ENERGY AUDIT AT TALCO - ALUMINIUM COMPANY IN TAJIKISTAN

Energy Audit Report

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Efficient, environmentally friendly and safe utilization of energy

EXECUTIVE SUMMARY

The World Bank Group has contracted a Consortium of the Norwegian, Ukrainian and Tajik companies, led by Norsk Energi, to perform a plant-wide assessment of energy efficiency options of all major equipment and production lines at TALCO – Tajik Aluminium Company, which is the largest aluminium manufacturing plant in Central Asia, headquartered in Tursun-zade. The project team includes Norsk Energi, SINTEF Materials and Chemistry, ESCO EnergoEngineering and Tajhydro.

Purpose and Methodology of Energy Audit

The main purpose of the assignment is to quantify energy usage at the site and highlight opportunities/measures for potential energy savings at TALCO. To achieve this, the study methodology comprises the following main tasks: (a) to complete a comprehensive energy audit; (b) to identify energy and, in particular, electric power consumption related to all equipment, processes and sub-processes in the plant; (c) to analyze and recommend opportunities to decrease energy use and costs, as well as estimate the associated investment needs; (d) identify priorities for energy efficiency improvements in terms of the potential for electricity savings and costs-effectiveness.

The project was launched in March 2012 with the Initial Data Collection. Further to this, plant tours were arranged in April and June 2012 to perform the baseline energy assessment. All main energy consumers, systems and sub-systems of TALCO were reviewed during these tours, in addition to raw data collection, interviews with key technicians and temporary metering at the selected aluminum cells (Al.cells), anode production plant, boiler houses, gas cleaning system, etc.

Further activities included identification of energy saving measures, their assessment upon technical and economic feasibility, as well as their potential for greenhouse gas (GHG) emissions reductions. Finally, the priority energy saving measures was identified based on their simple payback period on investments and incorporated into the Action Plan. In addition, most salient points for energy management, power regulation and energy security were highlighted. This final report presents analysis of baseline energy consumption by TALCO, identified energy saving measures and proposal for priority energy saving improvements.

Existing Energy Situation of the Audited Site

TALCO is Tajikistan's major industrial asset, which generates as much as 40% of the national GDP. The total aluminium production was 361 000 tons in 2009, 351 000 tons in 2010 and 281 000 tons in 2011. This is however significantly lower than the maximum aluminium production in 1989, which was 460 000 tons. The main reason for this decrease is the significantly lower number of cells in operation.

TALCO is the single largest power end-user in Tajikistan, consuming about 39% of the electricity generated (statistical data for 2009). 90% of the total energy consumed by TALCO accounts for electricity, while circa 10% accounts for natural gas. Specifically:

- Usage of electricity in 2011: 5,48 TWh, with 93,5 % being used in the electrolysis process;
- Usage of natural gas in 2011: 45,9 mill Sm^3, with 83% being used for producing prebaked anodes.

Seasonal variations of power and natural gas use are very small at TALCO. However, the company's power consumption is strongly dependent on the production output of Al.cells; the natural gas consumption has both fixed and seasonal demand and therefore is less correlated to the production output.

Consultant's Opinion on Current Energy Accounting and Management Practices

The energy audit concluded that both electric power and natural gas accounting are at satisfactory levels at TALCO, as it has a large number of metering stations, while power and natural gas imbalances do not exceed the accuracy of meters. However, all meter readings are done manually by inspection, while the best practice is based on automatic energy accounting systems.

The current system of measuring thermal energy use allows only rough and incomplete accounting, mainly in the interest of settling bills from the energy suppliers. There is no metering of generation, distribution and use of thermal energy, except for steam generation. Therefore, it is difficult to perform energy monitoring and targeting based on the data currently available.

During the audit we observed some of the elements of the energy management, but there is an essential lack of systematic activities and major developments need to be done to put an effective energy management system in place.

Technical Condition of Power Supply and Distribution Systems

Technical condition of the power supply and distribution equipment, i.e., 220 kV lines, transformer substations, low voltage power lines, wire, high voltage insulators, as well as Si-converters is satisfactory. Power losses are within the design range, and below (where the power systems are under-loaded). Most of the equipment though has been in operation since the factory was built in the 1970s and modern analogues are available on the market.

Benchmarking TALCO's Energy Consumption

When benchmarking TALCO with other aluminium companies, the specific consumption of electric energy in the electrolysis process is the main parameter, since it accounts for 93.5% of electricity consumption by the plant. Other important benchmarking parameters are: (-) the specific energy consumption for production of prebaked anodes and (-) specific anode consumption for production of aluminium.

