
Actual	€ 71.74	€ 7.33	€ 79.07
PLEXOS	€ 58.98	€ 20.21	€ 79.19
Variance	(€ 12.77)	€ 12.88	€ 0.12

Peak prices Nov-Feb

	Sh. Price	Uplift	SMP
Actual	€ 99.86	€ 20.57	€ 120.42
PLEXOS	€ 67.66	€ 55.40	€ 123.05
Variance	(€ 32.20)	€ 34.83	€ 2.63

Base prices Nov

	Sh. Price	Uplift	SMP
Actual	€ 58.50	€ 5.21	€ 63.72
PLEXOS	€ 49.46	€ 15.70	€ 65.16
Variance	(€ 9.04)	€ 10.48	€ 1.44

Mid prices Nov

	Sh. Price	Uplift	SMP
Actual	€ 67.30	€ 6.96	€ 74.26
PLEXOS	€ 54.38	€ 21.94	€ 76.33
Variance	(€ 12.92)	€ 14.99	€ 2.07

Peak prices Nov

	Sh. Price	Uplift	SMP
Actual	€ 95.13	€ 19.22	€ 114.35
PLEXOS	€ 62.53	€ 61.38	€ 123.91
Variance	(€ 32.59)	€ 42.16	€ 9.57

Base prices Dec

	Sh. Price	Uplift	SMP
Actual	€ 55.85	€ 5.24	€ 61.09
PLEXOS	€ 47.46	€ 21.38	€ 68.84
Variance	(€ 8.39)	€ 16.14	€ 7.75

Mid prices Dec

	Sh. Price	Uplift	SMP
Actual	€ 64.47	€ 7.03	€ 71.50
PLEXOS	€ 51.89	€ 26.81	€ 78.70
Variance	(€ 12.58)	€ 19.78	€ 7.20

Peak prices Dec

	Sh. Price	Uplift	SMP
Actual	€ 99.44	€ 18.59	€ 118.02
PLEXOS	€ 58.88	€ 63.32	€ 122.20
Variance	(€ 40.56)	€ 44.73	€ 4.18

Base prices Jan

	Sh. Price	Uplift	SMP
Actual	€ 70.52	€ 5.96	€ 76.48
PLEXOS	€ 62.04	€ 10.76	€ 72.80
Variance	(€ 8.48)	€ 4.80	(€ 3.68)

Mid prices Jan

	Sh. Price	Uplift	SMP
Actual	€ 79.70	€ 8.57	€ 88.27
PLEXOS	€ 66.24	€ 15.68	€ 81.93
Variance	(€ 13.46)	€ 7.12	(€ 6.34)

Peak prices Jan

	Sh. Price	Uplift	SMP
Actual	€ 104.18	€ 25.53	€ 129.70
PLEXOS	€ 79.53	€ 53.12	€ 132.65
Variance	(€ 24.65)	€ 27.60	€ 2.95

Base prices Feb

	Sh. Price	Uplift	SMP
Actual	€ 67.51	€ 4.65	€ 72.16
PLEXOS	€ 59.82	€ 12.19	€ 72.01
Variance	(€ 7.69)	€ 7.54	(€ 0.15)

Mid prices Feb

	Sh. Price	Uplift	SMP
Actual	€ 75.57	€ 6.66	€ 82.23
PLEXOS	€ 63.52	€ 16.12	€ 79.65
Variance	(€ 12.05)	€ 9.46	(€ 2.59)

Peak prices Feb

	Sh. Price	Uplift	SMP
Actual	€ 100.44	€ 18.67	€ 119.10
PLEXOS	€ 69.53	€ 42.94	€ 112.47
Variance	(€ 30.90)	€ 24.27	(€ 6.63)

# Moyle, Hydro and Pumped Storage Were Also Examined

- KEMA GB model was updated and used in calibration as opposed to actual Moyle flows

- Monthly actual hydro generation was used and PLEXOS shaped hydro

- Pumped storage capacity and efficiency was put in model and PLEXOS determined pumped storage schedule

- This provides a better test than using actual data for these values

- Using actual values was examined and did not alleviate the over commitment issue

