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# THE EQUIVALENT PRICE OF ESTONIAN OIL SHALE TO THE PRICE OF COAL

While discussing the economical development of the Estonian oil shale industry in the interim 1920—1990, E. Reinsalu [1] described two periods with the oil shale output decrease in Estonia. The first period, 1941—1945, with the average yearly decrease of 7.6 %, was delimited by the World War II. The second period of decrease started after 1980 and is still going on. For the interim 1981—1990, the average annual decrease of the output was 3.4 %. The initial annual output when the decrease started was 31.3 million tonnes and it has fluently subsided to 19 million tonnes in 1991. According to [1] it is not clear whether the decline is temporary or it is the onset of the extinction of oil shale industry after the resources have been exhausted?

Today six underground and four open pit oil shale mines operate in Estonia. Their total resource for commercial output in 1991 was approximately 0.6 billion tonnes [2]. As a result of the exhaustion of their resources between 1993—2025 the majority of existing today oil shale mines in Estonia will be closed. On the basis of the rest of their 0.6 billion tonnes resource only one underground and one open pit mine will remain in operation after 2025. The 0.6 billion tonnes net resource is today included to the existing mines and no supplementary payment for the land as well as royalties is necessesary. That is not the case with new mines to be opened on the basis of additional oil shale resources. We can conclude from the above that the decline of oil shale output in Estonia results from the exhaustion of the cheapest available local resources.

The equipment of oil shale power stations as well as that of the oil shale processing units will be exhausted mainly during the first decade of the next century or even earlier [2]. Taking into account that in 1991 approx. 87 % of Estonian oil shale output (84 % in energy units) was utilized at the electricity generating stations, the primary energy resources must guarantee a lifetime of 30—40 years for the investments made in the first decade at electricity generating stations. For this purpose, new oil shale mines based on new resources should be opened. As an alternative to the oil shale as a fuel for power generating in Estonia imported hard coal can be used, in particular for the combined combustion with oil shale in CFB-boilers. The latter method enables to overcome the air quality problems and to do it without expensive desulphurization equipment [3]. With an alternative fuel at disposal we get search prices for both fuels that when exceeding one of them the other looses its competitiveness.

The price of oil shale has not been quoted at the international market while the price of the alternative fuel — imported hard coal has been. So, the oil shale must have an equivalent price to the price of coal, which will be the highest price for oil shale that a power generating station can afford. By higher price than the equivalent price the imported coal begins to compete with oil shale as a fuel. The International Union of Producers and Distributors of Electrical Energy (UNIPEDE) has presented long-term prognoses of international fuel prices for investment planning in the electricity generating stations.

The assessment of UNIPEDE from January 1991 [4] presents a forecast of fuel prices to the interim 2000—2030, taking into account that the lifetime of a thermal power plant is approx. 30 years. Forecasted price scenarios are needed to identify relative competitiveness of different types of generating stations. Assumptions for common coal price (CIF-price) were adopted by UNIPEDE: two extremal scenarios, high and low, covering the forecast values proposed by the experts of various countries and the medium scenario as the averaged version of them are presented in Table 1.

*Table 1.* **UNIPEDE 1991 coal price assumptions**

| Coal common price scenarios | Year | | | |
|---|---|---|---|---|
| | 2000 | 2010 | 2020 | 2030 |
| **Price US$-1990 per tonne** | | | | |
| High | 50 | 58 | 67 | 78 |
| Medium | 46 | 52 | 56 | 62 |
| Low | 42 | 45 | 45 | 45 |
| **Price ECU/t (1 ECU/t = 1.168 US$)** | | | | |
| High | 43 | 50 | 57 | 67 |
| Medium | 39 | 45 | 48 | 53 |
| Low | 36 | 39 | 39 | 39 |
| **Price ECU/GJ (1 tonne coal = 25.54 GJ)** | | | | |
| High | 1.7 | 1.9 | 2.2 | 2.6 |
| Medium | 1.5 | 1.7 | 1.9 | 2.1 |
| Low | 1.4 | 1.5 | 1.5 | 1.5 |

