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OIL SHALE ENERGY AND SOME ALTERNATIVES IN ESTONIA

AN ACADEMIC LECTURE DELIVERED BY PROF. **ILMAR ÖPIK**
AT THE THERMAL ENGINEERING DEPARTMENT OF TALLINN TECHNICAL UNIVERSITY ON DEC. 14, 2000 TO MARK THE 120 SEMESTERS SINCE THE *CUM LAUDE* DIPLOMA OF A MECHANICAL ENGINEER

INEFFECTIVE UTILIZATION OF OIL SHALE

Considering the losses, only 20% of the energy in mined oil shale is sold to final electricity consumers:

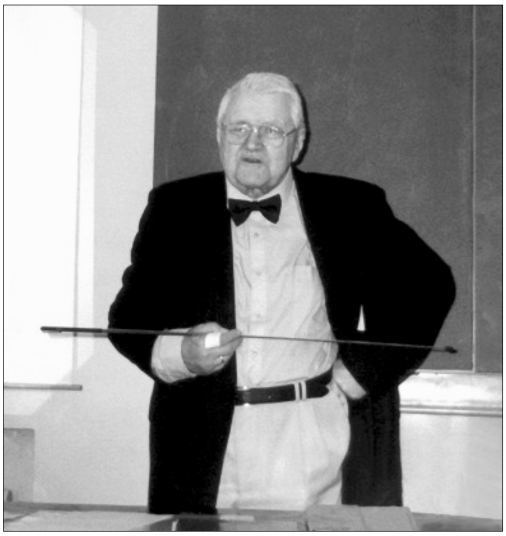
$$\mathbf{0.85 \times 0.3 \times 0.8 \approx 0.2 \text{ or } 20\%,}$$

where average efficiencies are 0.85 at oil shale enrichment, 0.3 at energy conversion and 0.8 at power transmission.

The amount of oil shale electricity needed in the winter half-year (1st and 4th quarters) is 60% more than in the summer half-year (2nd and 3rd quarters), and that consumed in December-January is twice as much as in July-August.

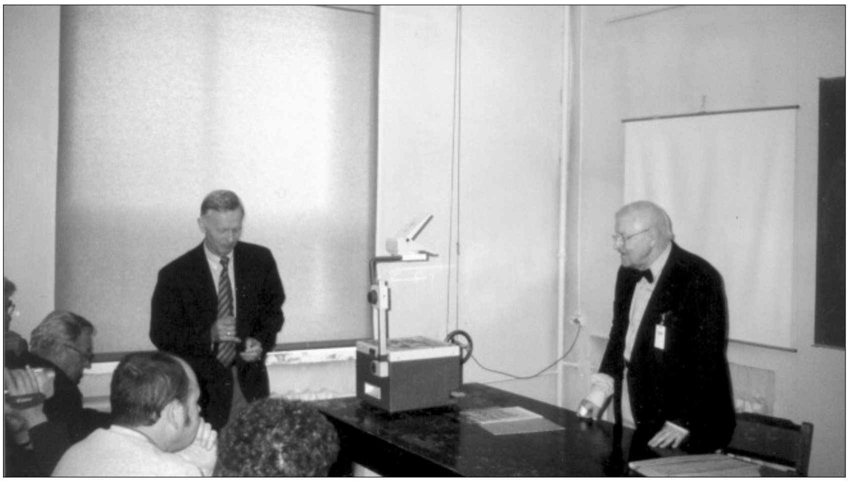
So, oil shale mines operate with lower production capacities than design resulting in a relatively high oil shale price. Underground production – mines – are especially influenced by overdesign. The latter as well as closing of mines before the exhaustion of their resources are considered a result of incorrect environmental policy, which when fixing the taxation rate of mines has not considered the relatively stronger impact of surface mines on the environment as compared with underground mining.

- Oil shale enrichment losses are great. 15–20% of oil shale kerogen gets lost during processing.
- Oil shale transport by railway, which is overloaded by transit of oil products, is expensive.
- Net efficiency of outdated basic power equipment – 200 MW condensation blocks – is extremely low (27–30%).
- Ineffective utilization of oil shales is accompanied by pollution of the environment with enrichment tailings, ash, sulfur and nitrogen oxides, carbon dioxide, etc.