When looking at the usage of electricity at TALCO, it was found out that the company needs about 20% more electricity per kilogram (kg) of aluminum (Al) produced than modern electrolysis facilities. The state of the art technologies based on the Hall-Heroult process have a specific energy consumption of about 10 kWh/kg Al, which is about 40% lower than at TALCO.

The potential for energy efficiency improvements related to technologies used at TALCO can be illustrated by the development in the SU III pot-line at Hydro Sunndal aluminum company (Norway), which, at its inception, was probably not very different from technologies currently used at TALCO. Hydro Sunndal gradually improved its efficiency and reduced its specific electricity consumption from 16,5 kWh/kg Al to 14,1 kWh/kg Al.

TALCO has almost three times higher energy consumption for the anode production compared to benchmarking facilities. Both the higher direct consumption of energy per kg anode and the higher consumption of anodes contribute to the overall high energy consumption per kg of aluminium produced.

These overall figures for benchmarking the electrolysis and anode production at TALCO show that the company has a significant potential for energy efficiency improvements.

Table 1: Specific energy consumption

Description/Process	Benchmark, state of art	TALCO
Specific usage of electricity	13-14 kWh/kg	16,63 kWh/kg Al
Energy consumptions in the production of prebaked anodes	1,31 kWh / kg anode	2,3 kWh / kg anode
Consumption of anodes in the electrolytic process	0,43-0,45 kg anode / kg Al	0,57-0,63 kg anode / kg Al
Energy consumptions in the production of prebaked anodes	0,58 kWh / kg Al	1,54 kWh / kg Al

Emphasis on Electrolysis Technology Improvements Needed

There are two main strategies for energy saving in the electrolysis process:

- Reducing the cell voltage;
- Improving the current efficiency.

At TALCO, the energy audit identified a large potential for improvements in the external circuit of the cell (busbars, current risers, anode assembly, etc.). Measured voltage distribution of Al.cells shows high voltage, especially on the anode side, mainly caused by (-) poor welding between the riser, flexible and anode beam; (-) high contact voltage between anode beam and the anode stem;(-) too slender anode beam/yoke construction; (-) very high contact resistance between anode stubs and carbon.

Measures aiming to reduce the cell voltage will be relatively inexpensive, and changes will not affect the delicate energy balance of the cells. The voltage losses should, at least, be brought down to the company's internal standards.

The current efficiency (CE) is the ratio between the actual amounts of produced metal and the theoretical production calculated from Faraday's law. The loss in CE mainly takes place by formation of dissolved metal in parasitic side reactions at the cathode, with subsequent loss of dissolved metal into the electrolyte and oxidation at the anode. At TALCO, the average CE for the 10 pot-rooms showed a variation from 85,22 % to 88,96 % in March 2012. This is significantly lower compared to the situation in modern well operated pot-lines, which work with CE in the range of 92-96 %. One of the main measures to increase CE is the introduction of alumina point feeders in combination with modern principles for automatic cell control and slotted anodes. These measures will contribute to reduce the anode effect and decrease accumulation of sludge at the cathode, which will help increasing the CE.

Importance of Anodes Quality Enhancement

The anode quality is very important in aluminium electrolysis. High anode consumption and decreasing productivity at TALCO during the last few years can be related to low anode quality. During the site visit we observed that cracking of anodes is a very common problem at TALCO. While the formation of excessive amounts of carbon foam is uncommon in cells with prebaked anodes, it appears to be a common issue at TALCO.

Low anode quality is closely related to the conditions of the anode baking furnace. The furnace is in bad condition with worn out linings and leakages. Further, there were complaints about insufficient cleaning of the anode butts before returning to the anode plant, which contributes to the destruction of the lining in the baking furnace. The furnace also does not have sufficient instrumentation, e.g., temperature measuring points, which results in too low temperatures in the anode baking furnace.

Poor quality of the carbon anodes leads to overconsumption of raw materials. Since improving the anode quality leads to a higher CE, improving the quality of the anodes is crucial for achieving energy savings in the electrolysis process. Further, the usage of electricity at the electrolysis cells and the usage of anodes are correlated: a reduction in operating cells voltage will also reduce the anode consumption.

