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MODELLING OF DEVELOPMENT SCENARIOS OF THE ESTONIAN FUEL—ENERGY COMPLEX

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Some results of the research work concerning economic-ecological modelling of the Estonian fuel—energy complex are discussed. The changing economic situation in the Estonian oil-shale industry and power engineering is analysed. The principles of the modelling of the fuel—energy complex as well as the results of formation and solution of the corresponding numerical model are presented. Possible development scenarios of the Estonian oil-shale industry and power engineering are constructed for the nearest years as well as for a longer period using dialogue analysis.

The disintegration of the Soviet Union and Estonia's transition to a market economy and the restructuring processes have caused a decline in the Estonian economy. In quite a number of industries the decline and structural changes have been quite essential. Among them there is also Estonian fuel-energy complex (FEC). As it is generally known, the oil-shale-based electroenergetical system was founded in Estonia during the previous socialist period. At present the power generation capacities in this system exceed about twice the local need. At the same time, most of the heat production is based on imported fuels, prices of which have risen some ten and even some hundred times over the recent years. The energy system as a whole is in bad technical condition, uneconomical and contaminating for the environment, the Estonian energy balance is negative. Under such conditions it is obviously unavoidable to use sustainable management strategies in the energy sector as well as in other industries.

The principles of the sustainable development and their application in economic-ecological modelling of the Estonian FEC have been thoroughly investigated at the Institute of Economics of the Estonian Academy of Sciences under the supervision of Prof. I. Kaganovich [1—3]. Based on these works this article discusses the possibilities of modelling the development of the Estonian FEC, taking into account the changes outside the complex (in other industries) as well as the economic situation in general. The main method of investigation is dialogue analysis with the help of the linear optimization model. This model describes on the one hand the relations in the Estonian FEC as well as in the spheres directly connected with the FEC, and on the other hand, the results of economic activity. Several optimization problems are solved according to this model. These problems actually simulate different economic conditions and the corresponding optimal solutions can be interpreted as optimal scenarios of the development of the Estonian FEC.

1. SURVEY OF THE PRESENT SITUATION IN FEC

1.1. Consumption of fuels

The consumption of fuels in Estonia had stabilized at about 430 PJ (15 million t c. e.) a year in the second half of the 1980s. In 1991 the consumption started to decline, in 1992 and 1993 the decline accelerated even further. The reduction of the consumption of imported fuels was especially noticeable in 1992: as compared to 1991, the consumption of imported fuels dropped by about 50%, while the total consumption of fuels dropped by 26% (Table 1). As to the imported fuels, the decrease in the consumption was most drastic in the case of natural gas. So in 1992 the consumption of natural gas was 40% and in 1993 55% smaller than in the previous year.

The rapid reduction in the consumption of imported fuels in recent years has been caused on the one hand by the general decline of production in Estonia, on the other, by the tremendous relative rise in the prices of fuels. The reduction in the consumption of fuels has been especially remarkable in construction, agriculture and industry. In these sectors the reduction is directly connected with the decrease in the production volume. For example, the industrial output decreased by 39% in 1992 as compared to 1991 (at June 1992 prices), and the consumption of fuels in industry declined by 38%.

Table 1

Consumption of fuels in Estonia [4—8]

Fuel	1990	1991	1992	1993	% 1991/1990	% 1992/1991	% 1993/1992	% 1993/1990
Total, PJ	431.9	399.3	295.9	225.2	92.4	74.1	76.1	52.1
1. Domestic:	239.9	219.7	201.2	158.8	91.6	91.6	78.8	66.2
oil shale	223.6	203.1	178.4	143.3	90.9	87.8	80.3	64.1
firewood	7.4	7.5	6.7	2.2	101.4	89.5	32.8	29.7
peat	5.3	5.7	4.1	3.1	107.7	70.6	75.7	58.5
peat briquette	3.6	3.3	2.6	1.9	92.7	77.9	71.6	52.8
wood waste			1.2	1.0			83.3	
shale oil			8.3	7.3			88.0	
2. Imported:	192.0	179.6	94.7	66.6	93.5	52.8	70.3	34.7
heavy fuel oil	64.4	57.4	25.5	29.5	89.1	44.4	115.8	45.8
natural gas	51.1	51.3	30.0	13.5	100.3	58.5	45.1	26.4
petrol	22.9	20.7	10.0	6.2	90.4	48.2	62.3	27.1
diesel oil	25.7	24.9	16.4	12.2	97.0	65.7	74.6	47.5
light fuel oil	6.5	5.2	1.5	2.0	80.4	28.5	134.3	30.8
coal	9.5	9.3	5.6	2.9	97.5	60.9	51.5	30.5
liquefied gas	1.2	1.1	0.4	0.3	94.1	40.6	60.0	25.0
heavy fuel oil for fleet	4.7	4.5	4.6		96.6	101.8		
others	6.2	5.3	0.8		85.2	14.8		

1.2. Production of electric energy

The decline in the consumption of fuels is directly connected with the decline in the production and consumption of electricity. As compared to 1991, the consumption of fuels for the production of electric energy decreased in 1992 by 20%, while the production of electric energy itself decreased by 19%. The falling production and consumption of electric energy are related to the slowdown of production in other sectors, mainly in industry. The reduction has been especially notable in the case of such energy-intensive products as mineral fertilizers, pulp and paper, building materials. The consumption of electric energy has decreased considerably also in agriculture.