Delivering the lecture

On the left prof. Aadu Paist



No wonder, therefore, that one may hear voices not only from Brussels, but from here in Estonia as well, in favour of stopping utilization of oil shale polluting the environment and of liquidating the ineffective and uneconomic oil shale industry.

Only natural gas or imported nuclear power could stand as realizable and immediate alternatives to oil shale in the Estonian power industry. The share of local fossil (peat) and renewable (wood, brush, wetland biomass, wind and water power, geothermal heat, solar radiation) energy resources in the nearest future will not depend on whether the concentrated power requirements of big central plants will be covered with oil shale or natural gas (or imported nuclear power).

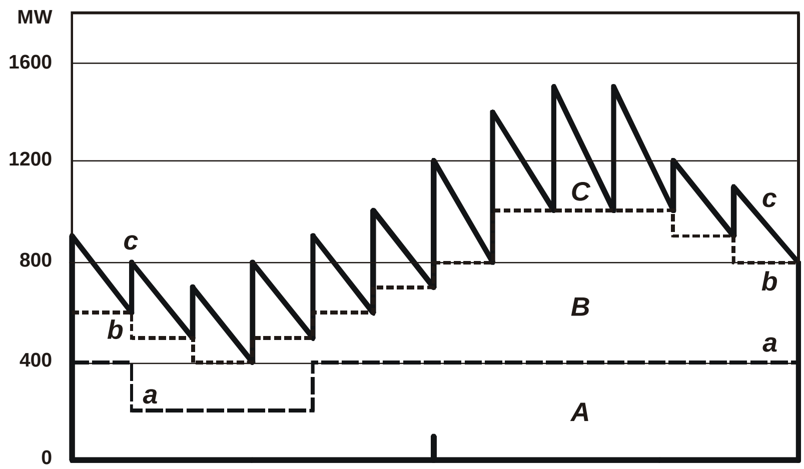


Figure 1. All-the-year-round load and production of Narva power plants (1998 year)

CONTINUOUS LOAD	The area *A* under the line *a–a*; 41% of the annual production ≈ 3.3 TWh.
CHANGING LOAD	The area *B* between the lines *a–a* and *b–b*, 39% of the annual production, ≈ 3.1 TWh.
FLUCTUATING LOAD	The area *C* between the lines *b–b* and *c–c*, 20% of the annual production, ≈ 1.6 TWh.

The peaks represent a monthly average maximum and minimum

DEVELOPING RENEWABLE RESOURCES AS AN ALTERNATIVE TO OIL SHALE

This problem is overpoliticized. The Estonian people have been misguided by fairy tales about local power resources as alternatives to oil shale.

It is high time to:

- Revoke the mandate in the Energy Act which forces grid enterprises to buy the power produced by combustion of renewable resources at a price near the one set for final consumer. This political mandate was added later, is indefinite is misguiding the power market. Such a system confused the California power market in the late 1980's and was terminated in 1989.
- Stimulate the production of renewable power in a complementary way and only by continuing use of fossil fuels and pollution taxes.

By the way, it would be foolish to hope that the competitive power of the Estonian economy as a whole could stand pollution taxes on the power industry that exceed the minimum rates established in the European Union.

Ligneous fuel as a by-product of forest industry is the most prospective renewable power source in Estonia.

Estonian local fuels include fossil fuels – oil shale and peat – and renewable biomass: all kinds of firewood (firewood, wood chips, timber residues and briquettes), energy brush and reed cultivated for fuel, straw, etc. Peat as the youngest resource renewable "only" within millennia is sometimes considered a biofuel as well. But due to the fact that peat combustion pollutes the Earth's atmosphere (with noncompensated CO_2 emission) it does not fit in this category.

The State Long-Term Plan for Developing Fuel and Power Management passed by the Estonian Parliament in 1997 foresees a considerable increase in the total output of peat and renewable biofuel in Estonia (Table 1, Figure 2).

