NERA
ECONOMIC CONSULTING

SunWater's Electricity Cost Model

A Report Prepared for the QCA

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Introduction

This report sets out NERA's explanation of SunWater's Electricity methodology as described in the background paper entitled "Electricity Cost Re-forecast"[1] (hereafter "background paper"). We then provide an assessment of whether the described methodology has been applied in SunWater's electricity modelling, apply the model to actual 2011 data, and suggest possible improvements for future regulatory periods.

1 SunWater, *QCA Review of Irrigation Prices, Electricity Cost Re-forecast*, (Background Paper), September 2011.

1. Overview of SunWater's Methodology

SunWater has estimated electricity costs for each of the 30 service contracts via one of two methods ('correlated' and 'uncorrelated'), with the choice of method determined by whether water use is correlated with electricity costs or not. Set out below is the selection criteria for each method as well as a description of the methods.

1.1. Selection of method

The presence of a statistical relationship between historical water use and electricity costs establishes the method to be used to forecast electricity costs. Specifically, each service contract has been classified as either "correlated" or "uncorrelated" with water use, with the method used to calculate electricity costs distinct to each group.

NERA understands that SunWater had originally used the coefficient of determination (R^2) to determine whether a linear association was likely to exist between these two variables for each service contract. However, following the study on variable costs undertaken by Indec,[2] SunWater revised its selection of correlated and uncorrelated service contracts to be in line with Indec's results, ie, those systems where electricity cost were fully variable were deemed to be 'correlated'. In its report, Indec concluded that electricity costs were fully variable for distribution service contracts and two bulk water service contracts – see Table 1.1 below.[3]

Table 1.1
Service contracts with Fully Variable Electricity Costs

Service contract
Barker Barambah Bulk
Upper Condamine Bulk
Bundaberg Distribution
Burdekin Distribution
Emerald Distribution
Eton Distribution
Lower Mary Distribution
Mareeba Distribution
St George Distribution
Theodore Distribution

Source: Indec Report, pages 53,55 and 56.

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2 See Indec, Qualitative Framework and Assessment of Fixed and Variable Cost Drivers, October 2011 (hereafter "Indec Report").

3 Indec Report, pages 53,55 and 56.

Section 1.2 below describes the different methods that apply to service contracts where electricity costs have a linear relationship (ie, were correlated) with water usage and those systems that do not (ie, are uncorrelated).

1.2. Description of SunWater's methodology

After classifying whether a service contract has electricity costs that are correlated or not with water usage, the relevant method is applied. Each of these methods is described below.

1.2.1. Correlated electricity costs

As stated above, ten of SunWater's 30 service contracts have been determined to have electricity costs that are correlated with water usage, with these service contracts comprising of all eight distribution systems, and the Barker Barambah and Upper Condamine bulk water service contracts. To calculate electricity costs for these service contracts, SunWater has:

1. where applicable, removed any non-variable electricity costs and water usage from the total electricity costs and water usage respectively;
2. undertaken linear regression on the total variable electricity and total variable water usage (excluding distribution losses) to estimate a $/ML estimate of electricity costs in 2011;
3. created a price path of the $/ML electricity cost up until 2017, based on the estimated 2011 $/ML cost; and
4. multiplied the price for each year (as calculated in step 3) by forecast water usage to obtain the total forecast electricity costs (if fixed costs were removed as in step 1, these are added back in in order to calculate the total forecast electricity costs).

Details of each of the above steps are described below.

1.2.1.1. Remove non-variable costs and water usage

For three of the correlated service contracts – namely Barker Barambah Bulk, Upper Condamine Bulk and Bundaberg Distribution – the electricity costs contained a fixed component. Therefore it is first necessary to remove this fixed component from the total electricity costs (and corresponding volume from total water usage) in order to estimate a variable $/ML cost. It is appropriate for SunWater to remove these fixed cost values from the total values. This is because the remaining electricity costs and water usage then reflect the total variable electricity costs and water usage, and these are the values needed for the regression analysis (explained in section 1.2.1.2 below).

After removing this fixed component, a total variable electricity cost is calculated by the method described in sections 1.2.1.2-1.2.1.4 below (ie, in the same manner as those systems that do not contain a fixed component). The total electricity cost is the sum of the total variable cost and the fixed component – ie, the fixed cost that was removed from the electricity costs is then added back to the total variable cost to obtain the total electricity cost.