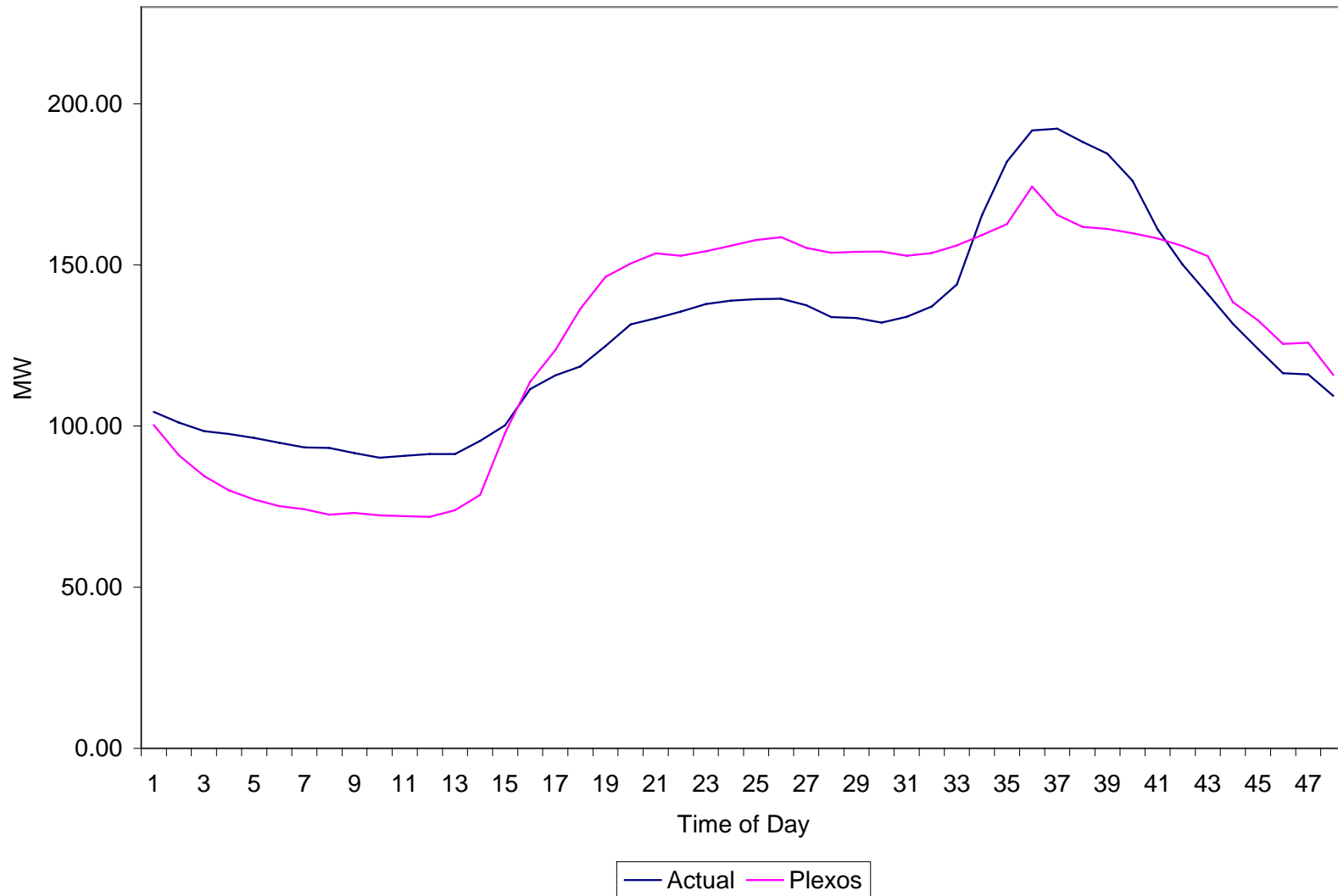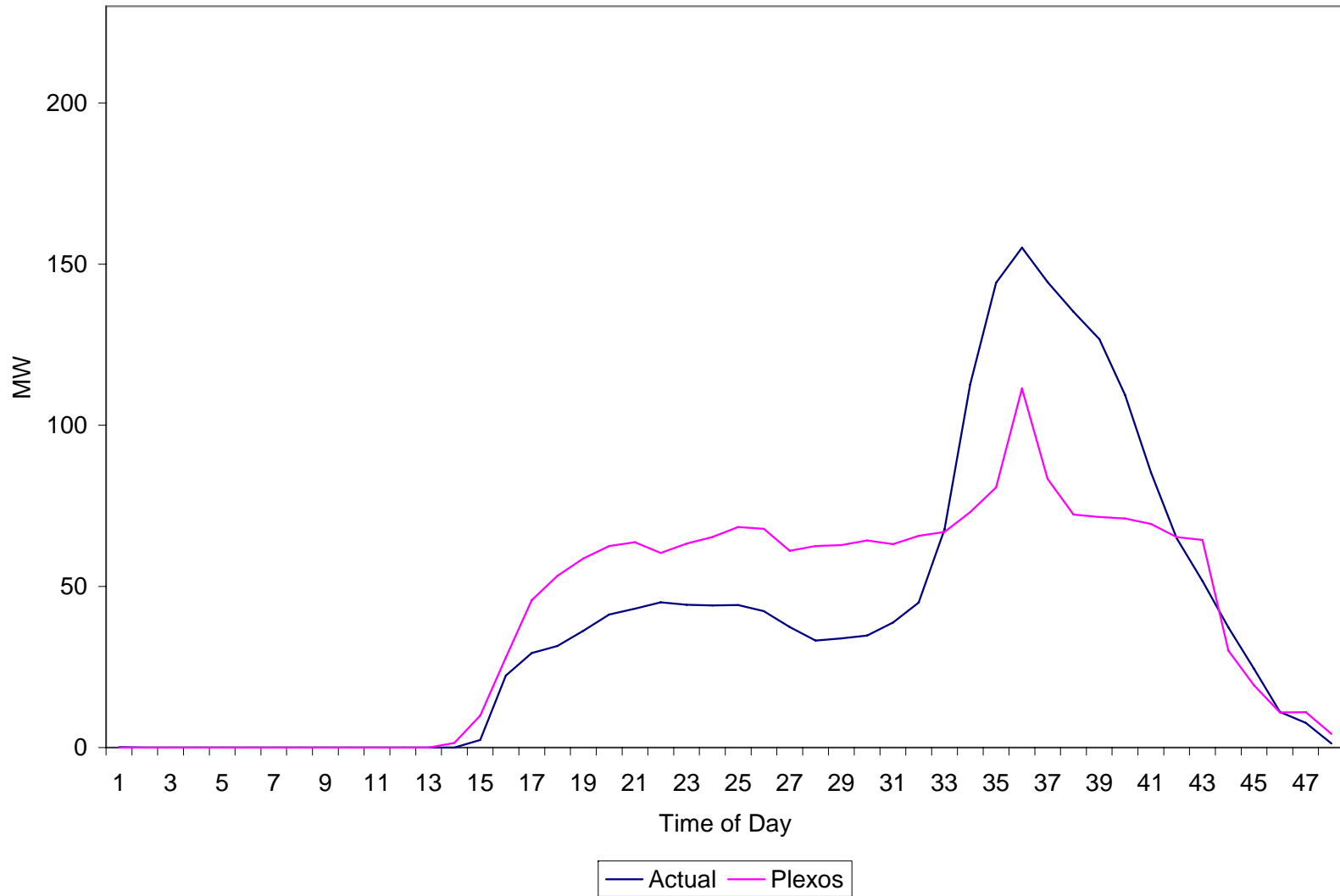## Moyle Comparison: November 2007 - February 2008
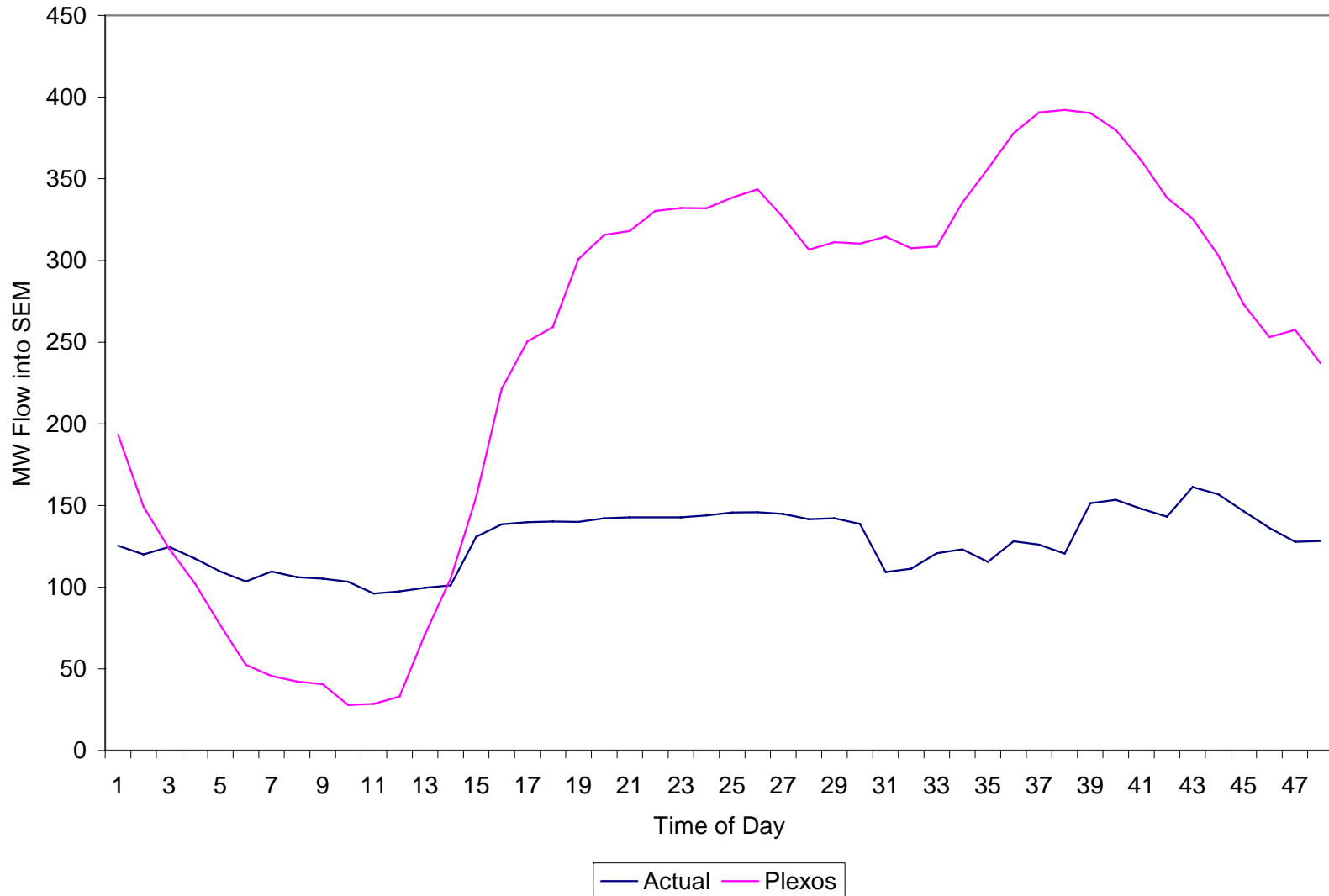
Calibration of PLEXOS

