

Modelling of The Capital Cost Risk for Coal Washing Plant -Assesment on The Coal Washability and The Quality of Asphaltites in Southeastern Anatolian Region of Turkey

Yıldırım İ. Tosun

Mining Engineering Department, Şırnak University, Şırnak, Turkey

Abstract—The overall objective of coal washing is the presence of a highly need to clean coal which can be produced economically. In the studies, at the cost-benefit criterion it has been considered, and thus the modeling of investment risk of washing plant became the main targeted economic research work.

The most appropriate model is determined by comparison for this data obtained by comparing the model results and the actual data has been confirmed. Model data trends observed in the average of approaches were examined and evaluated as a very well-parametric analysis of costs. It has been expanded by recent model costs. This risk analysis and plant construction, investors can provide insurance companies for risk assessment and product quality. Thus, the risk analysis will help in calculating the correct budgeting and insurance premiums.

Reserve characteristics of coal resources in addition risk analysis, the presence of hard to washability, to be eligible on the total ash and sulfur content of clean product, performances of washing units, waste sources and logistics, waste transfer, are discussed in parametric cost analysis management in the most efficient manner compatible with the environment. Assessment made after the necessary cost risk analysis on the cost parameters, probability approach, Gaussian, Markovian, and the resulted approach of cost risk analysis is discussed. The use of the pilot plant scale outcomes increase the risk on cost analysis and the capital cost model parameters of pilot plants such as quality and market change that increases risk of the capital cost and may omit the environmental risk of waste.

Keywords: risk assessment, cost estimation, simulation, probability simulation

1. Introduction

The almost 211TWh total electricity in 2011, Turkey were produced primarily from imported natural gas and domestic coal [1-4]. The total amount of asphaltite resource in reserves and production in Şırnak City are over 82 million tons of available asphaltite reserve and 400 thousand tons per year, respectively [5]. The most effective and cost-effective technologies are needed for clean coal products in today's modern technologies [5-9]. Turkish coal industry needs washing technologies and high performances at lower cost with various types of local coals.

Evaluation of natural resources, in parallel with the energy needs of our country will provide economic benefits by reducing fuel imports. Basically, energy production is made from imported natural gas and has a 46% share of health. After the energy production from coal imported natural gas is located in the second row and is provided by burning coal in thermal power plants with a share of 26% (TKI, 2013). Depending on the future energy demand, the ratio is expected to increase. A total of 83 million tonnes per annum of lignite and coal in boilers and industrial furnaces production was evaluated as the need for heating and energy. Quality coal ash minerals comprise micronized size particles[10]. In this study, the opening of the quarry closed in Şırnak region and the high-calorie but ash and sulfur content can be produced by washing it is considered to be the economic contribution of higher asphaltites. Şırnak asphaltites the washability studies made by developing potential flowsheets were compared accordingly wash washing plant investment and operating costs. The result of the feasibility study has identified suitable premises.

Asphaltites Şırnak Şırnak and Hakkari in Turkey's Southeastern Anatolia is located in the provinces. 120 million tons of proven reserves of Şırnak and Hakkari possible asphaltite of 0.2-1% moisture, 37-65% ash, sulfur burning 6,3-7.5% total sulfur 5.5-5.7%, 60-65% volatile matter and 2800-5600 kcal / kg has a lower temperature. Şırnak asphaltites beds are distributed or block-shaped space rock in the vein location [3]. Avgamasya and production is done in Karatepe veins approximately 15 years. Avgamasya and Karatepe veins 15-25 and 10-20 m thick clumps form. Also Hakkari, Uludere district was spread around 1-20 m thick layer of scattered asphaltites and as bed layers and as veins. as well as limestone bed rock, shale, marl clay, marl and argillaceous limestone is located. Şırnak asphaltites coal is soft with shale ash and macro size boyutta calcite micronized minerals as pyrite and pyrrhotite deposits are widely used in coal and shale asphaltites.