Table 1. **The Share of Local Fuels and Natural Gas in the Balance of Primary Energy of the State Long-Term Plan for Developing Fuel and Power Management, %**

Fuel	1995	2005	2010
Oil shale	62	52–54	47–50
Natural gas	11	16–18	18–22
Total	73	68–72	65–72
Peat and renewable energy resources	8	11	14
Fuel oils	6	5	4–5
Motor fuels	13	14	14

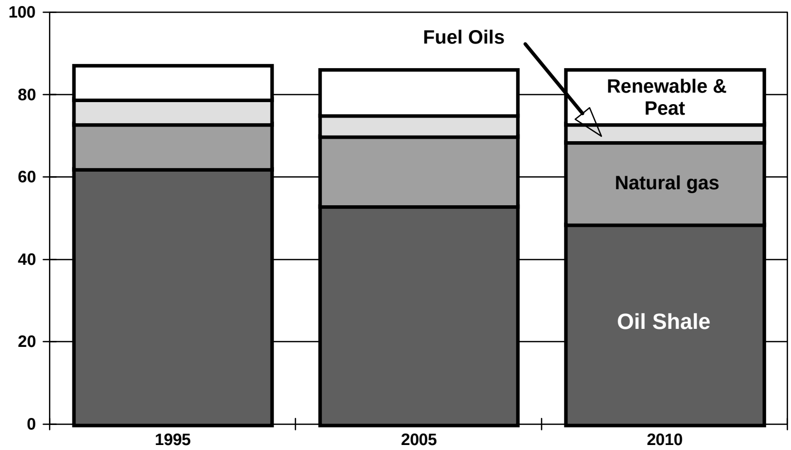


Figure 2. The share of local fuels and natural gas in the balance of primary energy of the State Long-Term Plan for Developing Fuel and Power Management, %

The data of Table 2 and Figure 3 (data of the Statistical Office of Estonia, ESA-2000) demonstrate a great decrease in production of oil shale power and a small one in the production of peat power, as well as a 3-fold increase in utilization of wood fuel. In the primary-fuel balance of the year 1999, the demands of the State Development Plan were fully satisfied with 51% Estonian oil shale (56% with the oil shale imported from Russia) and 13% peat + biofuel (see Table 1).

Table 2. **Production of Primary Fuel in Estonia in 1922–1999, TJ (the data are rounded-off within the range ±5%)**

Year	Oil shale	Peat	Biofuel
1922	2200	1400	13700
1928	11000	2400	5700
1960	137000		
1970	247000		
1980	338000	9200	5300
1990	279000	6500	7900
1993	127000	4999	6500
1996	134000	6500	24000
1997	131000	5500	26000
1998	113000	1500	22000
1999	98000	5500	21000

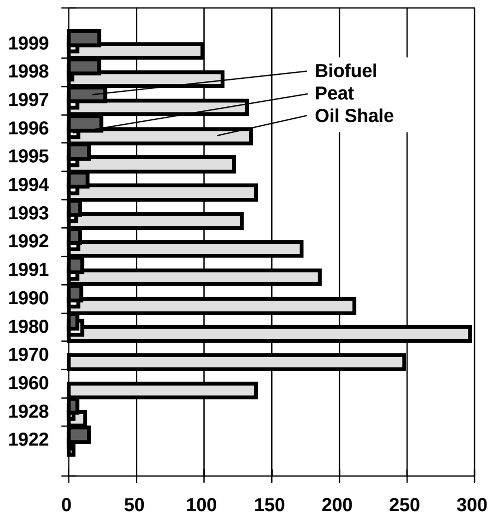


Figure 3. Production of biofuels in Estonia in 1922–1999, TJ

Table 3. **Timber Felling in 1922–1999**

Year	Solid cubic metres of cut timber, millions	Cut timber equivalent to burnt wood	
		Solid cubic metres, millions	%
1922		2.0	
1928		0.8	
1960			
1970			
1971	3.0		
1980		0.8	
1989	3.1		
1990	2.9	1.1	38
1991	3.1	1.2	39
1992	2.1	1.1	52
1993	2.4	1.2	50
1994	3.6	1.8	50
1995	3.8	2.0	53
1996	4.0	3.4	86
1997	5.5	3.7	68
1998	6.1	3.1	52
1999	6.7	3.0	31

The rapid increase in production and local use of biofuels observed in 1990–1997 has stopped despite the continued increase in timber felling and in the wood industry (Table 3 and Figure 4, ESA-2000). Since 1998 the production of wood fuel markedly lags behind the rate of timber felling. For example, 51 million solid m^3 of timber was felled in Finland in 1995. From this amount 84 PJ, equivalent to 12 million solid m^3 of cut timber or 24%, was used as fuel.