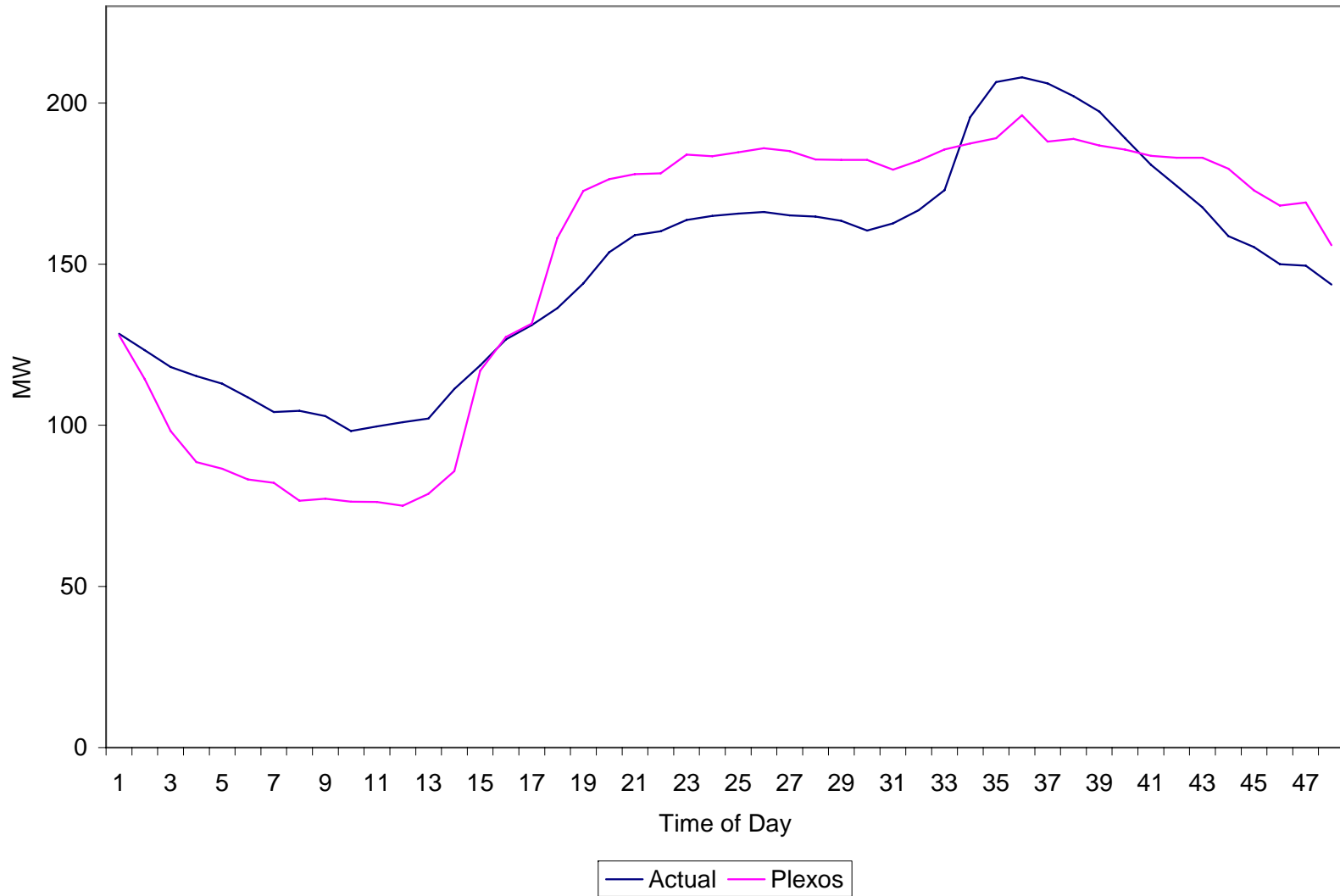## Hydro Comparison: November 2007 - February 2008