1.1 Washing coal with Larcodems and Humphrey Spirals

Larcodems medium types are widely used in coal washing operation for low and medium density. The separator shows efficient performance in cleaning and just one unit Larco in a single cycle can provide high capacity of 50 ton/h, such as

washing. This reagent is provided to those in severe ambient conditions can yield high as 1-6 mm in size and are determined can be reduced to less than 15% of ash content (Anonymous, 2015). Especially hard washable mixed product obtained in coal and enables you to process these musk again after shredding (Kemal and Aslan, 1999, Rules, 1991).

Humphrey spirals in the washing of coal in the high and medium intensity and especially in the washing of the pyritic sulfur in the coal is preferred widely (Anonymous a, b, c, 2015). In the high density and high ash coals Humphrey spirals in a specific amount during the washing was observed to increase the amount of mixed product.

1.2 Washing with the Coal Flotation

Flotation for washing the fine size coal (Jameson, 2001) is a method most commonly used. Some studies of coal particle size and density of mineral distribution in coal flotation (Warner, 1985) determined that significant side kinetic and may affect efficiency. Studies particle size increases, as can be shown that the yield decreases rapidly (Schubert, 2008). Generally yield falls in the flotation of coarse coal, but flotation rate is very low. Particle size is too big, not sticking on the bubbles. In contrast, a high efficiency in the fine coal flotation and flotation kinetics also increase (Gupta et al., 2001). In contrast, flotation rate depends strongly on the grain size medium size coal particles. In addition, the bubble clusters formed around the coarse coal particles was determined to be effective in the coal particles floated by flotation. Flotation in size, the solid ratio of reagent dosage and reactive species stated that effective flotation success (Wills and Napier-Munn, 2006, Klimpel and Hansen, 1987, Rules 1991).

Besides, the grain size on the flotation of coal ash and mineral substances with a coupling degree of covering of the mineral ash has been determined to be in effect (Laskowski 2001, Erol et al., 2003). Washing the flotation proper size range were found to be -500 microns. Bigger size and mechanical mixing of fine particles of coal has created different hydrodynamic effect (Jameson, 2001).

Şırnak asphaltites about coal reserves with the washability of the petrographic studies with standard flotation pyrite and clay depending on the structure of asphaltite moved, it has been identified as hard coal washability.

1.3 Washing with the Coal Column Flotation

Column flotation of fine coal is determined could very well yield can be floated in the microbubbles (Yianatos et al., 1988). Microbubble washing water in the form of shower foam zones consisting of may be possible to obtain more clean product coal with the addition. (Hadler et al., 2012 and Jameson, 2001) washable particularly difficult and shale and shale is a method used successfully in coal at high rates. Particle size and type of coal as the flotation column can easily affect efficiency. However, operating parameters, especially the foam height of the column unit, the wash water

is added, and the bias ratio is flammable operating parameters affect efficiency. (Finch and Dobby, 1990, Yoon, 1993, Yoon, 2000).

It was formed on an inclined foam zone to increase the effectiveness of the foam. with the effect that gravity is stated to reduce drift foam. This essential principles laid cyclonic column flotation cell (S-FCMC) provided a foam zone comprising inclined channels (FCMC) it proved to be effective in coal washing and widely China (Rubio, 1996) was used. the foam product has a third zone of the foam sediment are removed (Valderrama et al., 2011).

2 Method and Projects Studies

Avgamasya fleet asphaltites represent approximately 67% of the production is carried out from the coal mines has been reduced to 120 kg sample cone reduced by up to 18mm-fours under the hammer. Nuts are widely washed coal ash and high sulfur coal to be sold as industrial fuel asphaltites is intended to be sold. Optimum washing plant is determined by standard testing results performed. In the experiments, used Avgamasya fleet asphaltites crushing and screening prior to represent tuvenane size and distribution of fractional ash is given in Table 1. Figure 1 ash cumulative normal size and size distribution are described. Large and medium-sized ash content is more intense, it was reduced in particle size. Especially the range below 18 mm cumulative ash remained about 35%. The ash percentage was 41.6% in this distribution. It showed uniform distribution of the sulfur content in all fractions.