Table 1.2 below sets out the fixed electricity component for the each of the three service contracts.

Table 1.2
Fixed Electricity Component

Service contract	Fixed Electricity Cost ($2011)
Barker Barambah Bulk	$3,000
Upper Condamine Bulk	$5,020
Bundaberg Distribution	$97,495

Source: SunWater

1.2.1.2. Estimate variable 2011 electricity costs

To calculate the variable $/ML electricity costs for 2011, SunWater has performed simple linear regression analysis over the period 2007 to 2011 to estimate a line of best fit – ie, it has calculated the best estimate of a linear relationship between total variable electricity costs and total variable water usage using data from the past five years. For each correlated service contract, a simple linear relationship can be estimated by the following equation:

$$y = \beta x + \alpha$$

Where:

- y refers to the total variable electricity costs for the service contract (denominated in $2011 and rebased to the 2011 Benchmark Retail Cost Index (BRCI));[4]
- x refers to the total variable water usage for the service contract excluding distribution losses (denominated in ML);
- β is the slope of the line – here this amounts to be the variable unit cost of electricity, ie, the cost of electricity per ML;
- α is the y-intercept of the line – here this translates into the fixed cost of electricity, ie, when water usage (x) equals zero, this is the amount of the electricity costs still payable.

The values of total variable electricity costs (y) and total variable water usage (x) for each correlated service contract are set out in the table below.

[4] By adjusting the electricity costs to 2011 real dollars and indexing for the annual BRCI increases, the regression analysis is able to better capture the relationship between electricity costs and water usage. Indeed, these adjustments enable for a set of electricity prices that are less affected by time and so a relationship between electricity costs and water usage is estimated on a more comparable set of electricity prices.

See section 1.2.2 below for a description of how this indexation was performed.

Table 1.3
Data Used in Regression Model

Service Contract	Variable*	2007	2008	2009	2010	2011
Barker Barambah Bulk	Electricity costs (y)	10	8	16	5	7
	Water usage (x)	63	100	1,336	473	768
Upper Condamine Bulk	Electricity costs (y)	4	117	49	52	36
	Water usage (x)	0	16,761	8,853	9,922	7,401
Bundaberg Distribution	Electricity costs (y)	2,599	1,499	1,329	2,348	761
	Water usage (x)	74,380	47,718	51,582	79,499	25,845
Burdekin Distribution	Electricity costs (y)	3,574	3,054	2,975	3,464	1,827
	Water usage (x)	261,630	209,976	183,290	238,267	64,399
Emerald Distribution	Electricity costs (y)	222	108	78	51	32
	Water usage (x)	52,605	42,290	57,037	87,028	38,691
Eton Distribution	Electricity costs (y)	235	208	148	282	41
	Water usage (x)	18,457	15,642	10,835	21,527	1,644
Lower Mary Distribution	Electricity costs (y)	246	114	27	168	39
	Water usage (x)	8,335	2,092	3,227	5,521	687
Mareeba Distribution	Electricity costs (y)	297	279	253	375	258
	Water usage (x)	6,029	5,684	5,301	7,493	4,577
St George Distribution	Electricity costs (y)	31	44	39	48	31
	Water usage (x)	26,093	48,295	42,939	50,242	55,602
Theodore Distribution	Electricity costs (y)	116	92	134	119	24
	Water usage (x)	11,383	8,648	10,074	11,242	1,226

Source: SunWater data.

Notes: As per the descriptions of x and y above, electricity costs are denominated in $2011 and rebased to the 2011 Benchmark Retail Cost Index (BRCI) and water usage is denominated in ML.*

The above linear equation can also be estimated by forcing the intercept to be zero (known as a no-intercept model), which results in a line that passes through the origin. SunWater has undertaken such an approach, resulting in a linear equation that estimates electricity costs based solely on variable costs – ie, $/ML variable costs are equal to β. That is, the regression analysis estimates the price per mega litre in real 2011 dollar terms, with this being equal to β.

