2008 Long Term Acquisition Plan

BC hydro

APPENDIX F12

Effective Load Carrying Capability/Firm Energy Load Carrying Capability of Intermittent Resources

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1.1 Introduction

Intermittent resources have, by nature, varying output resulting in varying levels of energy and capacity contribution to system firm energy and dependable capacity requirements. BC Hydro has adopted the Firm Energy Load Carrying Capability (FELCC) and Effective Load Carrying Capability (ELCC) to estimate intermittent resource contribution to firm energy and dependable capacity respectively. This appendix updates the approaches used to determine FELCC and ELCC for small hydro and wind resources.

1.2 FELCC

The FELCC methodology follows the approach utilized in the 2007 SOP and extends the analysis to be consistent with both existing and potential new resources.

1.2.1 FELCC analysis conducted in the SOP

The methodology used in calculating the FELCC contribution of the small hydro energy to be acquired through BC Hydro's 2007 Standing Offer Program (SOP) was described in sections 3.3 and 3.4 the SOP application. For clarity, the relevant sections of the 2007 SOP application are provided at the end of this Appendix. BC Hydro's approach in the SOP was to evaluate historical streamflow data from seven small hydro projects that were awarded EPAs in the Small Project stream portion of the F2006 CFT. The monthly energy profile of these projects was tested against BC Hydro's critical period to determine the contribution to FELCC. The results of the SOP analysis indicated that 85 per cent of the small hydro average annual energy contributed to BC Hydro's firm energy supply. However, the analysis demonstrated that future resources contributing heavily in the freshet period may not contribute the same degree to system FELCC.

1.2.2 Small Hydro FELCC – Existing and Committed Resources[2]

For hydro projects within the F2006 CFT Large Project stream, the 2008 LTAP analysis assumed the incremental FELCC contribution is equal the contractual amount of firm energy associated with each EPA.

For existing pre-F2006 CFT small hydro resources and F2006 CFT Small Project stream projects, BC Hydro applied a factor of 85 per cent of average annual energy to estimate incremental FELCC contributions. The FELCC analysis from the SOP led to the conclusion that the SOP energy could be considered 85 per cent firm. Given that the energy from existing small hydro EPAs was pre-existent to the SOP and that the general locations of the existing projects and energy production (primarily in the Lower Mainland region) were considered to be reasonably reflected in the SOP analysis, the FELCC of the pre-existing small hydro was also set at 85 per cent.

1.2.2.1 Small Hydro FELCC – Future New Resources

KWL completed an analysis of the small hydro resource potential in B.C. This report documenting this analysis is contained in Appendix F-5. KWL identified resources on river basins where there was at least 10 years of data and provided BC Hydro an estimate of the average and firm annual energy of bundles of resources by cost and region. The firm energy listed in their report is based upon data from the calendar year with the lowest annual energy production.[3] A summary of the bundles is provided in Table 1-6.

To determine the FELCC contribution of these small hydro resources, a methodology was developed that made adjustments to the KWL firm and average energy numbers based upon the amount of energy provided in the freshet period. Table 1-1 shows 4 bundles of resources that were developed based upon the resources identified in the KWL report and presented in Table 1-6. FELCC studies were completed on these four bundles with results as follows:

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[2] BC Hydro is forecasting deliveries of about 2,100 GWh of energy contracted with Pre-F2006 small hydro IPPs (not including Arrow Lakes Hydro) and a further 500 GWh of energy from F2006 CFT Small Project Stream small hydro sites.

Table 1-1

Annual Energy_Profile	FELCC	FELCC % of Annual Energy
2,000 GWh/year on Vancouver Island	2,100	105%
2,000 GWh/year Lower Mainland (**LM**)	1,822	91%
4,000 GWh/year Lower Mainland[4]	3,590	90%
2,000 GWh/year East Kootenay	1,470	74%

The East Kootenay (**EK**) bundle was created to be reflective of interior small hydro projects.