Three major facilities have to be improved in order to increase the quality of the anodes: (-) improve the cleaning of anode butts; (-) improve the baking facilities; (-) improve the pressing of anodes. Most of the energy savings can be achieved by improving the baking facilities. Improving their current performance is considered as one of the main opportunity areas at TALCO, along with improved control of the electrolysis.

Identified Energy Efficiency Potential

TALCO has a large potential for energy saving in the electrolysis process, the carbon anode production and for all auxiliary equipment. The total estimated electricity and natural gas savings potential of the Action Plan is:

- 0,95 TWh/year could be saved in the electrolysis process;
- 0,17 TWh/year could be saved in the anode production;
- 0,23 TWh/year could be saved in plant services.

Table 2 shows the breakdown of the total estimated potential of identified energy saving measures for the three main processes at TALCO. The estimated total investments and simple pay-back periods per process are also given in the table.

The table shows that the main potential for saving electricity is within the electrolysis process where the aluminum is produced.

Table 2: Key financial and energy figures per process at TALCO

Location	Electricity saving potential (kWh/year)	Natural gas saving potential (kWh/year)	Annual energy cost savings (USD/year)	Invest. (USD)	Simple payback (years)
Electrolysis process	954 707 030	0	17 471 139	19 092 000	1,1
Anode production	3 169 200	166 243 936	27 213 744	63 376 000	2,3
Plant services	197 408 617	31 168 434	4 501 866	4 588 531	1,0
TOTAL	**1 155 284 847**	**197 412 370**	**49 186 749**	**87 056 531**	**1,8**

Main baseline parameters assumed for estimating the energy saving potential are:

- Usage of energy for the electrolysis, and the production of aluminium are based on figures from March 2012. This is due to the fact that there has been a large reduction in operating aluminium cells over the last two years which needs to be taken into account in order to provide realistic energy savings estimates;

- Usage of energy for producing pre-baked anodes, and the production rate of pre-baked anodes is based on average figures for the years 2009-2011;
- Usage of energy for the plant services are based on actual measurements done during the inspections in April 2012. Where historical data were available, the average energy usage for the years 2009-2011 are used as baseline.

In summary, implementing the identified energy efficiency measures in the Action Plan would allow TALCO to reduce its energy usage by about 22% over 2009-2011 average consumption and production levels, which corresponds to a reduction in electricity and natural gas consumption by about 20% and 37%, respectively[1]. It is important to note that production output, power consumption and energy savings are closely correlated: in the event production at TALCO increases, total energy use would increase while the absolute electricity savings from the identified energy efficiency measures would also be higher. Similarly, if production levels fall, total energy use and absolute electricity savings from the identified measures would be lower. A decline in production would translate to an increase in the net availability of power to other grid consumers.

The energy efficiency measures in the anode production as well as related process improvements, such as improved pressing of green anodes and cleaning of anode butts, will improve the quality of anodes and thus the performance and quality of the electrolysis process. It will also increase the lifetime of anodes and thereby reducing the demand for new anodes. Overall, the average payback period for energy efficiency measures for 'anode production' is still very attractive from a commercial perspective, despite higher investments and lower returns compared to the electrolysis process. It may be noted that these measures will also result in significant gas savings, which is currently imported at a very high cost.

Overall, implementing the Action Plan would also allow TALCO to improve its specific energy performance parameters by:

- 3,1 kWh /kg Al in the electrolysis process, i.e., reducing its electricity consumption to 13,32 kWh/kg aluminum;
- 0,5 kWh/kg prebaked anodes in the anode production plant, i.e., reducing energy consumption to 1,8 kWh/kg prebaked anodes[2].

Summary of Key Energy Saving Measures included in the Action Plan

Eighteen energy saving measures in the electrolysis process are identified. As mentioned, energy savings can be achieved either by reducing the cell voltage or improving the CE. Most of the ‘cell voltage’ related measures address certain improvements of the anodes and cathode sides, as well as busbar, and in most cases they are inexpensive. The exception from this is the construction of a more efficient anode assembly/stub hole.

Improvement of current efficiency requires major investments in point feeders and automatic alumina control. These measures are expected to result in an increase of CE from 86,57 to 92,78%. As a result,

[1] As noted, electricity consumption represents about 90 % of total energy consumption. Estimated energy savings in the electrolysis process are adjusted to the average production levels in 2009-2011 in order to provide an aggregated total reduction potential using a common baseline.

[2] Specific energy performance parameters refer to production output and process conditions in March 2012.

either the production output may be increased by 7,2% with no extra consumption of raw materials and energy, or power consumption could be reduced by 16,5%, but some of the cells would need to be shut to keep the production constant.