Table 2

The electric energy balance of Estonia, TWh *

	1990	1991	1992	1993	% 1993/1990
Output of power plants	17.18	14.50	11.74	9.02	52.5
Own needs of power plants and energy system	2.08	1.72	1.49	1.10	52.9
Net production of electricity	15.09	12.94	10.37	7.92	52.5
Losses of electric energy	1.14	1.09	1.03	1.47	128.9
Sold to consumers	13.97	11.69	9.22	6.45	46.2
incl. in Estonia	6.97	6.92	5.73	4.85	69.6
export	7.00	4.77	3.49	1.60	22.8

* Data of State Statistical Office and "Eesti Energia".

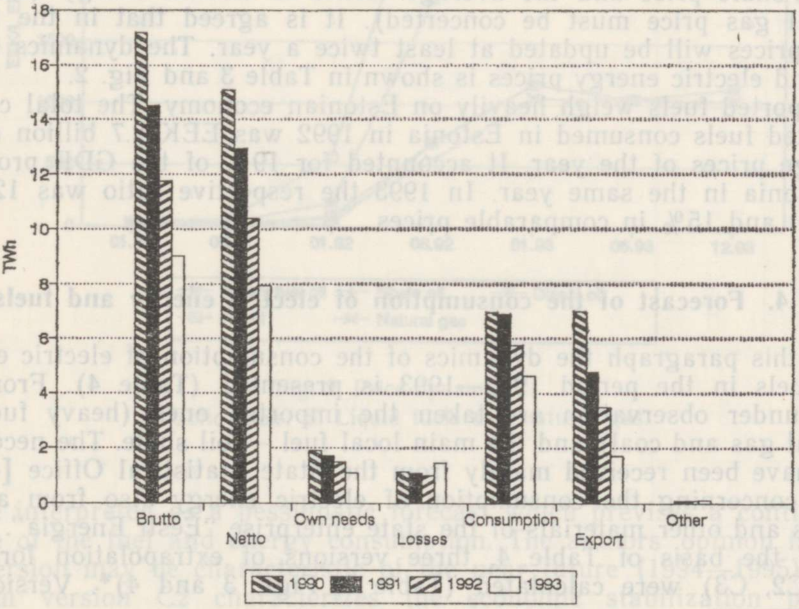

Fig. 1. Electric energy balance.

The reasons for the reduction of the export of electric energy were the following. As the Estonian Power System (state enterprise "Eesti Energia") has been a part of the North-West Interconnected Power System of the European part of the Soviet Union, its exchange of energy with the neighbouring areas — the Leningrad and Pskov oblasts and Latvia — was fixed by the energy balance of the whole system. To guarantee the stability of the system, these relations were also maintained after Estonia regained independence. However, as a general decline of economy was characteristic of both Russia and Latvia, the consumption of electric energy decreased in these countries as well and therefore their need to import power from Estonia also dropped. The rising energy and fuel prices coerce into saving power and better utilization of local resources. For example, Latvia has put its hydroelectric stations, which for some time had been idle, to the maximum use. The electric energy balance of Estonia is shown in Table 2 and Fig. 1.

A decrease of energy production means that the capacity of power plants is loaded ineffectively and thus the own consumption of power plants and losses in transmission are considerably big.

Due to the decrease of energy production the oil-shale consumption for electricity generation decreased from 22.4 million tons in 1990 to 12.6 million tons in 1993.

1.3. Prices of fuels and energy

The shortage prices of fuels in Estonia as a part of the former Soviet Union had, for a long time, been lower than the world market prices.

When Estonia began to introduce reforms aimed at the transition to a normal market economy, it was inevitable that the prices of fuels had to go up. The prices of most imported fuels were liberated, and in a very short period they rose almost to the world market level. Since 1993 the prices of most imported fuels have been stabilized.

At present, in the first half of 1994, the Estonian government controls the oil-shale price and the average tariffs of electric energy (also the natural gas price must be concerted). It is agreed that in the future these prices will be updated at least twice a year. The dynamics of the fuel and electric energy prices is shown in Table 3 and Fig. 2.

Imported fuels weigh heavily on Estonian economy. The total cost of imported fuels consumed in Estonia in 1992 was EEK 2.7 billion at the average prices of the year. It accounted for 19% of the GDP produced in Estonia in the same year. In 1993 the respective ratio was 12% in current and 15% in comparable prices.

1.4. Forecast of the consumption of electric energy and fuels

In this paragraph the dynamics of the consumption of electric energy and fuels in the period 1989—1993 is presented (Table 4). From the fuels under observation are taken the imported ones (heavy fuel oil, natural gas and coal) and the main local fuel — oil shale. The necessary data have been received mainly from the State Statistical Office [4—8], those concerning the consumption of electric energy also from annual reports and other materials of the state enterprise "Eesti Energia".