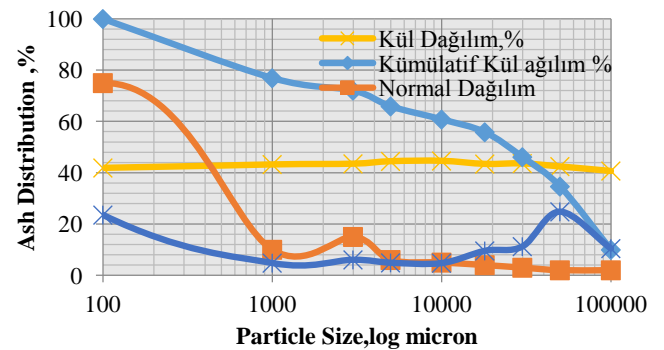


Figure 1. Distribution of Coal Ash Particle Size Sirnak Asphaltite connected Cumulative Distribution Ash and Ash Normal Distribution

30 kg samples were used in the study represent -10mm size of washability. -18 + 10 and -10 + 1mm separate flotation-immersion test for grain size fractions is made. the flotation-immersion test; 1:45; 1.55; 1.65; 1.70; 1.80 and 2 g / cm³ in density ZnCl₂ solution are used. -18 +10 Mm size fractions of the test results are based on the values of -10 to + 1 mm fraction in this study were similar.

2.1 Washability Studies of Sirnak Asphaltite

According to the results of the washability made one class; -18 And -10 + 10 mm + 1 mm grain obtained by calculating the cumulative classes washability test results are given in

Table 2. ash characteristic curve based on the data in these tables are described in Figure 2 and Figure 3 washability curve.

Table 1. Moisture, Ash and Cumulative Ash distribution of Sırnak Asphaltite with Coal Particle Size connected

| Size | Weight | Moisture | Ash | Ash Content | Ash Distribution |
|--------------|--------|----------|-------|-------------|------------------|
| + 100 | 10,44 | 1,1 | 40,71 | 425,01 | 9,96 |
| + 50 | 24,8 | 1,03 | 42,45 | 1052,76 | 24,67 |
| + 30 | 11,23 | 1,14 | 43,62 | 489,85 | 11,48 |
| + 18 | 9,54 | 1,25 | 43,43 | 414,32 | 9,71 |
| + 10 | 4,75 | 1,31 | 44,62 | 211,94 | 4,96 |
| +5 | 4,89 | 1,8 | 44,47 | 217,45 | 5,09 |
| +3 | 6,05 | 1,9 | 43,51 | 263,23 | 6,16 |
| +1 | 4,78 | 2,1 | 43,23 | 206,63 | 4,84 |
| -1 | 23,52 | 2,6 | 41,9 | 985,48 | 23,09 |
| Total | 100 | | | 4266,71 | |

Table 2. Float-Sink Test Results of Sırnak Asphaltite prior to coal flotation; (-18 + 1) mm grain washability values in its Density fraction

| Density (g/cm ³) | Float % | Float ash % | Ash Content. | ∑Float % | ∑Float Ash. | Float % Ash | ∑Sink.% | ∑Sink % Ash. | ∑Sink %. | Sink % Ash. |
|------------------------------|------------|--------------|----------------|----------|-------------|-------------|---------|--------------|----------|-------------|
| 1,45 | 13,5 | 10,8 | 145,8 | 13,5 | 145,8 | 10,8 | 100 | 4102,09 | 41,02 | 6,75 |
| 1,5 | 16,4 | 17,9 | 293,56 | 29,9 | 439,36 | 14,69 | 86,5 | 3875,29 | 44,80 | 21,7 |
| 1,55 | 16,9 | 28,8 | 486,72 | 46,8 | 926,08 | 19,78 | 70,1 | 3581,73 | 51,09 | 38,35 |
| 1,6 | 11,4 | 36,9 | 420,66 | 58,2 | 1346,74 | 23,13 | 53,2 | 3095,01 | 58,17 | 52,5 |
| 1,65 | 14,6 | 56,6 | 826,36 | 72,8 | 2173,1 | 29,85 | 41,8 | 2674,35 | 63,97 | 65,5 |
| 1,8 | 18,7 | 66,2 | 1237,94 | 91,5 | 3411,04 | 37,27 | 27,2 | 1847,99 | 67,94 | 82,15 |
| 2 | 8,5 | 81,3 | 691,05 | 100 | 4102,09 | 41,02 | 8,5 | 610,05 | 71,77 | 95,75 |
| Toplam | 100 | 41,02 | 4102,09 | | | | | | | |