For the above studies, a "freshet factor" was calculated which is the per cent of the average MW (**MWa**) produced in the freshet period as compared to the annual MWa. The freshet factor is shown in Table 1-2:

Table 1-2

Annual Energy Profile	Annual Energy	May-July Energy	Freshet Factor
	MWa	MWa	%
2,000 GWh/year on VI	228.3	146.8	64%
2,000 GWh/year Lower Mainland	228.3	359.5	157%
4,000 GWh/year Lower Mainland	456.6	719.0	157%
2,000 GWh/year East Kootenay	228.3	506.8	222%

The above FELCC studies were then used to create a formula-based factor to estimate (calibrate) the FELCC for each of the resource bundles in the KWL study. This created a method of treating the diverse group of resource bundles consistently, without having to do full FELCC studies for each one. The calibration was made based on the following two relationships:

[3] This definition of firm is not the same as BC Hydro's Firm Energy definition or FELCC.

[4] Two separate Lower mainland cases were run to test the sensitivity of the FELCC contribution to increases in volume.

- Five per cent is added to the firm annual energy percentage for all bundles to reflect a diversity (synergy) credit. This reflects an incremental value of the diversity that exists between hydro projects; and

- Two per cent is subtracted from the firm percentage for every 10 per cent the MWa of freshet energy is above the annual MWa . This was determined by weighting the freshet factor to achieve the FELCC contributions as shown in tables 1-1 and 1-2. For example, in the case of the 2,000 GWh/year LM bundle, the freshet factor is 157 per cent, or 57 per cent more MWa in the freshet than the annual MWa. This equates to:

  11% = 57% * 2 % / 10 %

Based on the above methodology, the estimated FELCC contribution by formula compares to the FELCC analysis of the four bundles as follows:

Table 1-3

Energy Bundle	Annual Firm Energy	Synergy Credit	Freshet Energy Reduction	Net Adjustment		FELCC Study Results	Difference (Net Adjustment minus FELCC study)	
	GWh	%	%	%	GWh	GWh	GWh	%
2,000 GWh/year on VI	2,000	5%	0%	+5%	2,100	2,100	0	0%
2,000 GWh/year LM	2,000	5%	-11%	-7%	1,861	1,822	39	2%
4,000 GWh/year LM	4,000	5%	-11%	-7%	3,721	3,590	131	4%
2,000 GWh/year EK	2,000	5%	-24%	-21%	1,598	1,470	118	8%

This methodology is applied to the resource bundles identified in Table 1-6. The net average firm energy (which reflects the FELCC contribution to the system) as a percentage of the average annual energy was 71 per cent.

1.2.2.2 Wind FELCC – Existing and New Resources

No additional FELCC analysis was undertaken in the 2008 LTAP for 2006 CFT wind projects or any new wind projects identified in the 2008 Resource Options Update. The FELCC contribution of the three wind projects awarded contracts in the F2006 CFT Large Project stream was assumed to be equal to their contractually firm energy.

The FELCC contribution for future wind resources was assumed equal to 100 per cent of the average annual energy identified by Garrad Hassan in their report (see Appendix F-6). This assumption is consistent with the assumption in the 2006 IEP/LTAP, and effectively assumes little or no correlation between wind generation and system inflows when measured over the duration of the critical period.

1.2.3 ELCC and Dependable Capacity

The ELCC analysis for the 2008 LTAP updates the small hydro ELCC analysis undertaken for the 2006 IEP/ LTAP. The wind resource ELCC analysis has not been modified.

1.2.3.1 Small Hydro ELCC

To establish the capacity contribution of small hydro resources, BC Hydro frequently has limited data such as monthly firm or average energies. To assess ELCC, a method of comparing locations and monthly shapes is required from sites that have data to extrapolate to sites with limited data. Two additional small hydro ELCC analyses have been undertaken since the 2006 IEP:

1. An analysis of hourly metered data from existing IPPs; and

2. An analysis of generic small hydro resources.

Hourly Metered Data From Existing IPPs

Two years of actual hourly data for 8 existing small hydro projects[5] were utilized to test the ELCC of existing resources. The test involved comparing hourly metered small hydro energy deliveries as follows:

1. Analyze the ELCC resulting from considering the hourly output during the coldest two weeks that occur[6];

2. Analyze the ELCC resulting from the coldest two months being December and January; and

3. Analyze the ELCC of a flat MWa profile January and December period.

The selection of the coldest two weeks is indicative of the potential flow reductions in small hydro during cold snaps when load conditions are the highest. Similarly, the months of December and January having the highest load and lower inflows are also a constraining period. The coldest two weeks had an ELCC equal to 57 per cent of the ELCC for the actual energy production of the two months. The coldest two weeks compared to the flat profile delivery over the two months providing a similar result (approximately 55 per cent). Given these percentages and the analysis of generic small hydro resources described below, BC Hydro concluded that an ELCC factor of 60 per cent of the average MWs produced in December and January appropriately reflects the ELCC of these existing resources.