If all the cut timber were combusted, the maximum yield of air-dry biofuel would average 7 GJ (6.4 to 7.6 GJ times more primary energy than in Finland, in 1997 – 4.7 GJ (1310 kWh), in 1999 – 3.17 GJ (881 kWh). Timber manufacture ought to explain and estimate this difference.

(If the year 1999 had been on the level of 1997, wood power could be produced in the amount of a third of oil shale power.)

The recession in biofuel production in 1998 could be explained by a temporary but extremely deep cut in crude oil (fuel oil) price.

In Estonia, annual utilization of wood fuel for heating only (without producing electricity) may rise somewhat over 30 PJ instead of the present 22–27 PJ constituting a third of the power produced by oil shale consumption. However, including larger amounts of biofuel in the Estonian fuel balance means its utilization in electricity production, too.

So, when deciding about financial support to researchers of TTU working for their M.Sc. and doctoral degrees, both the university and the Estonian Science Foundation should get their priorities right and concentrate on:

- **Investigating prerequisites and prospects for the utilization of wood, especially wood chips and wood briquette (pellets) in Estonia, considering alternative scenarios for the development of the forest industry.**
- **Growing utilization of wood chips in turn creates technical prerequisites for the applications of additional biofuels – field and wetland crops.**

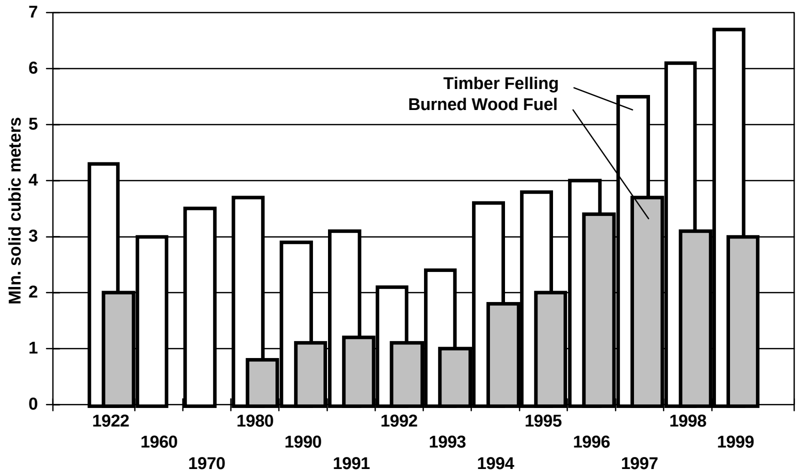


Figure 4. Timber felling in 1922–1999

In 2000 a newspaper article titled “Ecological economic miracle in Estonian way – let’s erect 128 new power plants” recommended to cultivate wetland crops reed and cat’s-tail on innumerable hectares of so-called productive wetlands. 128 new 1–17 MW power plants producing heat and power would be scattered all over Estonian peripheral areas.

According to the authors, the average capacity per plant would be 15 MW (electrical), their total capacity 420 MW. The expected total cost of these plants is 13.4 billion Estonian kroons, which is clearly an underestimate. Together with other expenses, among whose the greatest one is foreseen for precultivation of wetlands, the capital costs are assessed at 29.2 billion Estonian kroons. However, the estimate does not include great expenditures on the foundation of a new all-Estonian grid to gather surplus power accumulating in those small plants seasonally, weekly and daily, and to direct it to big centers and industrial enterprises with steady weekly energy demands.

Without such a redistribution grid the designed 5300-hour all-the-year-round full load of the power plants is not realistic, and, instead of the expected annual 2.2 TWh of salable electricity, this number would be only 1–1.5 TWh.

As for the offered price of electricity 1.5 Estonian kroons per kWh, calculated based on the expected full load, as compared to the actual one – no comments! The next step in using wood fuel is cultivation of field crops to be used for combustion. There is a long way from this stage to wetland production.

Hence, the task to be solved is to find a possibility to erect an experimental power plant for combusting energy brush and the reed of cat's-tail somewhere in the periphery.

Beside biofuel, there exists a whole range of renewable power resources whose development also needs state support. Putting them in the order of importance is not an issue of this report. It is a governmental task realizable through different pollution taxes.

As for local environmental protection, one must not be a more eager Catholic than the Pope, raising pollution taxes on burning oil shale, peat and natural gas to a level that would paralyse the entire Estonian economy.