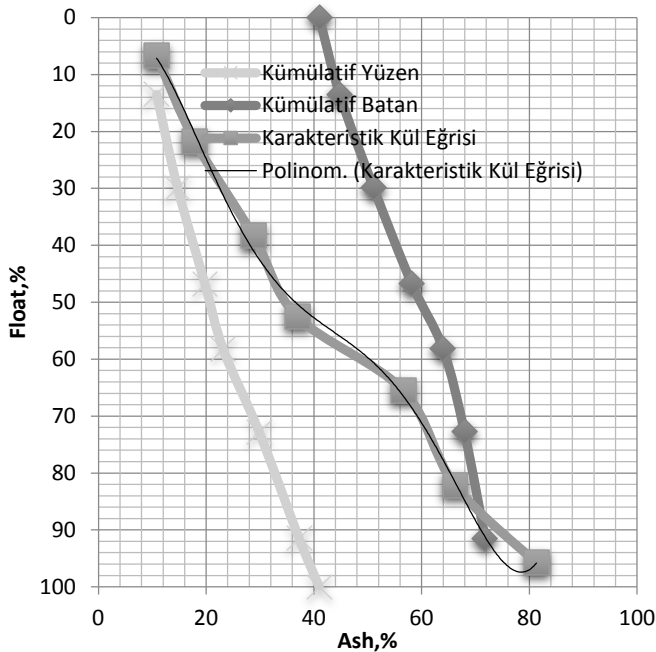


Figure 2. Characteristic Curve of Sırnak Asphaltite Coal Ash.

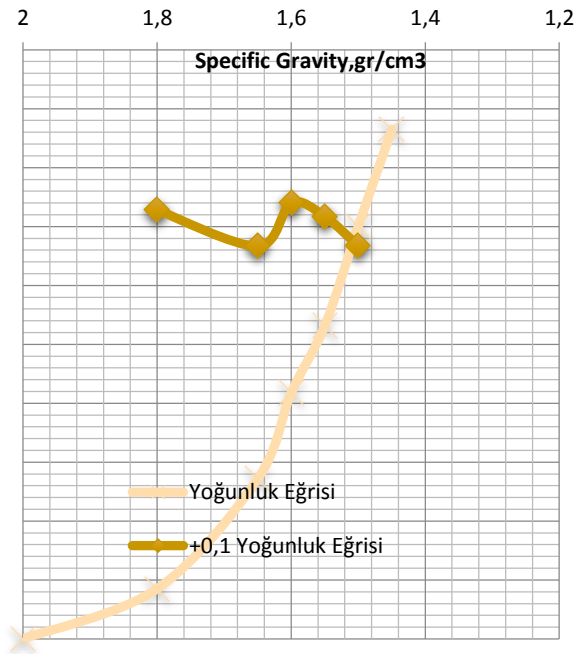


Figure 3. Curves of Sırnak Asphaltite coal washability.

tuvenane the weight of the sample in the flotation-immersion tests were represented in 56% water and 23.7% ash clean coal can be floated in a weight ratio of 58.2% intensity 1.6. 29.7% ash clean coal can be floated in a weight ratio of 68.2% concentration of 1.65. This identifies that has a heavy concentration of coal. 0.1 intensity change in the intensity curve 30% (> 10%) and the gravity washing jig such as a table is determined to be effective.

3. Results and Discussions

3.1 Washing Coal with Humphrey spirals

The representative samples in -3 + 0.5 mm grain size fractions in laboratory studies washability test was determined by the spiral. It made 5 pieces of test results mixed clean coal and shale waste yielded quite good results. -3 + 0.5 mm grain size fractions obtained from the washings with the Humphrey spiral results are given in Table 3 t.