The UNIPEDE l o w s c e n a r i o assumes a moderate growth in coal prices of around 0.7 % a year up to the year 2010, and following stable price of 45 US$/t. The h i g h s c e n a r i o with a high world economic growth assumes a rapid rise in prices: a price of 50 US$/t in 2000, subsequently increasing at a rate of 1.5 % a year. The equivalent price of an unit of the energy (MWh, GJ, kcal, BTU) of oil shale to the price of it in coal is determined according to relative effectivity by electricity generation in the oil-shale- and coal-fired-power stations.

The thermal efficiency of a coal-fired power plant is between 0.38 and 0.42. The same at oil-shale-fired power plants is limited in average with a net efficiency of 0.28. This low efficiency is a result of chlorine-caused corrosion and ash fouling of heating surfaces. The maximum steam temperatures in pulverized oil-shale-burning boilers are limited by steel corrosion at 515—520 °C while decreasing during a 10 weeks nonstop run approximately to 480—490 °C. The steam temperatures at coal-fired blocks are stable and reach 550—570 °C. So, the thermal efficiency of an oil-shale energy-generating block will be only 0.67—0.75 compared to that at a modern coal station.

During the combined combustion of coal and oil shale in CFB-boilers the heat surfaces corrosion and fouling activity of shale fly ash is due to low temperature combustion suppressed. So, the thermal efficiency of power generation can be higher than in the stations with high temperature pulverized oil-shale combustion. The efficiency of such a station can rise up presumably to 0.32—0.34 or approximately to 0.85 from the thermal efficiency of a coal station. The operation and maintenance (O & M) costs as well as capital costs at a pulverized oil-shale-fired station are higher as at a coal station.

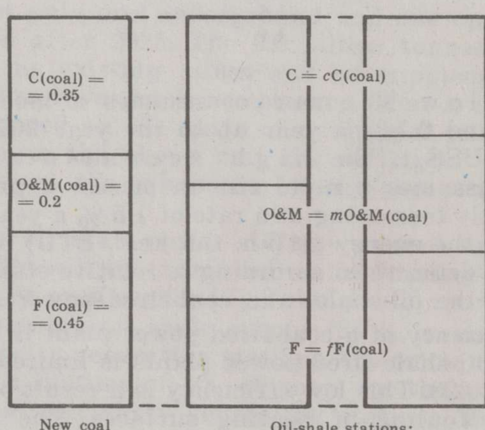
Specific repairs of boiler units inside the boilers as well as repairs of fuel- and ash handling equipment increase the O & M costs. O & M costs for planned coal stations in different countries are from 0.45—0.5 cECU/kWh in the Netherlands, Portugal and Canada up to 1.05—1.25 cECU/kWh in Belgium and Japan, in average 0.72 cECU/kWh. The maximum O & M costs in Europe are 1.45 times higher than the average O & M costs. There is no reason to evaluate that the O & M costs at a new pulverized oil shale burning station will be lower than their maximum values for coal stations.

The capital costs for coal stations vary from 0.95 (the Netherlands) to 1.6 (Italy) in Europe and 1.8 in Japan. The maximum of capital costs in Europe is approximately 1.2 times over their average (1.36 cECU/kWh). But the investment cost of a 215 MWel pulverized oil-shale boiler is approximately on the level of the investment cost of a 400 MWel lignite fired boiler. So, the capital cost per kWel for an oil shale boiler unit will be approximately 1.7—2 times higher than for the lignite boiler unit, and the additional investment cost per kW for an oil shale station will be about 15—20 % over these of the lignite (brown coal) station or 25—35 % more than at the coal station.