The large potential for saving natural gas is within the anode production, first of all through improvements at calcination and baking ovens. Their implementation will be capital intensive, but it generates significant gas savings and improves the quality of the pre-baked anodes used in the electrolysis. Investments required for upgrading the anode baking facility is expected to account for about 60% of the total capital cost for all measures included in the Action Plan, however, the average payback period of 2,3 years is still very attractive from a commercial perspective. Other major energy saving opportunities in the anode production include the reduction of direct energy losses by warming up of pitch and coke, as well as by increasing waste heat recovery from calcination ovens.

This report also defines measures to save electricity for other plant services and auxiliary equipment, which are servicing the electrolysis and production of pre-baked anodes. Most of these measures are typical energy saving projects, and can be implemented independently from each other. The key measures are: (-) implementing an energy management system, which is important for continuously identifying and realizing energy savings; (-) regulating speed of electric drives and motors; (-) improved insulation, (-) improved boiler operation and maintenance.

Bundling of Measures

The potential for saving energy is calculated for each proposed measure individually. It may be noted that there are positive interrelations between some of the proposed measures. For instance, energy saving measures reducing the voltage at the aluminium cells will lead to additional improvements of CE, and thereby result in additional energy savings. These additional savings from positive spill-over effects are not accounted for in the individual energy saving estimates.

The Action Plan recommends implementing the measures related to alumina point feeders, automatic alumina control, change in electrolyte composition and slotted anodes together. The bundled measures will have a simple payback of 2,6 years, which is significantly lower than if the alumina point feeder measure is implemented alone.

Abatement of Greenhouse Gases (GHG) Formation

Global warming due to formation and emission of GHGs has become an international concern during the latest decades. Since TALCO's aluminium production is based on hydropower, CO_2 emissions related to power consumption are negligible. Nonetheless, total GHG emissions from TALCO are relatively high due to GHG emissions related to the electrolysis process.

There are two major sources of GHG emissions from the electrolytic process: the high use of anodes, which emits CO_2 and the reactions at the anodes, producing perfluorocarbons, PFC. These sources generate as much as about 10 000 kg CO2eq /t Al.

The emissions of PFCs, which are formed during the anode effect, may be the worst problem from a global warming point of view. The PFC gases are powerful GHGs, having greenhouse warming potentials that are 6500 (CF_4) and 9200 (C_2F_6) times higher than for CO_2. The anode effect occurs when the electrolyte becomes depleted in alumina, and the normal cell reaction is not possible. TALCO had an average anode effects frequency of 2,65 AE/cell/day during March, 2012, while modern plants frequently operate with anode effects frequency below 0.1 AE/cell/day. Therefore, reduction of anode effects frequency will also reduce the GHG emissions at TALCO.

The identified energy saving measures offer a potential reduction of about 2 000 000 tons of CO_2 equivalents per year, which is very significant. Most emission reductions will be a result of improvements at the electrolysis cells.

The Proposed Action Plan

The identified energy efficiency measures are put into 3 groups based on their simple pay-back period on investments:

- First group includes measures with a pay-back within one year.
- Second group includes measures with a pay-back between one and three years;
- Third group includes measures with a pay-back between three and seven years.

A 7 year payback period was used as a cut-off for measures included into the Action Plan. Table 3 shows important parameters for each of the groups included in the Action Plan.

Table 3: Prioritized list with economic figures for the proposed measures

Location		Electricity saving potential (MW/ kWh/year)	Natural gas saving potential (kWh/year)	Annual energy costs savings (USD/year)	Invest. (USD)	Simple payback (years)
1 Group	Immediate implementation	13/ 114 316 505	12 559 996	2 614 488	770 000	0,3
	Needs engineering/ planning	75,9/ 664 708 153	35 938 746	17 959 211	6 330 000	0,4
2 Group	Immediate implementation	0,4 / 3 444 600	0	63 036	174 120	2,8
	Needs engineering/ planning	41/ 358 644 187	95 986 577	26 196 230	69 404 000	2,6
3 Group	Immediate implementation	1,3/ 11 421 950	0	209 022	675 411	3,2
	Needs engineering/ planning	0,3/ 2 749 452	52 927 052	2 144 762	9 703 000	4,5
TOTAL		**131,8/ 1 155 284 847**	**197 412 370**	**49 186 749**	**86 911 531**	**1,8**

Within each of the groups, measures are sub-divided into two categories based on their technical complexity: some measures can be implemented immediately by TALCO without additional preparatory work, while others need planning and engineering before implementation.