On the basis of Table 4, three versions of extrapolation forecasts (C1, C2, C3) were calculated (Table 5, Figs. 3 and 4)*. Version C1

* The statistical data for 1993 are preliminary and may be adjusted, so in forecast calculations were used data for the period 1989—1992.

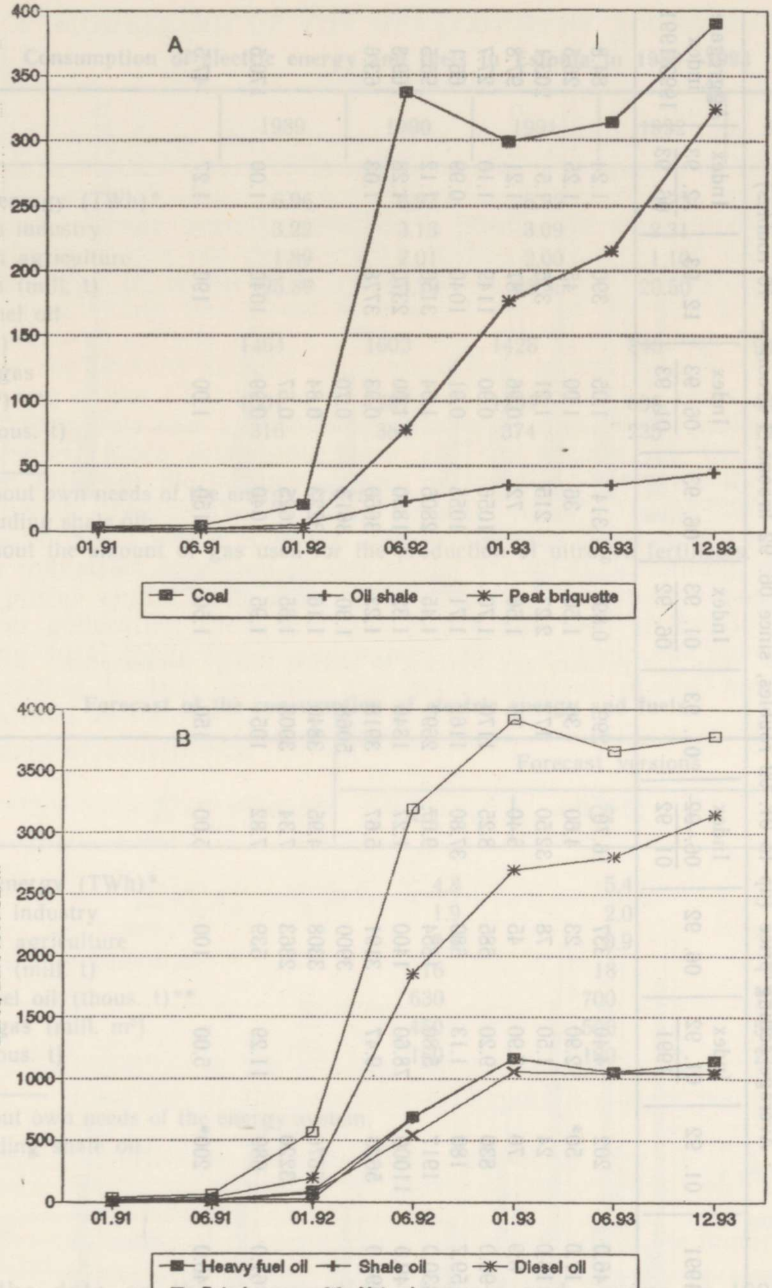

Fig. 2. Price dynamics.
A. Solid fuels. B. Liquid fuels and natural gas.

can be interpreted as a pessimistic forecast which previses a continuing decline of the fuel and energy consumption. The authors' opinion is that this version may be characteristic of the near future (1994—1995). The medium version C2 characterizes the economic stabilization period, presumably in 1996—1999. A more optimistic forecast version C3 corresponds to the economic rise which may start in 2000.

Table 3

Development of prices [9]