Note that this approach is consistent with Indec's findings that electricity costs are to be fully variable for distribution service contracts and the two bulk water service contracts.[5] Further,

[5] Indec Report, pages 53,55 and 56.

this equation implies that if no water is used in a service contract, the electricity costs would also be zero – NERA understands from SunWater that, in practice, if water usage was zero for these correlated service contracts, electricity costs would be close to zero.

Further, as stated in section 1.2.1.1 above, if SunWater is to calculate the electricity costs that do not include a fixed component as fully variable costs, then it is necessary to remove these fixed components from the total electricity costs and water usage. This enables SunWater to undertake the same regression analysis (as described above) for all correlated service contracts. An alternative approach is discussed in section 4.2.

1.2.1.3. Electricity price path

To create a price path of $/ML unit electricity costs for the upcoming period, SunWater has taken the 2011 $/ML price and escalated this for each upcoming year. This escalation is based on the average BRCI from 2008 to 2012 and the expected carbon price impact[6], deflated by the target Consumer Pricing Index (CPI). In numeric terms, this results in an index value equal to:

- 100 per cent in 2011; and
- the previous year's index inflated by (1+BRCI)(1+"carbon price impact")/(1+CPI), for 2012 onwards.

Table 1.4 below sets out the index used by SunWater to inflate the 2011 estimate of unit electricity costs in $/ML over the upcoming period. Note that this index is also used to inflate the 2011 real fixed cost component for the three service contracts that have both fixed and variable electricity costs (ie, those systems set out above in Table 1.2).

Table 1.4
Index Used to Escalate $/ML Electricity Costs

	2011	2012	2013	2014	2015	2016	2017
BRCI		6.60%*	10.47%	10.47%	10.47%	10.47%	10.47%
CPI		2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
Carbon Price Impact		0.0%	10.0%	0.0%	0.0%	1.0%	0.0%
Index	100.0%	104.0%	123.3%	132.9%	143.2%	155.9%	168.0%

Source: SunWater, Background Paper, page 9.

*Notes: * The actual BTCI is available for 2012, and this figure is used instead of the average.*

6 The expected carbon pricing impact has been sourced from the Federal Treasury Paper entitled "Strong Growth, Low Pollution: Modelling a Carbon Price". This report presents the results of Treasury's modelling, including estimates for the increases in household energy prices due to carbon pricing of 10 per cent in 2012/13 and a total increase of 11 per cent by 2015/16. These percentages have been used by SunWater to approximate the change in SunWater's electricity costs due to carbon pricing.

See The Treasury, *Strong Growth, Low Pollution: Modelling a Carbon Price*, September 2011, pages 135-137.

1.2.1.4. Annual total forecast electricity costs

To calculate the annual total forecast electricity costs, SunWater has taken the escalated $/ML unit price for each year and multiplied this by the forecasted total variable water usage excluding distribution losses (denominated in ML). This results in a forecast total variable electricity cost for each year.

1.2.2. Electricity costs deemed 'uncorrelated'

Twenty of SunWater's bulk water service contracts have been considered to have electricity costs that have no linear relationship with water usage, ie, are uncorrelated. To calculate the annual forecast electricity costs for these service contracts, SunWater has used a simple arithmetic average of the actual electricity costs from the past five years – ie 2007 to 2011 – normalised to 2011 BRCI. That is, SunWater takes the total electricity costs from the past five years (in $2011), normalises these to 2011 BRCI, and then takes a simple arithmetic average of these values.

The SunWater model used to estimate the electricity costs in the background paper contained a slight error in the estimation of the index used to normalise the historic electricity prices. However, this error has now been corrected and Table 1.5 below sets out the effective indexation used to normalise the historic electricity cost figures to 2011 BRCI – note that this is also the index used to rebase the variable cost figures used in the regression analysis (see section 1.2.1.2)

Table 1.5
Index Used to Normalise Historic Electricity Costs

	2007	2008	2009	2010	2011
BRCI		11.37%	5.38%	15.73%	13.29%
CPI		4.81%	3.14%	3.04%	3.58%
Index*	75.0%	79.7%	81.4%	91.4%	100.0%

Source: SunWater.

*Notes: * The Index is calculated as:*

- *100 per cent in 2011; and*
- *the next year's index multiplied by (1+CPI)/(1+BRCI), for all years prior to 2011.*

2. Results of Review

NERA can confirm that SunWater has calculated its electricity costs in line with the methodology described in the background paper. Further, the SunWater model contained only one minor error (see section 1.2.2 above), and this has now been corrected. After this correction the electricity costs have been recalculated and are set out in Table 2.1and Table 2.2 below.