Calculations show that a scattered system of small peripheral power plants burning reed and cat's-tail and selling electricity for a price not below 1.5 Estonian kroons per kWh cannot compete with modern oil-shale-fired power plants even if the latter had to pay CO_2 emission charges twice as high as the ones prognosticated by the European Union for the nearest future (4–10 USD per ton of CO_2). Local higher pollution taxes would damage and paralyse Estonian's ability to compete in almost all branches of the economy. Raising CO_2 pollution taxes up to 500 kroons per ton would increase the expenses of electricity production by 4 billion kroons per year!

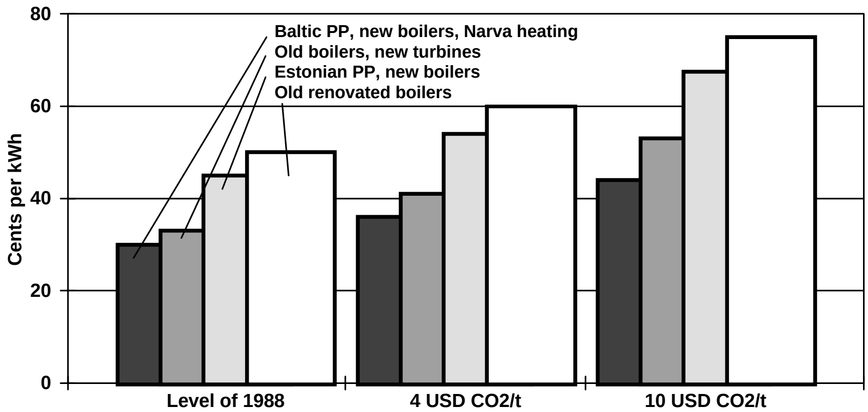


Figure 5. 200 ± 20 MW blocks of Narva PPs. Electricity price depending on CO_2 pollution taxes

In Estonia, our first task is a national utilization of by-products of the forest and wood industry. If not combusted, they decay, polluting the atmosphere just the same as burning them. Besides, they are more easily available than other biofuels the year around. We have to estimate the quantity, quality and availability of this resource before deciding about the exploitation of wetlands and fields to produce biofuels.

Waterpower would occupy the second place in the range of renewable biofuels in Estonia. It is not a matter of small power plants but using waterpower instead of oil shale to smooth power load peaks. We have to find out how to pump water into Narva reservoir with the help of reversible turbine generators which would be erected somewhere on the Estonian shore, and also to choose a suitable bay for erecting a water power plant.

A large-scale use of wind power would be possible only after solving hydro storage problems.

HOW EXPENSIVE WOULD THE EXTINCTION OF OIL SHALE ENERGETICS BE?

Liquidation of oil shale power and its replacement with alternatives means that within the next 20 years it would be the most expensive option even at the present level ~6 TWh/a of power consumption and 2000 MW. The capital and interest would cost about 60–100 billion Estonian kroons (at their present value).

There exists an extremely easy way for suppressing the oil shale industry. One need only raise resource and pollution charges to a level that would scare off prospective investors.

An "expert" in environmental protection recommended the collection of **400–500** kroons per ton of gaseous CO_2. It is problematic, however, whether the Estonian economy could stand such a pressure, considering that in 1995 the corresponding rate proposed for 2010 was 4–10 USD per ton of gaseous CO_2.

One has to consider

that utilization of oil shale can become much more economical and friendly to the environment.

RENOVATION OF NARVA POWER PLANTS

Various operating conditions of the Narva power plants are the key problems to be solved:

- The Baltic Power Plant carries the yearly heating and thermal loads of the town of Narva 0.8 TW_{th} h/a that allows cogenerating new boilers and 200 MW_{el} blocks, to reach a 48–49% efficiency and to reduce fuel consumption and pollution taxes by 1/3 in comparison with condensation blocks with analogous boilers.
- The Estonian Power Plant, located farther away from the City, economizes as much financially based on threefold lower charges for fuel transportation and ash disposal. However, this does not offset the lower charges for gaseous wastes in Narva.