Table 3. washing Sirnak coal Asphaltite spiral of -3 ± 0.5 mm particle fraction, Test Values in (Run-of- mine coal by weight of 26.3%, 65.7% of the coal fine)

| Products | Weigh t,% | Ash, % | Ash Content,% | Comb. Sulfur,% |
|------------|-----------|--------|---------------|----------------|
| Clean Coal | 45 | 28 | 30,80685 | 4,40 |
| Mikst | 15 | 42 | 15,40342 | 4,90 |
| Shale | 40 | 55 | 53,78973 | 7,80 |
| Feed | 100 | | | |

26.3% by weight of the crusher-run coal (-3 + 0.5) of the washing in mm size fraction is observed with the 57.5% yield of coal ash dust could be recovered as 28.4% Table 3 asphaltites.

3.2 Washing with the Coal Flotation

1 liter Denver laboratory flotation cell for clean coal coal flotation tests were used to produce mixed and waste products. 3 min 3 min in duration and fitness testing coal, flotation time was used for 2min mixed. 20% solids / IV ratio was studied in a mixing speed 1500rpm. Coal flotation tests, kerosene 300 g / ton MIBC 400 g / t conditioned 70.52% to 56.28% of coal have been won as coke yield 24.3% ash washed coal ash coal crusher-run 61% of the content will be longer shale (see Table 4).

Table 4. Wash with Asphaltite Sirnak Coal Coal Flotation Test Values of 0.5 mm grain class. (Run-of- mine coal by weight of 17.9%, 42.3% of the coal dust)

| Prod ucts | Weig ht% | As h, % | Ash Content % | Comb.S ulfur,% | Sulfur Content, % | Comb.M atter% | Comb Yield % |
|-----------|----------|---------|---------------|----------------|-------------------|---------------|--------------|
| C Coal | 42 | 24 | 24,24 | 5,50 | 39,74 | 70,50 | 56,28 |
| Mik st | 18 | 35 | 15,15 | 5,90 | 18,27 | 59,10 | 20,22 |
| Shal e | 40 | 63 | 60,60 | 6,10 | 41,98 | 30,90 | 23,49 |
| Feed | 100 | | 100 | | | | 100 |

Crusher-run coal can be washed with some weighing as high as 17.9% when the flour and powdered coal slimes on my

reputation for 42.3% constituting 0.5 mm grain size Şırnak asphaltites flotation yields were obtained. This is thought to be caused by asphaltites bitumen content. However, shale and coal have also been coupled in parallel as clean coal product. The cumulative result of the mixed clean coal obtained from the test; 76.5% side with an efficiency of 28.4% can be recovered as pulverized coal ash product is seen from Table 4.

3.3 Washing with the Coal Column Flotation

Representation of -0.5 mm samples are reduced to grinding - 100mikro controlled size. 1 m glass column 3 cm in diameter laboratory column cell flotation cell used in the coal and reagents used in conventional flotation column flotation tests were performed in the tests. Coal column flotation tests kerosene 300 g / ton MIBC 400 g / t were conditioned foam height is kept constant at 30 cm. Zero Bias ratio is used to produce clean coal and shale waste products. flotation time was used for 3 min and 5 min time condition coal in tests. 20% solid / liquid ratio of 200 ml / min were studied in the wash water.

Column flotation tests results from clean coal, shale waste can be taken as % sulfur and ash yield Equilibrium distribution is given in Table 5. Accordingly (-100mikro's) mm grain size in Şırnak asphaltites is mixed with clean coal all 66% in cumulative yield ops will be thrown when earned as coal is washed. 24.3% ash content of the ash in coal 64% shale waste (Figure 4).

Table 5. Washing Sirnak Asphaltite with Column Flotation of Coal -0.1 mm particle fraction, Test Values (Run-of- mine coal by weight of 10.7%, and 35.2% of the coal dust)

| Prod ucts | Weig ht% | As h, % | Ash Content % | Comb.S ulfur,% | Sulfur Content, % | Comb.M atter% | Comb Yield % |
|-----------|----------|---------|---------------|----------------|-------------------|---------------|--------------|
| C Coal | 35 | 22 | 18,68 | 5,40 | 32,55 | 72,60 | 47,94 |
| Mik st | 10 | 27 | 6,55 | 5,60 | 9,64 | 67,40 | 12,71 |
| Shal e | 55 | 56 | 74,75 | 6,10 | 57,79 | 37,90 | 39,33 |
| Feed | 100 | | 100 | | | | 100 |