Generic Small Hydro resources

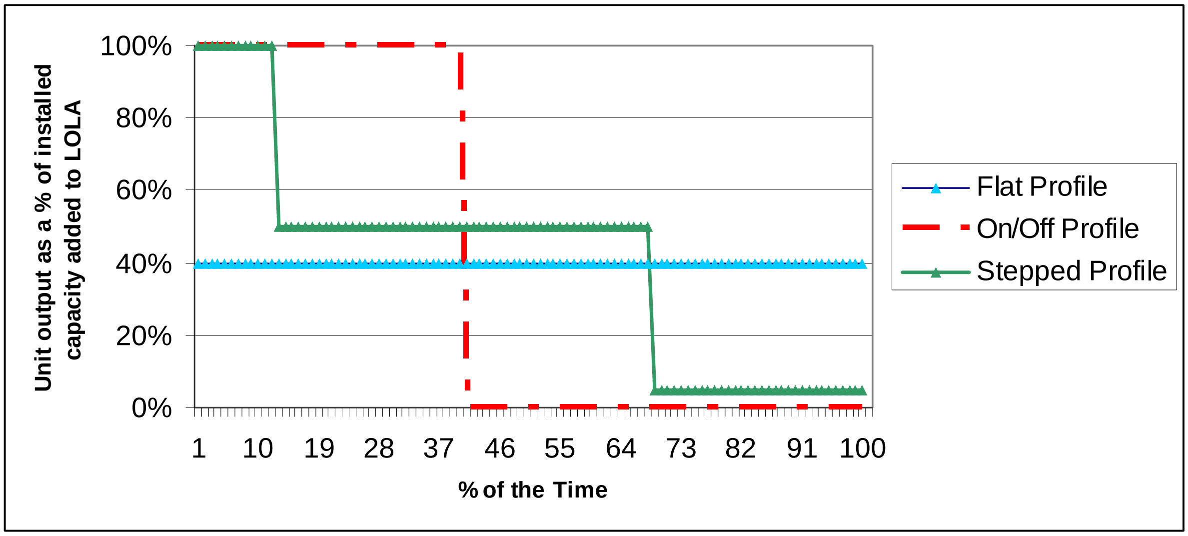
To further test the ELCC contribution of small hydro resources, including those that may be located in different locations, a further generic analysis was undertaken. A number of duration curves were created that would span the range of possible resource outputs as

[5] The 8 sites included 7 in the VI/LM region and one in the SI region. The years were F2006 and F2007.

[6] Given that it is BC Hydro's expectation that IPP fuel availability will be most constrained during the typical two week cold snap, we have selected an ELCC value corresponding to the two week period..

shown in Figure 1.1 to rationalize the potential capacity contribution that a resource could provide. The three profiles were: 1) flat (equal to the AMW in the two month period); 2) on/off (based on a binary dispatch with either zero output or full output); and 3) Mixed (a combination of 1 and 2 to create a three step duration curve. Figure 1-1 illustrates the three generic profiles using a 40per cent capacity factor[7] case as an example.

Figure 1-1



ELCC calculations of the three generic energy profiles were tested at 40 per cent and 15 per cent capacity factors for the critical months of December and January to analyze the impact of the delivery pattern in those months on the ELCC of the system. Table 1-4 summarizes the results of this analysis.

Table 1-4

Simulation #	**1**	**2**	**3**	**4**	**5**	**6**
Capacity Factor	40%	40%	40%	15%	15%	15%
Profile	Flat	On/off	Mixed	Flat	On/off	Mixed

[7] Capacity Factor reflects the ratio of the average MW output to the machine rated MW output.