Fuel	Unit	Average selling price (up to 01. 92 roubles, since 06. 92 kroons, 1 kroon = 10 roubles)											
		1991	01. 92	Index 01. 92 / 1991	06. 92	Index 06. 92 / 01. 92	01. 93	Index 01. 93 / 06. 92	06. 93	Index 06. 93 / 01. 93	12. 93	Index 12. 93 / 06. 93	Aggregate index 1993/1991
Coal	t	46.0	202	4.40	337	16.70	299	0.89	314	1.05	390	1.24	84.8
Oil shale	t	17.0	50*	2.90	23	4.60	36	1.60	36	1.00	45	1.25	26.5
Peat briquette	t	16.0	24	1.50	78	32.50	177	2.27	215	1.21	325	1.51	203.1
Firewood	cu. m	8.9	70	7.90	45	6.40	75	1.66	72	0.96	87	1.21	97.8
Heavy fuel oil	t	90.0	830	9.20	685	8.25	1170	1.70	1056	0.90	1149	1.10	127.7
Shale oil	t	159.7	180	1.13	680	37.80	1162	1.71	1055	0.91	1040	0.99	65.1
Diesel oil	t	330.0	1917	5.80	1854	9.67	2697	1.45	2805	1.04	3150	1.12	95.5
Light fuel oil	t	140.0	11000	78.60	1400	1.27	1846	1.32	1850	1.00	2370	1.28	169.3
Petrol	t	594.0	5623	9.47	3191	5.67	3918	1.23	3660	0.93	3778	1.03	63.6
incl. A-95	t				3900		5068	1.30	3613	0.70			
A-93	t		6676		3308	4.95	3840	1.16	3223	0.84			
A-76	t		3220		2363	7.34	3905	1.65	2625	0.67			
Natural gas	1000 cu. m	61.0	689	11.29	539	7.82	1051	1.95	1040	0.99	1040	1.00	170.5
Electric energy	MWh	40.0	200*	5.00	100	5.00	150	1.50	150	1.00	190	1.27	47.5

* Since 17. 01. 1992.

Table 4

Consumption of electric energy and fuels in Estonia in 1989—1993

	1989	1990	1991	1992	1993
Electric energy (TWh)*	6.96	6.97	6.92	5.73	4.85
incl. in industry	3.22	3.13	3.09	2.31	1.90
in agriculture	1.89	2.01	2.00	1.10	0.78
Oil shale (mill. t)	25.89	25.70	25.35	20.50	16.47
Heavy fuel oil (thous. t)**	1464	1603	1428	846	914
Natural gas (mill. m³)***	1301	1207	1231	638	401
Coal (thous. t)	316	384	374	235	121

* without own needs of the energy system;
** including shale oil;
*** without the amount of gas used for the production of nitrogen fertilizers.

Table 5

Forecast of the consumption of electric energy and fuels

	Forecast versions		
	C1	C2	C3
Electric energy (TWh)*	4.8	5.4	5.9
incl. in industry	1.9	2.0	2.3
in agriculture	0.8	0.9	1.0
Oil shale (mill. t)	16	18	20
Heavy fuel oil (thous. t)**	630	700	770
Natural gas (mill. m³)	450	500	550
Coal (thous. t)	160	180	200

* without own needs of the energy system;
** including shale oil.

As the data on the consumption of fuels and energy in 1993 were not used in forecast calculations, we can conditionally compare these data with the forecast version C1. As we can see in Tables 4 and 5 and in Figs. 3 and 4, the accordance is quite exact as concerns electric energy and oil shale. With respect to imported fuels there are essential differences, especially concerning heavy fuel oil. So the decline in the consumption of natural gas and coal was sharper in 1993 than it was forecasted in version C1. To compensate these declines the consumption of heavy fuel oil was even increased. One reason was obviously also the colder heating season in 1993 than in the previous years. The forecast versions can be used as separate expert estimations, but in this investigation they were mainly used as the initial data for the block "Consumption" of the optimization model.

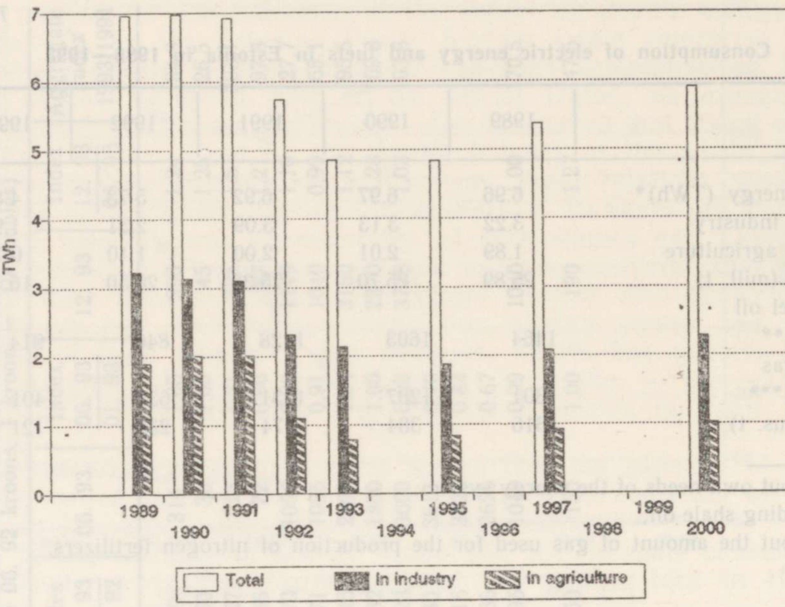

Fig. 3. Dynamics and forecast of electric energy consumption.