Table 2.1
Final Electricity Costs for SunWater's Correlated Service Contracts

Service Contract	Background Paper $/ML rate for 2011	New $/ML rate for 2011	Fixed Electricity Cost* ($2011)
Barker Barambah Bulk	$11.46	$11.55	$3,000
Upper Condamine Bulk	$6.15	$6.19	$5,020
Bundaberg Distribution	$30.99	$30.92	$97,495
Burdekin Distribution	$14.80	$14.80	n/a
Emerald Distribution	$1.57	$1.56	n/a
Eton Distribution	$13.13	$13.11	n/a
Lower Mary Distribution	$29.11	$28.94	n/a
Mareeba Distribution	$50.10	$50.11	n/a
St George Distribution	$0.83	$0.83	n/a
Theodore Distribution	$11.13	$11.14	n/a

*Notes: * The fixed electricity costs remain unchanged from the figures previously provided to the QCA.*

Table 2.2
Final Electricity Costs for SunWater's Uncorrelated Service Contracts

Service Contract	Background Paper forecast for 2011 ($2011)	New forecast for 2011 ($2011)
Bowen Broken Bulk Supply	$96,728	$97,103
Dawson Bulk Supply	$27,996	$28,113
Eton Bulk Supply	$192,048	$192,403
Burdekin Bulk Supply	$79,608	$79,734
Proserpine Bulk Supply	$4,224	$4,229
Mareeba Bulk Supply	$4,812	$4,822
Bundaberg Bulk Supply	$7,715	$7,726
Lower Mary Bulk Supply	$-	$-
Upper Burnett Bulk Supply	$6,120	$6,134
Boyne Bulk Supply	$-	$-
Callide Bulk Supply	$5,542	$5,541
Lower Fitzroy Bulk Supply	$1,135	$1,136
Three Moon Bulk Supply	$7,611	$7,623
Chinchilla Weir Bulk	$-	$-
Maranoa Bulk Supply	$-	$-
Cunnamulla Weir Bulk	$-	$-
St George Bulk Supply	$6,979	$6,986
Macintyre Brook Bulk	$1,293	$1,296
Pioneer Bulk Supply	$3,292	$3,297
Nogoa Bulk Supply	$11,025	$11,046

3. Application of Model to 2011 Data

NERA has undertaken an assessment of the SunWater regression model to determine the total predicted electricity costs when the model is applied to the actual water usage figures in 2011.[7] That is, the estimate of the $/ML electricity rate for 2011 (as calculated by the regression analysis – see Table 2.1) is multiplied by the actual total variable water usage in 2011. This calculation results in predicted total variable electricity costs for 2011.

The predicted total variable costs for 2011 are then compared to the actual total variable costs for 2011,[8] with each of these values set out in Table 3.1 below.

Table 3.1
Predicted and Actual Total Variable Electricity Costs

Service Contract	Actual Electricity Cost ($'000 2011)	Predicted Electricity Cost ($'000 2011)	Difference ($'000 2011)	Difference (%)
Barker Barambah Bulk	7.0	8.9	1.8	26%
Upper Condamine Bulk	35.6	45.8	10.2	29%
Bundaberg Distribution	761.0	799.0	38.0	5%
Burdekin Distribution	1,827.4	953.1	-874.2	-48%
Emerald Distribution	31.5	60.5	29.0	92%
Eton Distribution	40.5	21.5	-19.0	-47%
Lower Mary Distribution	39.0	19.9	-19.1	-49%
Mareeba Distribution	258.5	229.3	-29.1	-11%
St George Distribution	30.6	46.3	15.7	51%
Theodore Distribution	23.5	13.7	-9.9	-42%
TOTAL	3,054.6	2,198.0	-856.6	-28%

Source: SunWater data and NERA analysis

When comparing the predicted total variable costs to the actual total variable costs, it can been seen that for half of the service contracts the model over-estimates the total variable electricity costs and the remaining half have electricity costs that are under-estimated by the model. Note that it is highly unlikely for a model to exhibit predicted costs equal to actual costs, and given that the model has an even split between over-estimated and under-estimated costs for 2011, it appears reasonable.