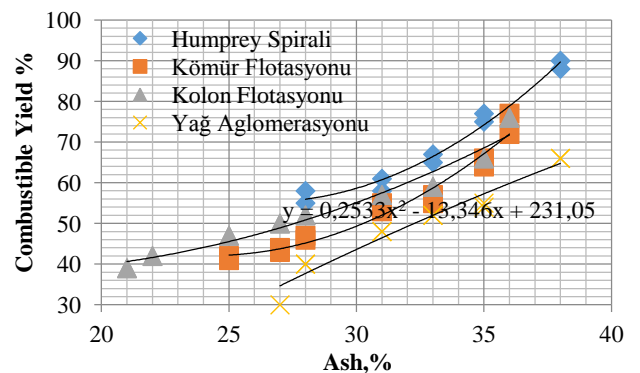


Figure 4. Clean Coal Ash connected Asphaltite Sirnak Coal Washing Powder Unit Size Yield Value of Coal Airports efficiency of clean coal products produced from the results of tests of the spiral 26% to 84% of coal ash has fallen 52% value. Flotation test results produced for the clean coal product yields from 74% to 24% of the coal ash has fallen

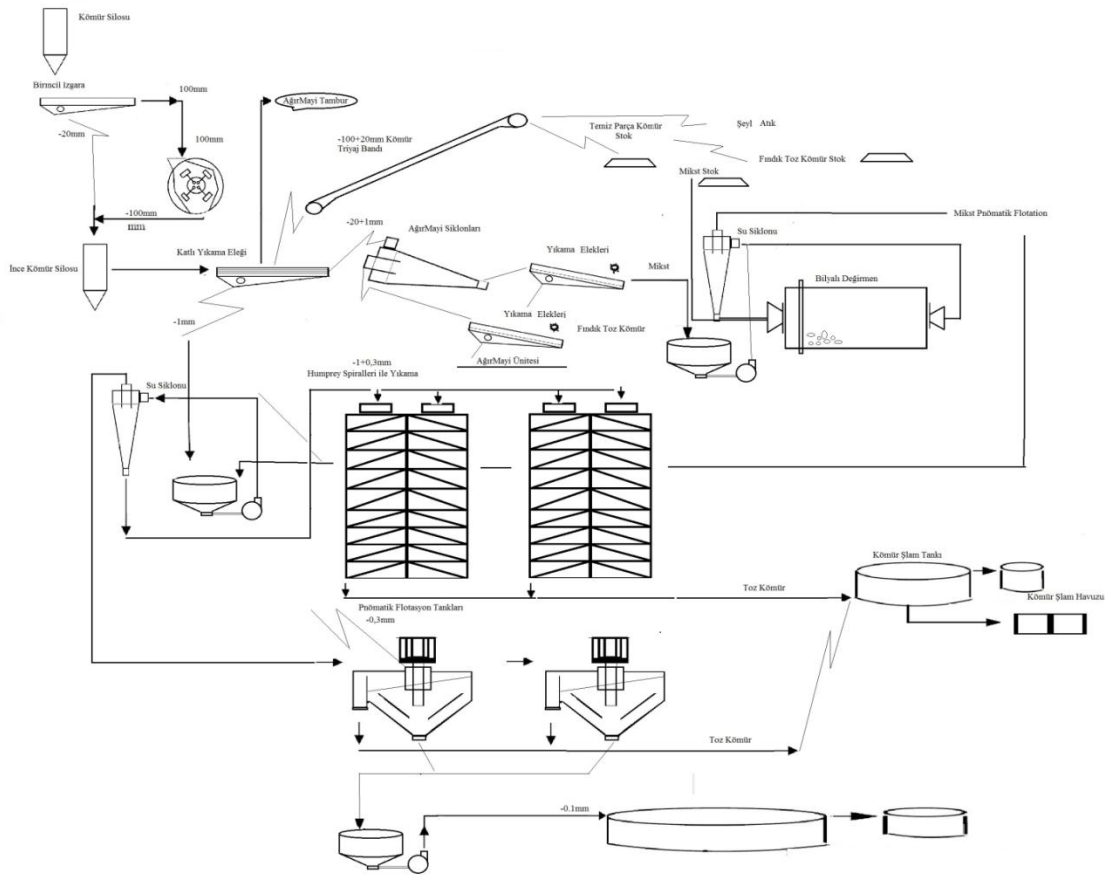


Figure 6. The general flowsheet of Project Design B for Sirnak Asphaltite washing facility.