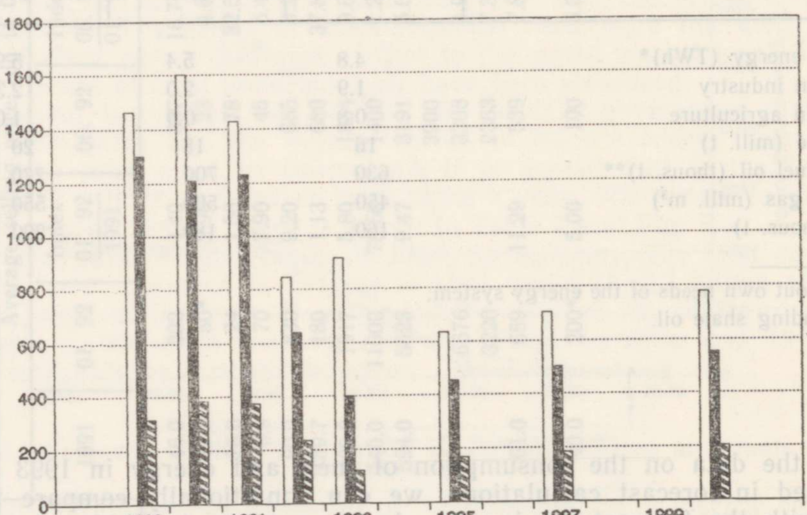

Fig. 4. Dynamics and forecast of the consumption of imported fuels.

2. MODELLING OF THE DEVELOPMENT SCENARIOS

2.1. Model description

Model analysis of the Estonian FEC was performed with the help of the deterministic linear optimization model. The defects of this choice (linearity, simplifications by not taking into account the uncertainty, etc.) have already been considered. It should be mentioned that the main attention was not concentrated on the optimality but on the fact that this type of model is a good instrument for large-scale variant calculations. Using this model it is quite easy to describe formally all the spheres of activity of the FEC under study. Changing during the dialogue the present as well as perspective initial conditions of the functioning of the FEC in the model, and analyzing the respective optimal solutions we can follow the reactions of the output parameters of the complex. More interesting here are the changes in the relations between different blocks and objects of the FEC. So with the help of simulation of the initial conditions we can finally estimate the development possibilities of the complex, and present the development scenarios.

The industries described in this model are oil-shale mining, oil-shale-based power engineering and heat production, alternative possibilities of power generation (peat and coal power and heat stations), oil-shale retorting, local consumption and import-export of fuels and energy.

According to this structure the main relations of the model may be presented as follows:

System of constraints:

$$\sum_{j=1}^{J} a_{ij}^{(t)} x_j^{(t)} \leqslant q_i^{(t)}, \quad i=1, \ldots, I, \quad x_j^{(t)} \geqslant 0; \tag{1}$$

$$\sum_{j=1}^{J} a_{kj}^{(t)} x_j^{(t)} - z_k^{(t)} \geqslant 0, \quad k=I+1, \ldots, I+K. \tag{2}$$

Objective function:

$$\sum_{j=1}^{J} P_j^{(t)} x_j^{(t)} \to \min, \tag{3}$$

where i — identifier of the oil-shale mining enterprise, $i=1, \ldots, I$;
k — identifier of the produced or imported energy resource, $k = I+1, \ldots, I+K$;
j — identifier of the production technology (or of the import-export activity or of the sphere of consumption) of the energy resources;
$x_j^{(t)}$ — intensity of the production technology (or of the import-export activity or of the sphere of consumption) j of the energy resources in the year t;
$a_{ij}^{(t)}$ — production of the oil-shale mining enterprise i at the unit intensity of the technology j in the year t;
$a_{kj}^{(t)}$ — production or import ($a_{kj}^{(t)} \geqslant 0$) and export or consumption ($a_{kj}^{(t)} < 0$) of the energy resource k at the unit intensity of the production technology (or of the import-export activity or of the sphere of consumption) j in the year t;
$q_i^{(t)}$ — production capacity of the oil-shale mining enterprise i in the year t;
$z_k^{(t)}$ — forecast of the minimum demand of the energy resource k in the year t;

$P_j^{(t)}$ — processing and capital costs at the unit intensity of the production technology j or unit price (cost) of energy resource imported by activity j ($P_j^{(t)} \geqslant 0$) or unit price (income) of energy resource exported by activity j ($P_j^{(t)} < 0$) in the year t.

The results of modelling are also used for forecasting the transfer and impact of the air pollution emitted by the energetical objects. The optimal solutions describing different development scenarios — functioning intensities of the energetical objects are used as initial information for model EMEST [10]. This model enables to estimate the level and impact on ecosystems of the air pollution on the area of the oil-shale complex as well as on the whole territory of Estonia.

2.2. Construction of the numerical model and the scheme of the dialogue

The model describing the FEC was tuned up, and the scheme of the dialogue was worked out on the basis of an optimization problem consisting of the following blocks:

M — "Mining" — oil-shale mining and peat production (9 objects or technologies);

E — "Energy system" — power stations with their service systems (8 objects or technologies);

R — "Retorting" — oil-shale retorting and upgrading (3 objects or technologies);

I — "Import-export" — import and export of fuels and energy (6 activities);

C — "Consumption" — consumption of fuels and energy outside the FEC (5 industries).