Marking the ratio between the oil shale equivalent price and the price of hard coal by $r$, the value of $r$ will be:

$$r = f(k, c, m),$$

where $k$ — is the ratio between the thermal efficiency of an oil-shale electric power station and that of a coal station;




Relative costs of electricity generation for the equal price of coal- and oil-shale-generated electricity in Estonia.

The equivalent price of oil shale as a fuel to the price of coal is determined by the coefficient

$$r = kf = k = \frac{1 - cC(\text{coal}) - mO\&M(\text{coal})}{F(\text{coal})}$$

where — C, O &M and F = 1 — C —O & M are the capital, O & M and fuel cost components by electricity generation;
— $c$, $m$ and $f$ are the ratios between the costs components at oil shale and coal stations;
— $k$ is the ratio between the thermal efficiency at an oil shale station and that of a coal station

$c$ — is the ratio of capital costs per kWh;
$m$ — is the ratio of O & M costs per kWh.

The determination of $r$ is explained in the Figure.

For a new pulverized oil-shale-combustion station with $k = 0{,}85$, $c = 1.25$—$1.35$ and $m = 1.5$, the value for $r$ will be:

$$r = 0.43\text{—}0.50 = \text{approx. } 0.45.$$

For a reconstructed oil-shale plant with minimum investment costs the capital costs per kW of reconstruction will be approximately 50—60 % of the cost at a new station, accordingly with $c = 0.65$—$0.8$. In this case, with $k = 0.85$ and $m = 1.5$, the value for $r$ will be:

$$r = 0.79\text{—}0.93 = \text{approx. } 0.9.$$

By making the presented calculations we assumed that the construction, installation and maintenance costs in Estonia between 2000—2030 will be on the same level as in the Central Europe.

*Table 2.* **Oil shale equivalent energy price to forecasted by UNIPEDE coal energy price for the interim 2000—2030, ECU/GJ**

| Year | Eqivalent oil shale price scenarios ($r = 0.45$) | | |
|---|---|---|---|
| | High | Medium | Low |
| 2000 | 0.80 | 0.70 | 0.60 |
| 2010 | 0.90 | 0.80 | 0.70 |
| 2020 | 1.00 | 0.90 | 0.70 |
| 2030 | 1.20 | 0.95 | 0.70 |

*Table 3.* **Oil shale average equipment prices in Estonia for the interim 2000—2030, ECU/t**

| Year | Average value of oil shale, GJ/t | Oil shale price scenarios ($r = 0.45$) | | |
|---|---|---|---|---|
| | | High | Medium | Low |
| 2000 | 9.6 | 7.3 | 6.5 | 6.0 |
| 2010 | 9.9 | 8.5 | 7.6 | 6.7 |
| 2020 | 8.6 | 8.5 | 7.4 | 5.8 |
| 2030 | 6.7 | 7.8 | 5.7 | 4.5 |

In Tables 2 and 3 the equivalent oil shale prices are presented for the interim 2000—2030. The annual output of oil shale in Estonia in Table 3, is the output from the resource 0.6 billion tonnes, included to the Estonian mines in 1991 [2]. By higher oil shale prices than given in Tables 2 and 3, the imported hard coal will remain economically more preferable as fuel for Estonian electricity generating thermal power plants. But the equivalent price of oil shale as a fuel may be substantially higher in case of economic crisis situation, for example as in the Baltic States at the time of the collapse of the Soviet economy. In such a situation the capital costs can be reduced to minimum and there are also essentially lower O & M costs taking into account the lag of real wages and salaries in this situation. With $c$ approx. 0 and $m$ approx. 1—1.2, the value of $r$ will be about 1.3—1.5. In this case, the energy in oil shale has the higher value compared with the energy in imported coal, and the equivalent price of Estonian oil shale will be approx. 18—25 ECU a tonne.

Due to the lack of the calculations based on hard currency (excluded [5]) and of estimates for Estonian oil shale electricity generating projects, some data in the present paper could be disputable and need to be specified.

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