According to the demand of coal washing plant tuvenane \$ 21 /tonne will be washed in monetary value is purchased at washery plant. The proposed facility will be made for thin washes washing and coal dust. The cyclone dust slimes dimensional asphaltites with slim size products will be washed with flotation unit. 43.40% and 25.4% ash of washed fine coal dust (-2 + 0.5 mm) will be produced. The weight ratio of the coal slimes was of 6.7% and average ash will be 25.4%. Clean coal with 25.4% ash was produced from Şırnak asphaltites and was containing 4.7% combustible sulfur with 7,200 kcal/kg, lower heat value (Table 6), washed coal can be used as the equivalent heating fuel asphaltites be produced. 120 million tons, 160 million tons of visible-Şırnak asphaltites are possible reserves.

Table 6. Cost Analysis Results of Sirnak Coal Washing Plant Products

| Mining Cost | B 500 thousand ton/y | A 1 million ton/y | A 3 million ton/y | B 1 million ton/y | B 3 million ton/y |
|---------------------------|----------------------|-------------------|-------------------|-------------------|-------------------|
| Coal excav cost | 20 | 20 | 20 | 20 | 20 |
| logistics | 25 | 25 | 25 | 25 | 25 |
| Land scraping | 15 | 15 | 15 | 15 | 15 |
| Environmental restoration | 13 | 13 | 13 | 13 | 13 |
| Project Engineering | 12 | 12 | 12 | 12 | 12 |
| Total | 90 | 90 | 90 | 90 | 90 |

70-74% of the ash in the coal is now able to be taken (see Table 3-4-5) in washing plant. This reserve of 1 million tons / year can be operated with production capacity of more than 80 years. In the washing process to be made to the proposed design of the facility, facility was capable of 1.7 g/cm³ density in the wash, year; as household fuel (19-10 mm) 450 000 tons, industry as fuel (-10 / -0.5 mm) is 200 000 tons, as the central

fuel (-10 + 2 mm; 35% ash mixed asphaltites) washed 135 000 tons of asphaltite be produced (Table 5).

Table 7. Operation Cost Analysis of Sırnak Coal Washing Plant

| Operation Cost | 500bin ton/yıl | 1milyon ton/yıl | 1 milyon ton/yıl | 2 milyon ton/yıl |
|------------------------|----------------|-----------------|------------------|------------------|
| Worker | 14 | 14 | 14 | 14 |
| Electricity | 10 | 10 | 10 | 10 |
| Chemicals | 2 | 2 | 2 | 2 |
| Media | 4 | 4 | 4 | 4 |
| Fix | 12 | 12 | 12 | 12 |
| lending | 40 | 40 | 40 | 40 |
| Social expenses | 5 | 5 | 5 | 5 |
| Management-Engineering | 3 | 3 | 3 | 3 |
| Total | 90 | 90 | 90 | 90 |

Facility will produce 350 000 tons of washed coal equivalent is around 750 000 tons of runoff- mine coal. as heating fuel in Şırnak washed coal, coal will be saved, but instead use unwashed (150 000 tons/year) to 1.2 million per year cost of transportation is. With approximately \$ 35 million facility B investment capital, current bank interest rates (7%) and will be produced annually 600 thousand tons of washed coal and 135 thousand tons of mixed product's total annual operating costs 39.32 per / ton and a ton of washed tons of coal in the plant washing costs approximately £ 60.68/ton would be calculated (Figure 7).