For the constraints of the basic variant of the numerical model the data on production, import-export and consumption of fuels and energy in 1992 and 1993 were used as well as the actual technical and economic indices for the objects of the Estonian FEC. Most of these data have been presented in the first part of the article with the description of important economic changes in the given years. The alternatives for the existing oil-shale, heavy fuel oil and gas power plants are coal and peat ones. The necessary technical and economic data for them are taken from "Energy Master Plan for Estonia", composed as an Estonian-Swedish-Finnish joint project in 1992—1993.

For the objective function was chosen minimization of the production costs, which in our opinion expresses in the best way the principles of sustainable development. The production costs include conversion costs as well as investments for renovation, reconstruction or expansion of production. The need for investments is modified in a very wide range — beginning from indispensable expenditures in the short term until the full renovation of the energy system. In the block "Energy system" the production costs are calculated in three versions: basic version without investments (E1), for the short term with minimal investments (E2), and for the long term with maximal investments (E3). All the costs of the coming periods are discounted. For the calculation of the annuities of investments the interest rate 9% is used**.

Exceptional is the calculation of the production costs in mining enterprises of the state-owned mining company "Eesti Põlevkivi". The reason is that the economic indices for the mines and opencast pits

** Discount rate and interest rate are equal and they are corresponding to the conditions of the World Bank energetics loan.

are very different due to the differences in mining and natural conditions and mining technologies. Therefore in the block "Mining" three versions of oil-shale production are produced: 12, 15 and 18 million t per year (M1, M2, M3). These versions discuss which mining enterprises will continue work and at what capacity, and which ones will be closed. In the latter case the costs connected with liquidation and conservation of mines should also be taken into account. According to the calculations of "Eesti Põlevkivi" mines of Sompa and Kohtla will be closed according to the minimal version of oil-shale production (M1), Tammiku and Ahtme will be conserved. Version M3 was used only in the basic variant of the numerical model, as the oil-shale production has remarkably decreased since 1992.

For the modelling in the form of dialogue the system of analysis of linear optimization models [3, 11] was used. The scheme of the dialogue is presented in Fig. 5. In the first stage of the dialogue the basic solution was calculated. The versions of the initial conditions used for the basic solution were E1 (for energy system) and M3 (for oil-shale mining). In the block "Consumption" the actual data in 1992 were used. After that two series of optimal solutions were generated. The first series represents the versions of short-term development of the FEC and the second describes the versions of long-term development. There are 4 main solutions in the first series and 6 in the second. These solutions correspond to the different combinations of the initial conditions of the blocks of the FEC under study:
I series: E2M1C1, E2M2C1, E2M1C2, E2M2C2;
II series: E3M1C1, E3M1C2, E3M1C3, E3M2C1, E3M2C2, E3M2C3.

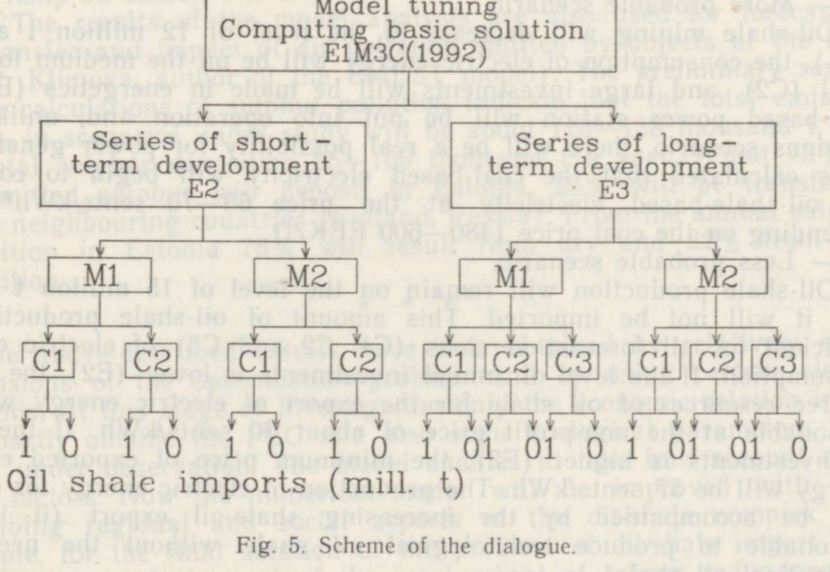

Fig. 5. Scheme of the dialogue.

The solutions of both series were received at the oil-shale imports of 1 million t a year, and without oil-shale imports (see Fig. 5). In addition, some versions were solved in both series to determine the price level of the electric energy exports at which the exports will be economically useful under different conditions.

2.3. Analysis of the results of modelling

In consequence of the dialogue analysis of the above-described optimization problem and some additional factors the following development scenarios of the Estonian oil-shale industry and energetics were defined:

1. In the short term (up to 2000)

— More probable scenario.