Calibration of PLEXOS
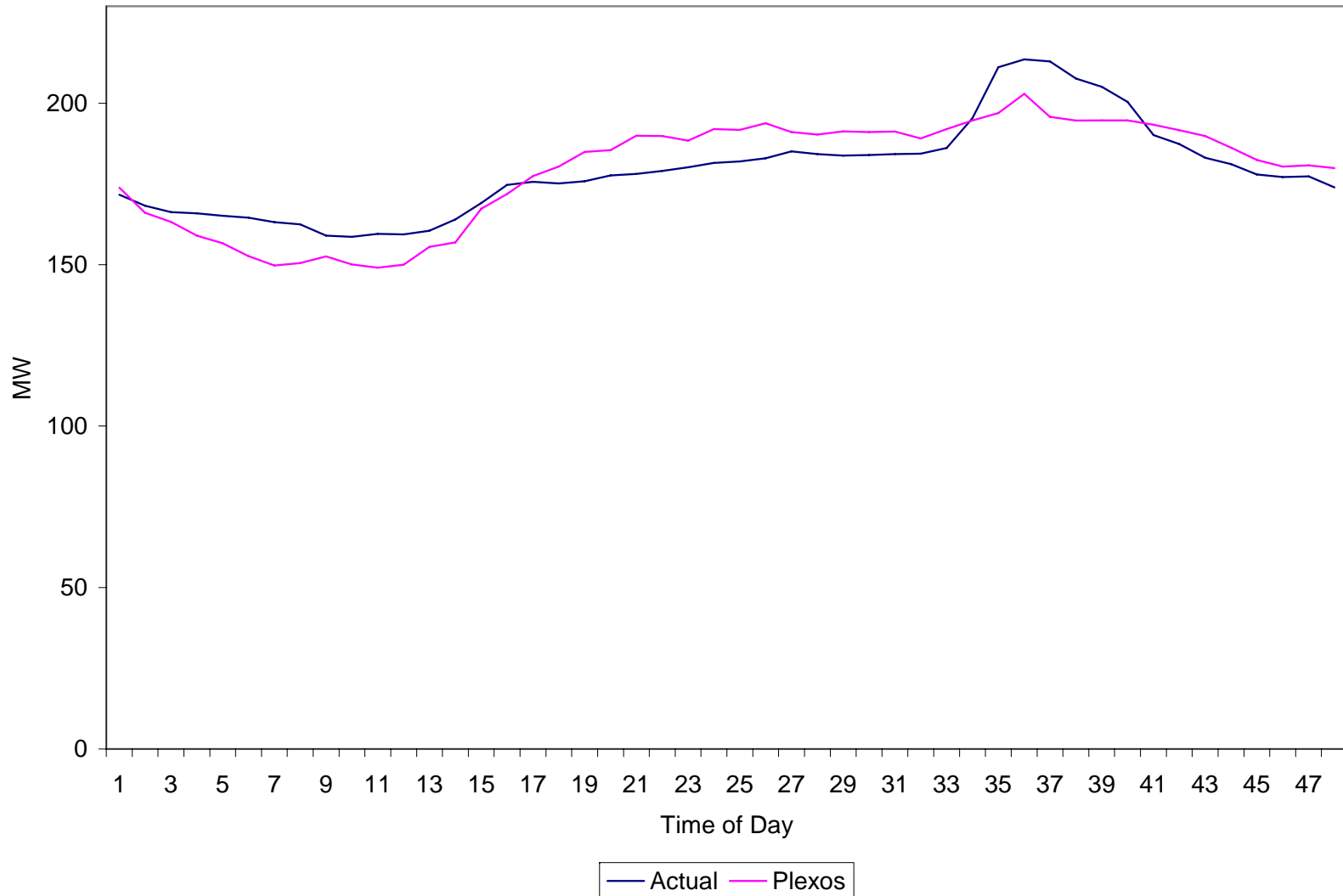
Hydro Comparison: November 2007