Description				Profile		
ELCC	40% (A)	14%	28% (B)	15% (C)	5%	10% (D)
ELCC Ratio (Mixed Profile vs. Flat Profile	**69% (B / A)**			**62% (D / C)**		

This analysis shows that the best ELCC that could be contributed from a resource would be flat delivery that would result in at most the ELCC being equivalent to the capacity factor. By adding a delivery shape, the ELCC drops to as low as 35 per cent of the capacity factor for an on/ off operation. For a more moderate operation as reflected in the stepped shape, the ELCC values are approximately 62 per cent to 69 per cent of the capacity factor or average MW supplied over the December/January period.

BC Hydro has come to the following conclusions as a result of these analyses:

- For existing pre-F2006 CFT small hydro projects, the resource ELCC will be set at 60 per cent of the winter MWa of deliveries[8]. This results in an ELCC equal to 17 per cent of the installed capacity before attrition.

- For the projects from the F2006 Call Small Project Stream, the ELCC is set at 60 per cent of the December/January MWa of delivery that was forecast by the proponent. This results in an ELCC of 23 per cent of the installed capacity before attrition.

- For the projects from the F2006 Call Large Project Stream, the ELCC is set at 100 per cent of the MWa of firm commitment made with respect to each project in the December/January period. This results in an ELCC of 17 per cent of the installed capacity before attrition.

- For the generic small hydro study, the ELCC was set for each block of generic resources at 60 per cent of the forecast MWa of generation in the December/January period. This

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results in a range of ELCC percentages generally reflective of the region where the resources are situated, averaging at 13 per cent for the total of all bundles.

- The results are reflective of the resource (fuel) availability and do not include plant or unit physical reliability. Capacity (both ELCC-based and Dependable Capacity-based) will continue to be included in the capacity side of the load/resource balance. As a result, such capacity will draw the 14 per cent capacity reserve allocation because the reserve margin accounts for plant or unit reliability.

A sensitivity analysis was completed with respect to Dependable Capacity of small hydro projects in the VI/LM. The two years of test data analyzed above for ELCC was also analyzed for Dependable Capacity. The Dependable Capacity was calculated for the 7 coastal IPPs based on the definition of the 85th percentile output during the 2 coldest weeks. The resultant average Dependable Capacity from these 7 coastal sites was approximately 10 per cent of the installed capacity over a 2 year period.

1.2.3.2 Wind ELCC – Existing and New Resources

The ELCC of wind resources are treated the same as in the 2006 IEP/LTAP. The ELCC for on-shore and off-shore projects will be assumed to be 21 per cent and 29 per cent of installed capacity respectively.

[8] Historical data from the winter of F2005, F2006, and F2007 was analyzed to determine average winter MW.

1.3 Summary Table

The table below provides a summary of the small hydro and wind FELCC and ELCC values

Table 1-5 – Small Hydro and Wind FELCC and ELCC Values

Resource	FELCC	ELCC
Small Hydro – Existing Pre-06 CFT	85% of Average Annual Energy	60% of the historical average MW in December/January
Small Hydro – F2006 CFT Small Project Stream	85% of Average Annual Energy	60% of the forecast average MW in December/January
Small Hydro – F2006 CFT Large Project Stream	Contractually committed firm energy levels	As per contractual firm energy commitment (100% of average MW in December / January period)
Small Hydro – New Resources	Region and bundle specific values used. Weighted average of all bundles approximately 70% of Average Annual Energy	Region and bundle specific values used. Weighted average of approximately 60% of the forecast average MW of potential in the December/January period
Wind – Existing and New Resources - Onshore	100% of Average Annual Energy	21% of Installed Capacity

Wind – Existing and New Resources - Offshore	100% of Average Annual Energy	29% of Installed Capacity

1.4 Extract from the 2007 Standing Offer Program (SOP application)

Section 3.3

3.3 Relative Firmness of Product

In acquiring electricity from renewable resources to meet customers' needs on a reliable basis, BC Hydro assesses the firm energy contribution of the particular resources. The firm energy contribution of renewable resources (primarily small hydro and wind) varies depending upon:

1) *The amount of the resource's physical generation available;*
2) *The monthly and yearly variability of the resource's fuel supply (e.g. water, wind, etc.) relative to BC Hydro's Heritage hydro resources and load shape; and*
3) *The ability of the system to absorb the resource's generation. For the BC Hydro system, this is primarily limited by the ability of the hydro system to back off during the May – July freshet period.*

Firm energy capability contribution of adding a resource is determined by calculating the increase to the system's Firm Energy Load Carrying Capability (FELCC). The FELCC is defined as the maximum amount of annual energy that a hydroelectric system can produce under critical water conditions where critical water conditions are the most adverse sequence of stream flows occurring within the historical record[9]. To properly assess a resource's FELCC contribution to the system for a fuel-limited resource (hydro, wind, etc.), an assessment of fuel input and expected energy output based on historical data is required. Ideally, the historical data would match the data used for the Heritage hydro system (back to the 1940s). However, assumptions can be made that will provide a reasonable assessment of a resource's firm energy contribution even if less data is available.