The oil-shale production will remain on the level 15 million t a year (M2), the consumption of electric energy will correspond to the version C1 (4.8 TWh), which is not more than today. Large investments will not be made in the energy system (E2) — it means that the price of electric energy will not rise remarkably. All the consumption of electric energy will be covered with oil-shale-based electricity. The maximum export of electric energy and shale oil will be, respectively, 1.6 TWh and 170 thousand t a year. The oil-shale import is useful if its price is not higher than that of local oil shale. If the import of oil shale is not possible, the export of the electric energy will decrease to 1 TWh a year.

— Less probable scenario.

Oil-shale mining will not exceed 12 million t a year (M1). In this case there will be a real danger in the near future that the amount of oil shale will not suffice for covering the local consumption of electric energy. The situation will be especially serious if the oil-shale imports are not possible or the consumption of electric energy rises to the medium level of the forecast — 5.4 TWh (C2). For this situation the model provides to engage conditionally a coal-based power station — it actually means the import of electric energy (in the nearest years putting into operation a coal-based power station is not realistic).

2. In the long term (since 2000)

— More probable scenario.

Oil-shale mining will decrease to the level of 12 million t a year (M1), the consumption of electric energy will be on the medium forecast level (C2), and large investments will be made in energetics (E3). A coal-based power station will be put into operation and, unlike the previous scenario, there will be a real possibility for power generation. It is calculated that the coal-based electricity will begin to compete out oil-shale-based electricity at the price 65—70 sents/kWh*** — depending on the coal price (480—600 EEK/t).

— Less probable scenario.

Oil-shale production will remain on the level of 15 million t (M2), and it will not be imported. This amount of oil-shale production is sufficient for all forecast versions (C1, C2 and C3) of electric energy consumption. If the level of annual investments is lower (E2), the usage of free resources of oil shale for the export of electric energy will be reasonable at the non-profit price of about 30 sents/kWh. If the level of investments is higher (E3), the minimum price of exported electric energy will be 57 sents/kWh. The production of electric energy for export will be accompanied by the increasing shale-oil export (it is not reasonable to produce technological oil shale without the need for energetical oil shale).

*** Here and further — without net profit.

3. CONCLUSIONS

On the basis of these results the following final conclusions can be drawn as useful for planning the development of oil-shale energetics.

1. The above-described model enables to analyze the development of the Estonian oil-shale industry and energetics as well as of the whole FEC of Estonia, taking into account the forecasts of fuel and energy consumption and other factors (for example import-export possibilities). With the help of the model analysis the interactive effect of the relations and factors of the FEC can be estimated. The result may be quite different from the separate effect of these factors. Also, the changes on the macro level of the economy, environmental and regional conditions, etc. should be considered.

2. For the nearest years oil-shale-based electric energy will be cheaper in comparison with that produced on the basis of imported fuels (first of all coal). For this reason it is significant to keep the oil-shale production on the level of about 15 million t a year.

3. The oil-shale import from Russia was, until now, economically reasonable. The further suitability of the import depends on the price proportions with the local oil shale, on the opportunities of electric energy export and different non-economic factors.

4. The coal-based electric energy will begin to compete with oil-shale-based electric energy at the price level 65—70 sents/kWh. So the final result of the aspirations for raising the oil-shale price may be the driving out of the oil-shale-based power stations by coal stations or the substitution of electric energy production with imports.

5. Shale-oil production and exports depend, besides the oil-shale price, also on the production of lumpy oil shale. If the energetical oil shale will be imported in bigger quantities the local oil-shale production (incl. lump oil shale) will decline.

6. The results of the model analysis are also used for forecasting the transfer and impact of air pollution emitted by objects of the FEC (by E. Klimova, author of the EMEST model). The preliminary results of the calculations of sulphur pollution indicate that the total emission of SO_2 in scenarios under study will be about 110—138 thousand t, and the total sulphur deposition 85—106 thousand t a year. About 75% of the emitted sulphur will deposit in Estonia, 25% will be transferred to the neighbouring countries (Finland, Russia). From the annual sulphur deposition in Estonia 78% will result from dry and 22% from wet deposition.

* * *

The above-described results have been obtained by relatively small dimensions of the optimization problem and by using certain simplifications. At this stage of investigation only the economic relation inside and partly outside the FEC and also some ecological parameters were taken under observation. The model enables to take into account much more factors. Now the numerical model will be improved with data describing regional and social aspects of the oil-shale complex. For example, for the final solution of the problem of oil-shale import it is necessary to add the cost of the employment of labour redundancy in oil-shale industry elsewhere or of maintenance and retraining of the unemployed. It is also important to add the information about the land tenure. An essential drawback is the still missing marketing research. At the same time, the consumption and export of electric energy is the keyproblem in the development of the whole oil-shale industry and energetics. It is very important to fix up at what price the export of the electric energy is possible at all.