Energy Saving Measures not included in the Action Plan

During the energy audit, 7 additional measures were identified with a payback period on investments beyond seven years. These measures are not included in the Action Plan and are mainly related to Plant Services, e.g., frequency converters and lighting systems.. It is noteworthy that in other countries, where energy prices are much higher, such measures would normally be a part of energy efficiency programs. Therefore, it is advisable to review financial viability of these measures, if energy prices for TALCO increase.

Another energy-related project not included in the Action Plan is to replace the existing converters 220/10/840 DC with a DC-converter type 220/840 DC built in container. Our conclusion is that up to 0,3% of the total electricity consumption can be saved by this project by removing one transformer step. While these energy savings wouldn't ensure financial viability of the project, the main benefits of this project would be operational, i.e., improved quality of power supply to aluminium cells.

During the energy audit, the team also looked into the option of upgrading the 220/10 kV power inlets by replacing old single phase transformers at each of the inlet with modern 3-phase transformer of 250 MW in capacity. The calculations suggest that the pay-back is far above 7 years. In addition, TALCO may need to strengthen the 10 kV busbars, switchyards and the carrying capacity of the 10 kV distribution grid at TALCO, which will require significant investments.

TALCO has its own reactive power sources, but their utilization is not effective. Only part of the reactive power consumed by the company (mainly converters, induction furnaces and motors) is offset by the company's own means. By installing active compensation equipment, TALCO will be able to reduce daily consumption of reactive power and related energy costs by 75%, as well power load on the main inlet transformers. However, the energy savings are not expected to return the investments in the short- or medium term. As compensation of reactive power is mainly done manually, one low-cost alternative would be to trace more carefully variations of production loads in order to minimize costs of the reactive power use.

Power Load Management Possibilities

The Consultant examined potential options, which TALCO may consider, for using seasonal tariff advantages by shifting part of its load from energy deficient winter months to the summer season. The two main possibilities are: (-) schedule the major repair of the cells during the winter time; (-) reduce cell amperage during the winter time.

It is technically possible to schedule the major repair of the cells during the winter time. The result will be fewer active cells during that period and more active cells during the summer period. The method requires taking the cells gradually out of operation, as it happens now, keeping the disabled cells in stock for a longer period than now and re-starting all cells during a major campaign in the spring. In winter time, the electricity consumption will go down in average by 22 GWh per month, while in summer time it will increase accordingly. TALCO may save about 860 000 USD per year by using the advantage of the seasonal tariff, while the power load on the national grid may get reduced by 2,5 MW per winter month. However, TALCO may face relatively high investment requirements concentrated over a short time period to procure all the required goods for the major repair and implementation of energy efficiency measures. Further, TALCO may encounter difficulties in ensuring quality of repairs due to the concentrated restart in spring.

In addition, it is also technically possible to reduce the amperage without damage to an aluminium cell in order to reduce the energy consumption in winter season. Subject to further in-depth evaluations in-house, it is proposed to review an option involving a reduction of amperage by 20 kA for 4 months (122 days) in 'cold' season. TALCO may save approximately USD 4 000 000 over the 4 'cold' months, but its production of aluminium may shrink by 11 000 t over that period. This measure cannot be executed on a short notice.

Next steps

TALCO can immediately implement seven simple measures of the 1 group, which require no further engineering work or studies. The electricity demand, thus, could be reduced by 114 GWh/year, while the power loads on the national grid would be reduced by 13 MW. There are also five simple measures in the groups 2 and 3 which could be implemented without additional preparatory work. Their energy saving potential is 15 GWh/year, while the power load could be cut by 1,7 MW. The majority of these measures can be implemented within one year.

The rest of the measures may require further engineering studies and technical preparations, so that their implementation could take up to 4 years. It is, however, recommended to initiate their planning immediately in order to commence them as quickly as possible. TALCO may need assistance from consultants and/or the engineering department of a major international aluminium company for implementing some of these measures. The 2 largest investments are related to (-) Improvement of current efficiency by performing automatic feeding and control of alumina content in aluminum cells, and (-) Improvement of baking facilities.

7 energy saving measures in the electrolysis process require disconnection of Al.cells. However, the measures could be implemented gradually and scheduled during major repairs of the cells preferably during winter months.