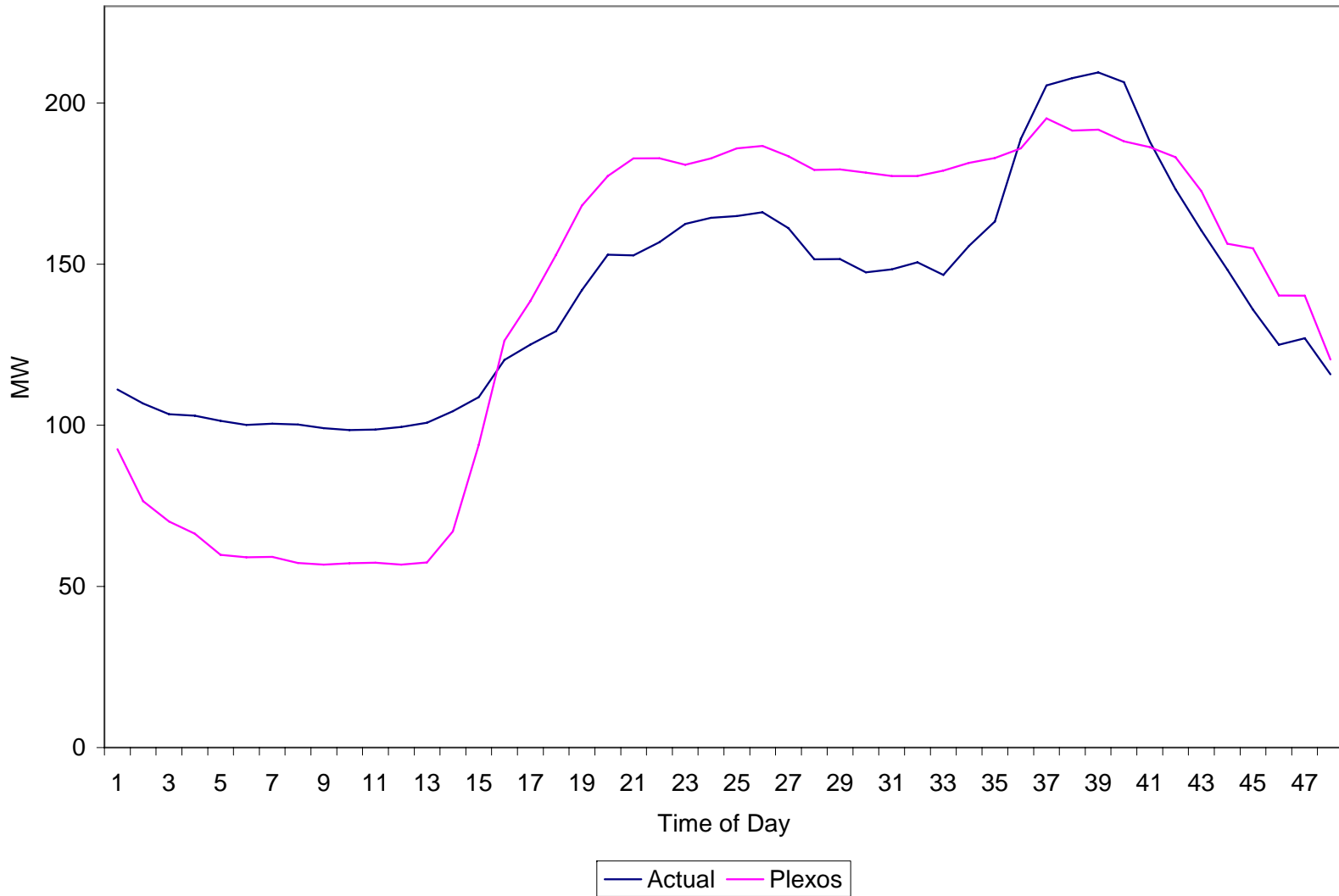## Hydro Comparison: December 2007

Calibration of PLEXOS

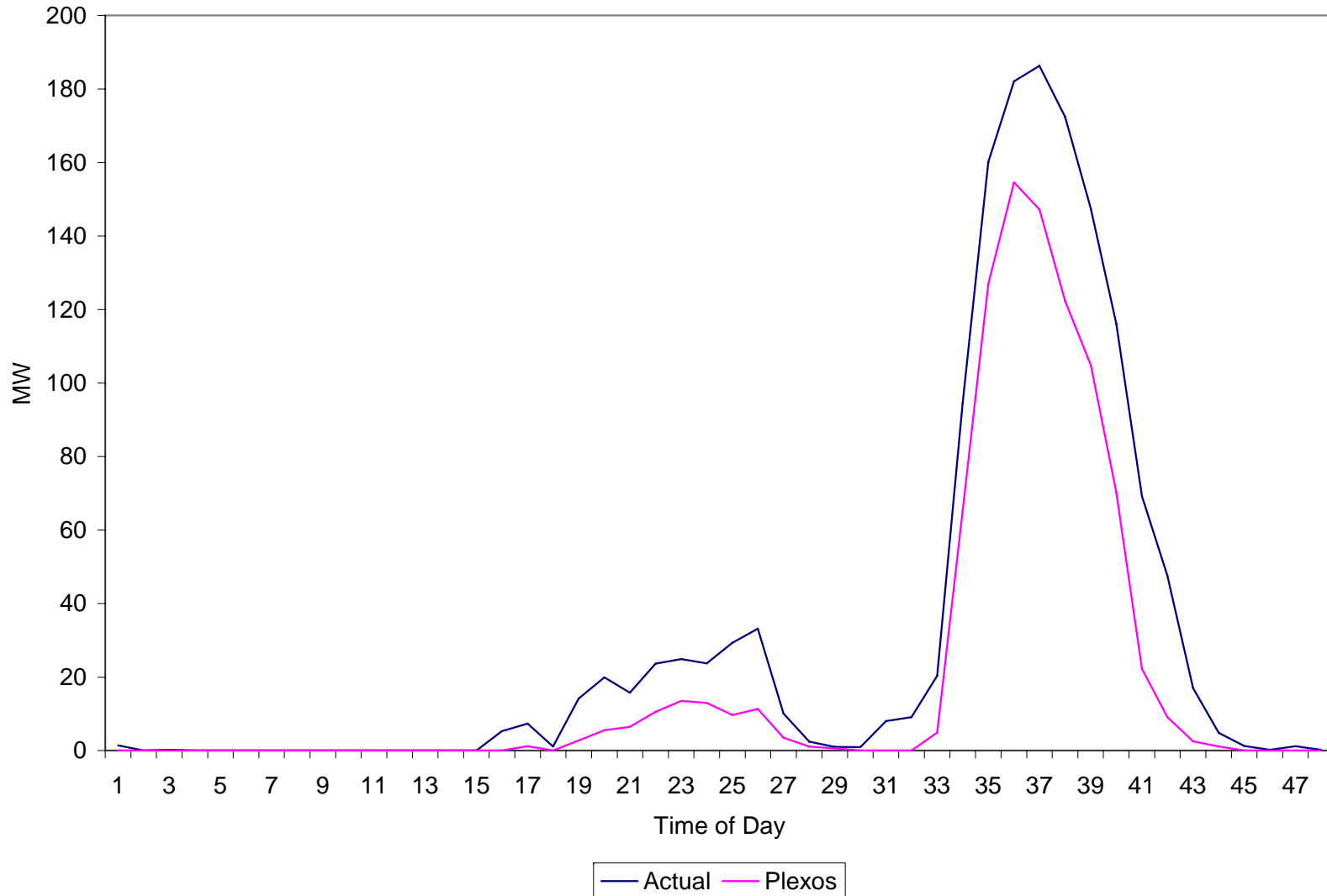## Hydro Comparison: January 2008

Calibration of PLEXOS

Hydro Comparison: February 2008

Calibration of PLEXOS

Pumped Storage Comparison: Nov 2007 - Feb 2008

Calibration of PLEXOS: MSQs

Unit	Avg MW Delta	Cap Fact Delta	Unit	Avg MW Delta	Cap Fact Delta
Moyle Net into SEM	114.7		…continued		
PBC	-62.6	-13%	TP1	-0.3	-1%
HNC	17.0	5%	ED1	0.3	0%
AD1	-15.3	-6%	AP5	-0.3	-1%
TY	-13.9	-3%	TB4	-0.3	0%
B10	-11.1	-11%	RH1	-0.2	0%
MP2	-8.6	-3%	SK3	0.2	0%
MRC	8.3	7%	DB1	-0.2	0%
CPS CCGT	-6.7	-2%	RH2	-0.1	0%
B4	-6.5	-4%	B6	-0.1	0%
K1 Coal 220	5.8	2%	SK4	0.1	0%
K2 Coal 220	5.7	2%	CGT8	0.0	0%
NW4	-5.6	-4%	KGT1	0.0	0%
MP1	-5.5	-2%	Wind	0.0	0%
B31	-4.0	-2%	AT2	0.0	0%
PB2	-3.8	-3%	BGT1	0.0	0%
B32	-3.8	-2%	BGT2	0.0	0%
PB1	-3.0	-3%	GI1	0.0	0%
B5	-2.9	-2%	GI2	0.0	0%
HN2	-1.9	0%	Hydro	0.0	0%
TB3	1.6	1%	KGT2	0.0	0%
MP3	1.4	0%	PB3	0.0	0%
AT4	-0.9	-1%	TB1	0.0	0%
AT1	-0.8	-1%	TB2	0.0	0%
LR4	-0.8	-1%			
NW5	-0.7	-1%	Pumping Load	16.4	
GI3	-0.4	0%	Pumped Storage	-11.5	-5%
WO4	-0.4	0%			
continued…			**TOTAL**	**0.0**	