The cost calculation equations of the plant,

- Calculation of unit cost of the facility,
- Calculation of the investment costs of the facility at which it will go into production,
- Plant operating costs and the calculation of the annual income,

$$TV_C = T_x + F + O_{m\&o} + D \quad (1)$$

$$Q(n) = 8760xCF(n)xK \quad (2)$$

where R is the revenue, Q is the capacity, P is the sale price, r is the interest rate, m is month, n is the integer of month, E is investment cost, f is debt rate, c_m is capacity factor, L is the debt, u cost function, t is time, Θ is the time unit parameter.

$$R(n) = Q(n)xP(n) \sum_{m=1}^M 1/(1-r)^{M-m} \quad (3)$$

$$E(0) = (1-f) \sum_{m=1}^M Cm(1+r)^{M-m} \quad (4)$$

$$L(0) = f \sum_{m=1}^M Cm(1+r)^{M-m} \quad (5)$$

Storage may greatly affected by the cost of storage material and process units complexity. The proposed cost of

investment were depending on flow rate of stored material and conversion to heat or energy as given below.

As given Table 7 the cost distribution changed by model type and capacity. Risk point was similar to both models. As shown in Figure 7 risk parameters occurred in the projected cost risk analysis. As seen in Fig 7 the capital cost was ranged up to 180 million \$ for washing plant A.

$$u(x; t; \theta) = \sum_{i=0}^n u(x, t) + \phi(x; t; \theta). e^{-ti\theta} \quad (6)$$

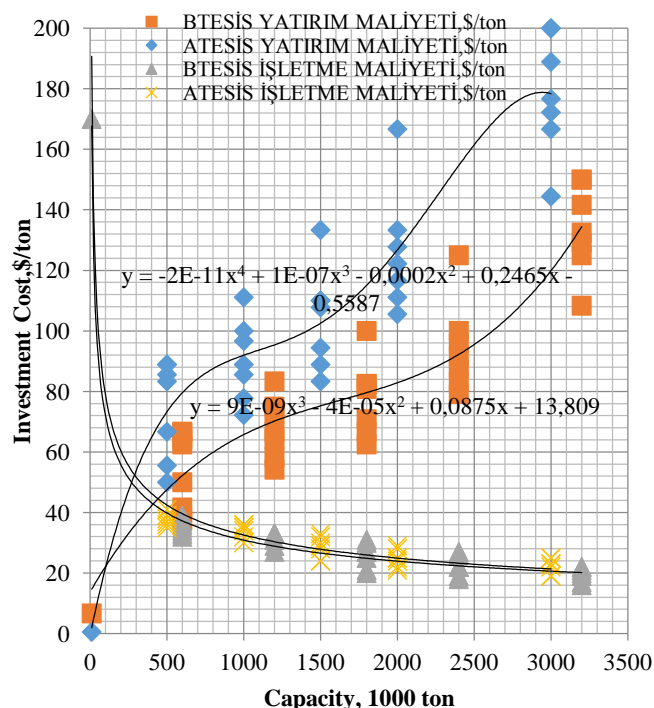


Figure 7. Variation of the project Capacity of the Facility Investment and Operating Costs

5. Conclusions

Due to the high ash content of Şırnak asphaltites and show that conventional flotation can be as low column flotation The yield was also determined not reduced sufficiently, as well as clean coal product can be sulfur. 42 % ash in the coal washing plant material 62 %'is being removed from the coal. 38% of the combustible sulfur can be disposed .

Clean asphaltite with 25.2% ash could be produced in washing process, if carried out, and would have the 4.3% combustible sulfur, and a 6700 kcal/kg, lower heat value could be beneficial for both heating and for industrial boilers using washed clean fuel.

This washing application should be mandatory. Especially the company off-product quality, excavated shale rocks of the same color will be involved in the production by mixing will be reduced. Also washing process because there is very little difference between the density of the shale and coal will be more difficult.

The washing capacity of 1 million tons/ year planned to be installed capacity washing plant at the time of commissioning of about £ 39,4% of the cost is due to the burden of interest on the amount in tons of coal a three-year foundation stage. £ 39/tonne capital cost and operating profit forecast by 40% when calculating the amount of coal; The cost of coal dust in the plant will produce £76/ton value reaches.

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