7 In practice, it would not have been possible for SunWater to estimate its electricity prices based on the estimated $/ML electricity rate, given that actual 2011 electricity values were used in the regression analysis that derived the $/ML rate.

8 Note that the below analysis does not draw any statistical conclusions about the appropriateness of the fit of the model to 2011 values when compared to other years. Indeed, the magnitude of the residuals (ie, the difference between the predicted and actual values) depends on the scale of the data.

In terms of the dollar value differences between the predicted and actual electricity costs, on average, if SunWater were to have used these predicted values in 2011, it would have under-recovered by approximately $857,000.[9] Further, for the schemes for which the model would have over-estimated the total variable electricity in 2011, the difference between the predicted and actual values amount to a negligible proportion of total revenue – no greater than 2 per cent.

Additionally, the direction of the difference between the predicted and actual electricity costs that is seen in 2011 may not been the same in future years – eg, if the model under-estimated the electricity costs for a service contract in 2011, then it does not imply that the model will also under-estimate the electricity costs in 2012.

4. Possible Future Improvements

NERA has been asked to provide commentary on SunWater's electricity costs methodology. This section sets out NERA's comments in relation to the selection of correlated service contracts, the form of the linear regression model and the model inputs.

4.1. Selection of correlated service contracts

As stated above, SunWater classified service contracts as correlated or uncorrelated based on the Indec Report classification of whether electricity costs were fixed or variable. NERA notes that Indec undertook a detailed assessment in order to classify electricity costs as variable or fixed for each service contract. However, if such an assessment were *not* to be undertaken again, NERA would advise SunWater to classify its electricity costs based on the following:

- the significance of β; and
- the coefficient of determination (R^2) from the simple liner model (with an intercept).

The remainder of this section discusses each of the above methods.

4.1.1. Significance of β

In order to determine the significance of beta (ie, whether water usage is likely to have a linear relationship with electricity costs) the following method can be employed:

1. perform a simple linear regression of the form $y=\beta x+\alpha$, where the variables and coefficients are as described in section 1.2.1.2 above. That is, undertake regression analysis in the same manner as what has currently been done by SunWater, but including the intercept;
2. calculate the t-statistic of β – calculate the t-statistic of β by dividing the value of β by the standard error of β; and
3. compare the t-statistic to the critical value – the critical value is obtained from the t-distribution with n-2 degrees of freedom:

[9] See footnote 7.

  - If the test statistic is greater than the critical value, the null hypothesis of β=0 can be rejected and so it can be concluded that a linear relationship is likely to exist between electricity costs and water usage.
  - However, if the test statistic is less than the critical value, the null hypothesis of β=0 can not be rejected and so it can not be concluded that a linear relationship is likely to exist between electricity costs and water usage.

While it is possible for this regression analysis to be performed on quarterly data, NERA has been advised by SunWater that annual data is a more appropriate basis than quarterly data. We agree with this conclusion because quarterly data may not accurately reflect costs due to accounting methods. For example, some service contracts contain negative electricity costs in a number of financial quarters.

The analysis of electricity data for the current regulatory period has been based on five years worth of annual data, and as such, the data set is relatively small. However, for the next regulatory period, the dataset will be larger and may therefore be able to be used to undertake the above analysis, ie, will include values from 2007 until 2016.

4.1.2. The coefficient of determination

The coefficient of determination (R^2) could also be used alongside the beta coefficient to determine whether a linear association was likely to exist between these two variables for each service contract.

For a simple linear model – ie, of the form y=βx+α (see section 1.2.1.2) – R^2 measures the proportion of variability in electricity costs that is explained by the linear model via water usage. Indeed, for models of this form, R^2 provides the proportion of variability in electricity costs explained by the linear model above what is explained by using the average to estimate electricity costs. To calculate R^2 for a simple linear model, the following formula is employed: [10]

$$R^2 = \frac{\sum_{i=1}^{n} (\hat{Y}_i - \overline{Y})^2}{\sum_{i=1}^{n} (Y_i - \overline{Y})^2}$$

Where:

- R^2 refers to the coefficient of determination;
- n is the size of the sample – SunWater states that its electricity cost analysis is based on five years worth of annual data from 2007 to 2011, which would amount to a sample size of five;
- Y_i refers to actual electricity costs (denominated in $2011);

[10] Note that for a simple linear regression, R^2 is equivalent to raising Pearson's correlation coefficient (r) to the power of two, where r is as described in NERA's memo entitled SunWater's Electricity Cost Methodology. See NERA, SunWater's Electricity Cost Methodology, 5 March 2012.