Calibration of PLEXOS

Recommendations

- **Results:** PLEXOS is producing reasonable and unbiased SMP results and while shadow price/uplift mix is far off there is sufficient consistency in SMP to have confidence in the results

- **MSL Filter:** Continued use is needed

- **Warm starts**: Model only warm start costs as opposed to hot, warm and cold

- **Rounded Relaxation settings**: leave setting at 5

Development of Updated PLEXOS Database

Overview of PLEXOS Forecast Model

- Optimization based on generator costs

  - Heatrate curve, allowing for no-load and incremental heatrates

  - VOMs/MWh, as appropriate

  - Start costs based on fuel off take at start and VOMs/start

- Use same settings from backcast

  - Warm starts

  - RR at level 5.

- Moyle

  - GB Market modelled through aggregate generation units

  - PLEXOS optimization algorithms determine flows, based on prices in relative markets

Overview of PLEXOS Forecast Model

- Wind

  - Half-hourly wind profile

- Hydro

  - Monthly hydro generation limits.

  - PLEXOS optimizes hydro.

- Pumped Storage

  - PLEXOS optimizes, based on pumping efficiencies and reservoir limits.

Process for System Updates

- Contacted Market Operator to update relevant PELXOS inputs:

  A. Half-hourly demand

  B. Wind profiles and capacities

  C. Outage schedules

  D. Monthly hydro generation forecasts

  E. Retirements, new units, derates, and expansions

  F. Embedded generation profile

  G. Generator loss factors

  H. Pumped storage reservoir limits

Process for System Updates

- **Results of Market Operator Contact:**

  A. Half-hourly demand:
    - NI and ROI forecasts combined into one SEM forecast
    - Includes DSM adjustments (ROI and NI)
    - Includes demand met by embedded generation (ROI only)

  B. Wind profiles and capacities
    - Profiles for three ROI wind regions. Same profiles in KEMA's validated model from last year.
    - ROI profile A is used for NI, as was the case in last year's model.
    - Quarterly wind capacity forecasts for each ROI wind region and for NI.

Process for System Updates

- **Results of Market Operator Contact (Continued):**

  C. Outage schedules
    - Up-to-date outage schedules provided for each unit.
    - Moyle outages, both complete and partial, included.

  D. Monthly hydro generation forecasts
    - This year's model uses same monthly energy totals from last year's model – these were figures provided by MO.

  E. Retirements, new units, and unit capacity changes
    - Retirements and unit capacity changes incorporated into the model.
    - There were no new units in the forecast horizon.

Process for System Updates

- Results of Market Operator Contact (Continued):

F. Embedded generation profile

- Embedded generation profile provided for ROI.

- For NI, no profile was required. NI demand provided is exclusive of NI embedded generation.

- In last year's model, embedded gen in ROI was assumed to run at 100% capacity factor. This year, a typical profile is used instead.

- Last year, 5 MW of NI CHP embedded gen was included, which is not included this year because embedded gen is not in the NI demand forecast.

G. Generator loss factors

- Updates provided.

H. Pumped storage reservoir limits

- No change from last year's model.

Process for Gen Unit Updates

- Initial Generator Contact (8-Feb-2008)

    - Described to generators NERA's role in validation process

    - Requested any and all updates to KEMA-validated database

    - Asked for explanations of differences between:

        - New submissions and submissions to KEMA
        - New submissions and actual submissions to market

- Compared submitted data against market offers

- Compared submitted data against KEMA model

Process for Gen Unit Updates

- Had follow-up correspondence with generators where:

  – Submitted data differed materially from data offered to market or from KEMA database, and where insufficient explanation was provided

  – Submitted data were unclear or incomplete

- Conflicts between submissions to NERA and market submissions:

  – Generally resolved with agreement to use market data

  – With acceptable justification, data submitted to NERA was accepted

  – In some cases differences in data or interpretation were not resolved. In these cases market offer data were accepted.

- Sent draft final dataset to all gen companies with their units' data

  – Not an opportunity for resubmission, but for typo correction

Confidentiality

- Last year, all data except for VOM costs and outage schedules were published. KEMA database available on AIP website.

- This year, NERA asked each generator specify which data items were confidential.

  - Initially, several generators marked all of their submitted data confidential.

  - Other generators only marked their VOM data as confidential

  - Still other generators were willing to publish all data items, so long as every generator agreed to publish the same items.

- The RAs and NERA asked for clarification on confidentiality in several emails and phone calls to generators.

- The RAs intend to publish data except for VOMs and outage schedules.

Process for Fuel and Carbon Updates

- Fuel Commodity Prices

  – Quarterly forwards for LSFO, gasoil, natural gas, and coal.

  – NERA recommends using the same indexes that were used last year.