BC Hydro's treatment of renewable resources has evolved as it has gained experience and operating history with the integration of renewable resources. For early IPP EPAs with limited resource penetration, and therefore knowledge and/or operating history, the firm energy contribution of a renewable resource was assumed to be equivalent to the average output of the resource. In the F2006 CFT, with the expectation of greater renewable energy contribution, BC Hydro introduced contractually firm energy as a proxy for physically firm energy. The contractually firm energy was deemed to hold BC Hydro in a similar position as physically firm energy as BC Hydro would expect to acquire the energy with more certainty at the contract price given the protective measures in the respective EPAs.

While the F2006 CFT Small Project stream did not require a contractually firm product, BC Hydro expected that the energy acquired from these resources would contribute to the system's physically firm energy.

BC Hydro is currently working to establish the expected energy contribution history for the resources with which it has contracted for supply. Based upon these histories, BC Hydro is undertaking FELCC studies to determine the value to the system of various resource additions. As BC Hydro moves forward, it will continue to gather renewable resource operating data, develop operating histories and expected output data upon which it will

[9] SD 10 establishes the "firm energy capability" of BC Hydro's Heritage hydroelectric facilities to be 42,600 GWh/year.

estimate the contribution and value of these resources.

3.4 FELCC Assessment of SOP Firm Energy Contribution

This section describes the SOP FELCC analysis undertaken to assess the expected firm energy contribution of small hydro projects participating in the SOP. For the analysis, 500 GWh/year of average annual SOP energy[10] is assumed to be added to a portfolio consisting of all existing and committed resources, including:

- *Burrard Thermal Generating Station (Burrard) operating at 6,100 GWh/yr[11]*
- *Island Cogeneration Plant*
- *Pre-F2006 CFT IPPs*
- *Alcan Inc. (Alcan) 2007 EPA*
- *F2006 CFT IPPs*

For the purposes of the SOP, BC Hydro examined small hydro projects that were awarded EPAs in the Small Project stream portion of the F2006 CFT using the following procedure:

1) *Selection of seven small hydro projects on the basis that the seven projects had historical stream flow data. Six of these seven projects are located in the LM and one project is located in the Southern Interior.*
2) *Construction of a 14-year sequence of monthly energy profiles using historical stream flow data from each project.*
3) *Scaling the 14 year sequence to provide an average annual generation of 500 GWh over the 14 years.*

As stated earlier, BC Hydro would ideally assess a fuel-limited resource's FELCC contribution by matching a sequence of data directly with BC Hydro's system critical period.9 In the case of the projects considered in this SOP analysis, historical data back to this period was not available. To simulate the effect of the critical period, BC Hydro cycled the 14 years of data over the full 60 year Heritage hydro period and aligned the lowest amount of available energy over any 3 ½ year period to coincide with the system critical period. Based on this procedure, about 85 per cent of the average annual small hydro SOP energy would be available during the critical period10 and about 45 per cent of the average annual small hydro SOP energy would be available during the three month freshet period.

This FELCC result applies only to the small hydro SOP energy assumed in the study and is dependent on the following factors:
(1) the volume of SOP energy (500 GWh/year) assumed;
(2) the timing of the energy being added to the resource stack; and
(3) the monthly SOP energy shape.

[10] The 500 GWh/yr average annual estimate of SOP energy is the approximate mid point of the estimated amount of SOP energy to be delivered during the two year review period.

[11] The FELCC results have been tested for robustness with and without Burrard. Since the Burrard monthly energy profile generally follows the BC Hydro load shape, with generally low production during freshet periods, its impact on the FELCC results is minimal.

It is anticipated that the addition of similar future resources beyond this SOP may yield different (higher or lower) contributions to system FELCC.