- $\hat{Y}_i$ refers to the values of electricity costs predicted by the regression model; and
- $\overline{Y}$ refers to the mean[11] of the actual electricity costs.

For a simple linear no-intercept model (ie, of the form y=βx) R^2 has a different interpretation to that given above. For models of this form, the regression line does not pass through the means of the variables (electricity costs and water usage). Therefore, R^2 measures the proportion of variability as explained by the model compared to that from estimating electricity costs as zero. For the simple linear no-intercept model, R^2 is calculated as follows:

$$R^2 = \frac{\sum_{i=1}^{n}(\hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i)^2}$$

Where all variables are defined as above.

Therefore, the R^2 that should be calculated to determine the fit of the model is that associated with the simple linear model (with an intercept).

4.2. Form of linear regression model

SunWater estimated a simple linear no-intercept model (ie, of the form y=βx). Such a model is generally appropriate if:

- theoretically when water usage is zero, electricity costs should be zero; and
- the intercept term (α) is not statistically different from zero – this can be tested in the same manner as described in relation to β above (see section 4.1.1).

Given the findings of Indec and the relatively small size of the dataset, it seems reasonable that SunWater have assumed a no-intercept model for this regulatory period. However, for the next regulatory period NERA suggests that appropriateness of the no-intercept model should be evaluated by testing the significance of the α for each correlated service contract.

Note that if SunWater were to undertake the regression analysis (described in section 1.2.1) by not forcing the intercept to be zero, then the annual forecast electricity costs would be calculated as follows:

1. undertake linear regression to estimate a linear relationship between total water usage and total electricity costs – of the form y=βx+α. Note that *total* water usage and *total* electricity costs imply that for the three service contracts with a fixed component, fixed costs would not be removed from the totals for the regression analysis.
2. create a price path of both β and α up until 2017 using the same index to escalate these values as set out in Table 1.4 above; and

[11] Arithmetic average.

3. for each year, multiply the escalated β (as calculated in step 2) by forecast water usage and then add the escalated α to obtain the total forecast electricity costs.

4.3. Linear regression inputs

The simple linear regression model calculated by SunWater regresses total variable electricity costs on total variable water usage. This requires historic electricity costs to be denominated in $2011 and rebased to the 2011 Benchmark Retail Cost Index (BRCI) prior to undertaking the regression analysis.

An alternative method is to regress the total electricity usage on total water usage, to obtain the electricity usage per ML. This value could then be multiplied by the forecast water usage to estimate the total variable electricity usage for each year, which would then need to be multiplied by an estimated electricity price in order to obtain the total electricity cost.

The advantage of this method is that it does not require the historic variables used in the regression analysis to be rebased. However, it does require the variable electricity usage figures to be known and a price per electricity use would need to be estimated.

One possible regression model based on electricity usage and water usage is as follows:

$$y = \beta x + \alpha$$

Where:

- y refers to the total electricity usage for the service contract (denominated in kWh);
- x refers to the total water usage for the service contract excluding distribution losses (denominated in ML);
- β is the slope of the line – this describes the relationship between unit water usage and electricity usage, ie, the amount of electricity used per ML;
- α is the y-intercept of the line – here this translates into a fixed electricity usage component, ie, when water usage (x) equals zero, this is the amount of the electricity used.

After estimating the above linear equation, the total forecast water usage (excluding distribution losses and denominated in ML) would be substituted in to obtain the total electricity used (in kWh). If SunWater faces electricity prices based on both off-peak and peak tariffs, then the total electricity usage could be split into off-peak and peak usage using historical estimates of the apportionment values. These off-peak and peak electricity usages would then be multiplied by the off-peak and peak unit electricity prices respectively, where these prices have been indexed for the relative period (in a manner similar to the indexation used by SunWater – see section 1.2.1.3).

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