- Fuel Transport Prices

  – NERA contacted ESB PG and NIE PPB for updates to fuel transport charges to plants in ROI and NI.

  – In general recommendations of PG and PPB accepted. NERA checked reasonableness of values, comparing to KEMA's validated numbers.

  – For LSFO only, the transport charge in ROI was applied in NI.

    - NI provided transport costs based off of a *CIF* LSFO price.

    - The recommend LSFO index price is FOB.

    - The transport provided by PG for LSFO was based off of a FOB price, and this is used for LSFO transport to plants in both ROI and NI.
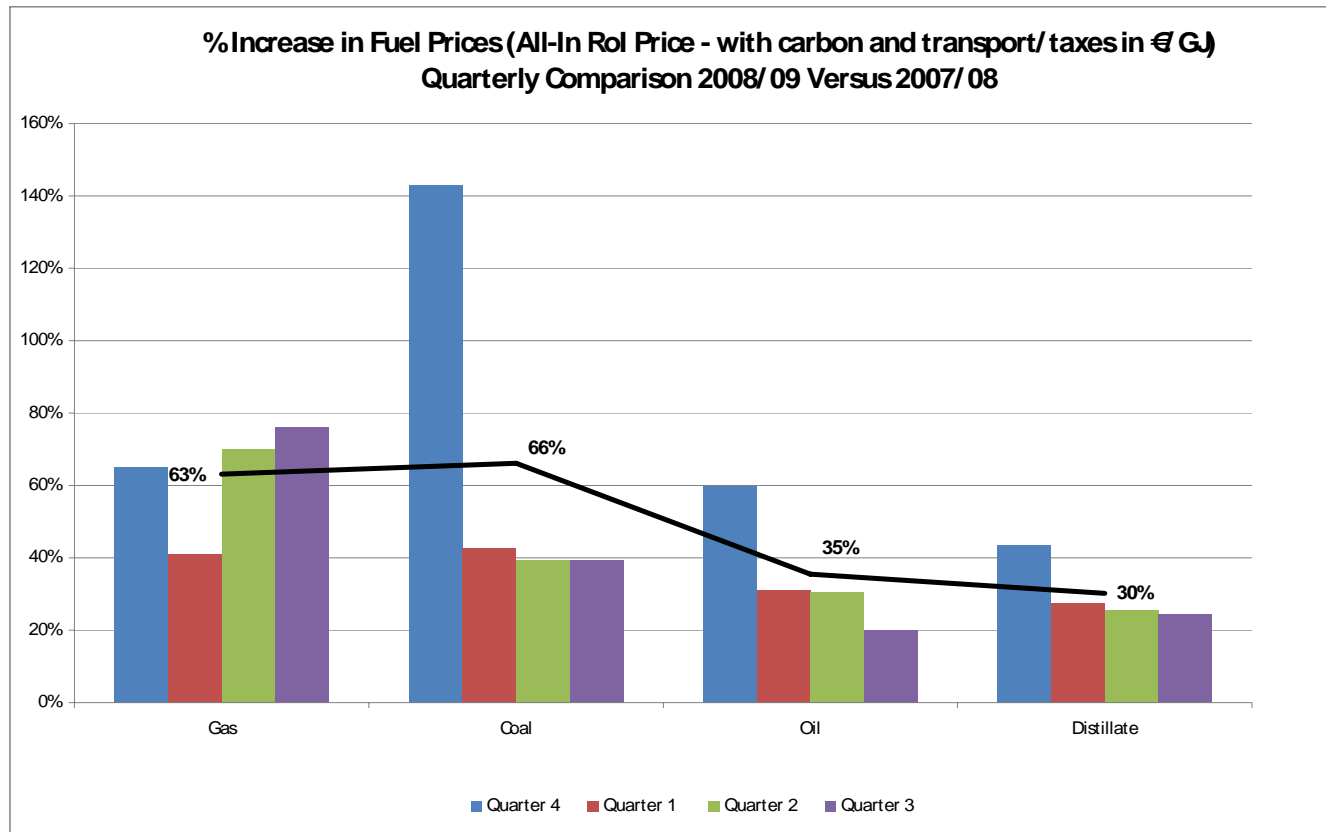
- Carbon Prices

  - The carbon price recommended is the LEBA carbon price.

  - The calculation, by fuel type, of tonne of carbon released per GJ of fuel consumed is unchanged from last year.

- The **total cost** of fuel a unit faces is the sum of the commodity price, transportation cost, and carbon price.

Major Changes

- The increase in fuel prices is the most significant input change since KEMA's validated model.

- See graph below of changes to **total** fuel costs (commodity, transport, & carbon)

% Increase in Fuel Prices (All-In RoI Price - with carbon and transport/taxes in €/GJ)
Quarterly Comparison 2008/09 Versus 2007/08

Observations for the Future

While Acceptable,
There is Room for Improvement

- Moyle model allows for Moyle to be overly responsive to SMP versus reality and direction of flow in reality is often inconsistent with relative prices indicating that there may be an unrepresented constraint

- Need for MSL filter and need to use only warm start costs shows that underlying unit commitment could be improved

- Relying on overestimate of uplift to offset underestimate of shadow price, while justified by consistency, requires leap of faith

Suggestions

- Conduct expanded calibration that examines a full year of SEM operation

- Re-evaluate MIP next year – solver improvements in the coming year may make MIP feasible

- Start calibration early in order to allow for possibility of PLEXOS enhancement