Table 1-6

Monthly Energy Profile Grouped by $10 /MWh Price Bundles and Transmission Region

* note: Only projects less than $110/MWh displayed.

			Firm Synergy Credit		5%	Fixed added to Firm/Avg		
			Freshet Penalty		20%	Per Unit above 100% Freshet		
VANCOUVER ISLAND								
	Avg Nrg	**Firm Nrg**	**Firm/Avg**	**Freshet 3 months**	**4*Freshet /Avg Nrg**	**Net Credit/Debit**	**Net Firm**	**Net Firm/Avg**
90 - 99	37.21	26.72	71.8%	7.99	85.9%	5.00%	28.06	75.4%
100 - 109	118.12	98.00	83.0%	17.18	58.2%	5.00%	102.90	87.1%
SOUTH INTERIOR								
80 - 89	166.56	143.18	86.0%	91.62	220.0%	-19.00%	115.97	69.6%
90 - 99	127.98	110.63	86.4%	69.89	218.4%	-18.69%	89.96	70.3%
100 - 109	199.65	131.37	65.8%	124.85	250.1%	-25.03%	98.49	49.3%
PEACE RIVER								
80 - 89	74.22	68.45	92.2%	43.68	235.4%	-22.08%	53.34	71.9%
90 - 99	54.45	50.22	92.2%	32.05	235.4%	-22.09%	39.13	71.9%
100 - 109	123.08	109.75	89.2%	67.21	218.4%	-18.68%	89.24	72.5%
NORTH COAST								
80 - 89	360.47	295.69	82.0%	149.15	165.5%	-8.10%	271.73	75.4%
90 - 99	361.98	293.30	81.0%	147.85	163.4%	-7.67%	270.79	74.8%
100 - 109	552.16	452.50	81.9%	226.11	163.8%	-7.76%	417.38	75.6%
LOWER MAINLAND								
50 - 59	167.88	110.53	65.8%	61.47	146.5%	-4.29%	105.79	63.0%
60 - 69	457.94	335.01	73.2%	170.50	148.9%	-4.79%	318.98	69.7%
70 - 79	897.05	674.11	75.1%	341.43	152.2%	-5.45%	637.37	71.1%
80 - 89	1011.18	788.64	78.0%	432.35	171.0%	-9.21%	716.04	70.8%
90 - 99	706.82	569.59	80.6%	288.24	163.1%	-7.62%	526.17	74.4%
100 - 109	661.60	512.08	77.4%	281.25	170.0%	-9.01%	465.95	70.4%
KELLY								
70 - 79	148.09	117.59	79.4%	74.04	200.0%	-15.00%	99.96	67.5%
80 - 89	127.76	109.13	85.4%	63.11	197.6%	-14.52%	93.28	73.0%
90 - 99	9.67	6.19	64.0%	4.44	183.5%	-11.70%	5.47	56.6%
100 - 109	111.12	97.88	88.1%	55.11	198.4%	-14.67%	83.52	75.2%
EAST KOOTENAY								
70 - 79	95.06	85.73	90.2%	50.66	213.2%	-17.64%	70.61	74.3%
80 - 89	432.38	367.21	84.9%	238.95	221.1%	-19.21%	296.67	68.6%
90 - 99	87.51	69.20	79.1%	46.91	214.4%	-17.88%	56.82	64.9%
100 - 109	285.56	242.79	85.0%	167.34	234.4%	-21.88%	189.67	66.4%
CENTRAL INTERIOR								
70 - 79	141.87	139.82	98.6%	72.77	205.2%	-19.57%	112.46	79.3%
80 - 89								
90 - 99	83.40	77.51	92.9%	41.45	198.8%	-14.76%	66.07	79.2%
100 - 109	148.73	133.42	89.7%	76.96	207.0%	-16.39%	111.55	75.0%
NICOLA								
80 - 89	325.17	294.23	90.5%	170.79	210.1%	-17.02%	244.16	75.1%
90 - 99	234.73	196.35	83.6%	138.05	235.3%	-22.05%	153.05	65.2%
100 - 109	100.77	88.67	88.0%	54.84	217.7%	-18.53%	72.24	71.7%
TOTAL	8410.17	6795.50	80.8%	3808.22	181.1%		6002.81	71.4%