REFERENCES

1. Каганович И. Негативные последствия природопользования: экономический аспект. — Proc. Estonian Acad. Sci. Humanities and Social Sciences, 1992, 41, 2, 95—110.
2. Barabaner, N. I., Kaganovich, I. Z. Oil shale production and power generation in Estonia. Economic and environmental dilemmas. — Energy Policy, 1993, 6, 703—709.
3. Барабанер Н., Каганович И., Лаур А. Моделирование и анализ горнопромышленного природопользования (на примере сланцевого комплекса). Препринт № 27. Ин-т экономики АН Эстонии, Таллинн, 1990, ч. I (65 с.), ч. II (53 с.).
4. Statistika aastaraamat 1993. Riigi Statistikaamet, Tallinn, 1993.
5. Kütuse ja energia tarbimine ja jäägid Eesti Vabariigis 1991. aastal. Statistiline bülletään. Eesti Statistikaamet, Tallinn, 1992.
6. Eesti energiabilanss. Statistiline kogumik. Riigi Statistikaamet, Tallinn, 1993.
7. Eesti energiabilanss 1992. Statistiline bülletään. Riigi Statistikaamet, Tallinn, 1994.
8. Kütuse tarbimine ja jäägid. Statistilised kuubülletäänid (jaanuar—detsember 1993). Riigi Statistikaamet, Tallinn, 1993, 1994.
9. Toodangu, tooraine, materjalide, seadmete ja kütuste keskmised hulgihinnad ja hinnaindeksid 1992. aastal. Statistiline kogumik. Riigi Statistikaamet, Tallinn, 1993.
10. Klimova, E. Modelling of transfer and impact on ecosystems of emissions from oil-shale power plants in Estonia. — Oil Shale, 1993, 10, 1, 67—78.
11. Лаур А. Интерактивный анализ линейных оптимизационных задач с учетом информационной неопределенности. — In: Анализ экономических и экологических систем. Ин-т экономики АН Эстонской ССР, Таллинн, 1986, 179—188.

EESTI KÜTUSE-ENERGEETIKAKOMPLEKSI ARENGUSTSENAARIUMIDE MODELLEERIMINE

Anton LAUR, Koidu TENNO

Vaatluse alla on võetud Eesti TA Majanduse Instituudis tehtavate uurimistööde tsükkel Eesti põlevkivitööstuse ning energeetika majanduslik-ökoloogilise modelleerimise ja arengustrateegia väljatöötamise kohta. Varasemates sama valdkonda puudutavates publikatsioonides on käsitletud säästliku (tasakaalustatud) arengu põhimõtteid ja nende rakendusvõimalusi. Käesoleval etapil on näidatud võimalust põlevkivitööstuse ja kogu energeetikakompleksi arenguvariantide leidmiseks, arvestades väljaspool kompleksi toimuvaid majandusprotsesse, keskkonnakaitse nõudeid ja teisi aspekte. Uurimismeetodiks on siinjuures kütuse-energeetikakompleksis ja sellega vahetult seotud tegevusvaldkondades toimivaid seoseid ja majandustegevuse tulemusi kirjeldaval optimeerimismudelil põhinev dialooganalüüs.

Väljatöötatud mudeli abil saab analüüsida nii Eesti põlevkivitööstuse ja -energeetika kui ka kogu energiamajanduse arengut, arvestades energiatarbimise prognoose ja muid tegureid. Mudelanalüüs võimaldab hinnata uuritavas kompleksis toimivate seoste ja tegurite koosmõju. Dialoogi abil on välja selgitatud Eesti põlevkivitööstuse ja -energeetika võimalikud arengustsenaariumid lähemateks aastateks ja kaugemaks perioodiks.

Töö järgmisel etapil on kavas laiendada vaadeldava kompleksi kohta käivat informatsiooni, eeskätt regionaalseid ja sotsiaal-majanduslikke parameetreid arvestades.

МОДЕЛИРОВАНИЕ СЦЕНАРИЕВ РАЗВИТИЯ ТОПЛИВНО-ЭНЕРГЕТИЧЕСКОГО КОМПЛЕКСА ЭСТОНИИ

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В статье рассматривается цикл работ, выполненных в Институте экономики АН Эстонии по экономико-экологическому моделированию сценариев развития сланцевой промышленности и энергетики Эстонии. В предыдущих публикациях по данной тематике обсуждались принципы ресурсо-сберегающего развития, а также прикладные проблемы, подкрепленные экспериментальными расчетами. На данном этапе показана возможность определения вариантов развития сланцевой промышленности и энергетики с учетом процессов на уровне экономики республики вне топливно-энергетического комплекса, средозащитных и других аспектов. Методом исследования при этом является диалоговый анализ на основе оптимизационной модели, описывающей связи и результаты экономической деятельности в топливно-экономическом комплексе и связанных с ним областях хозяйствования.

Разработанный модельный анализ дает возможность оценить развитие сланцевой промышленности, энергетики и всего энергетического хозяйства в целом, учитывая прогнозы потребления топлива и энергии и другие факторы, а также взаимодействие этих факторов. При помощи диалога определены возможные сценарии развития сланцевой промышленности и энергетики Эстонии на ближайший и более отдаленный периоды. На следующем этапе работы будет расширена информация за счет включения в анализ региональных и социально-экономических параметров развития рассматриваемого комплекса.