The life-expectancy of 200 MW blocks of both PP is almost the same. Taking the nominal capacity of all blocks for 200 ± 20 MW and considering the electricity price scenarios at different pollution taxes (see Table 5 and Figure 6) we may draw the following conclusions:

- **Substitution of new atmospheric circulating fluidized-bed boilers (ACFB) for the old ones, accompanied by other modernizations (turbines, etc.) is a top priority for one co-generation heating block of the Baltic PP, and for block No. 8 of the Estonian PP where there is no thermal-heat boiler yet.**
- **Installation of more new boilers may be uneconomical because of the aging of turbines and other structures of the power plants, and cheaper but less effective means must be found for renovation. Those expenses for renovating a block would be only a tenth of those for installing new boilers. It would be reasonable to renovate 4-6 blocks in this way.**
- **The remaining 6-4 blocks are used to cover peak loads, i.e. their annual production is so low that one has to accept their operation at low efficiency and high maintenance expenses instead of modernization.**

The following problems concerning Narva power plants are to be studied:

1. Environmental fees (ash, gases) are to be critically examined and forecasted
2. Prime cost of the heat (water, steam) is a political issue independent of the technology used for the production. The actual scientifically based price has to be established.
3. Boiler's offered working life 15 or 20 years is rather perfunctory not basing on the actual capital investments. According to international instructions the working span of a new block where fuel including gas is burnt

under pressure is 20 years while at the atmospheric pressure the span is 25 years. Besides, loan interests are usually not differentiated from capital interests in tables. All calculations must be better grounded, more detailed and precise.

4. The total investments seem to be somewhat underestimated (e.g. compared to NRG Energy business plan for 1998). The importance of this fact in comparative calculation has to be established.
5. The plan proposed usually does not mention different pollution rates for ash disposal or special agreements with governmental institutions who fix them. For example, the Baltic PP has to pay 33.6 Estonian kroons per ton of ashes, while the Estonian PP pays three times less. All these data have to be included in calculations.
6. The plan gives no data concerning the expenses for fly ash, SO_2 and NO_x apart and all together, although the renovation scenarios are characterized by different amounts of pollutants. These differences must also be included in calculations.
7. The price of natural gas used to cover peak loads and reserves – 1100 kroons per 1000 m^3 – evokes some doubt, especially when at heat input maximum gas is used not only for the town of Narva.
8. An alternative to cover Narva heating peak and minireserve has not been considered: purchase of heating electricity from the Estonian PP for smoothing daily power loads.

Table 4. **Comparison of Maintenance Cost for Baltic PP, Estonian Cents per Sold kWh**

Cost type	Old boilers	New ACFB boilers
Repair and maintenance	2.1–3.5	1.3
Brought service	0.9	–
Salaries	6.2–7.2	2.1
Materials	0.7–2.6	1.0
Total	9.9–14.2	4.4

With all measures taken to reduce oil shale consumption including enhancement of efficiency and reduction of enrichment losses, we would need only 7-8 million tonnes oil shale of average quality instead of 10 millions spent today for production of electricity.

Table 5. **200 ± 20 MW Blocks Needed to Cover the Load of Narva Power Plants**

	Block renovation design				Total
	New boilers, renovated turbines		Old boilers		
	Baltic PP (+heating of Narva)	Estonian PP	Renovated turbines	Extra repairs	
Number of blocks	1	1	6–4	4–6	12
Efficiency, %	48	36	31	29	34
CO_2 per MWh, t	0.85	1.1	1.25	1.35	–
Project working span, year	25	25	15	5	–
Working hours per year, h/y	7000	7000	3600	1800	–
Area in Fig. 1	*A*	*A*	*A, B, C*	*C*	–
Annual output, TWh	1.4	1.4	4.2	1.0	8
Renovation cost, billion kroons	2.1(?)	2.1(?)	1.6–2.4	0.6–0.4	7(?)
Price of 1 kWh, cents:					
• at the pollution charges of the year 1998	30	33	45	50	41
• at 4 USD (1995 currency) per ton of CO_2	36	41	54	60	49
• at 10 USD (1995 currency) per ton of CO_2	42	49	63	70	57

The need for oil shale electricity and, therefore, oil shale production may be suppressed or lessened by local so-called combination-plants burning gas, peat or wood chips. However, basic annual loads will still be covered by oil-shale-fired 200 MW condensation blocks in Narva. Their share in power production may be increased by closing down some nuclear power plants in Lithuania and neighbouring countries.

The 20% efficiency of oil shale present utilization may be increased as a result of higher efficiency of new equipment (34%), limited rate of shale enrichment and decreases in grid losses by:

$$\mathbf{0.95 \times 0.34 \times 0.85 = 0.275 \text{ or by } 1/3}$$

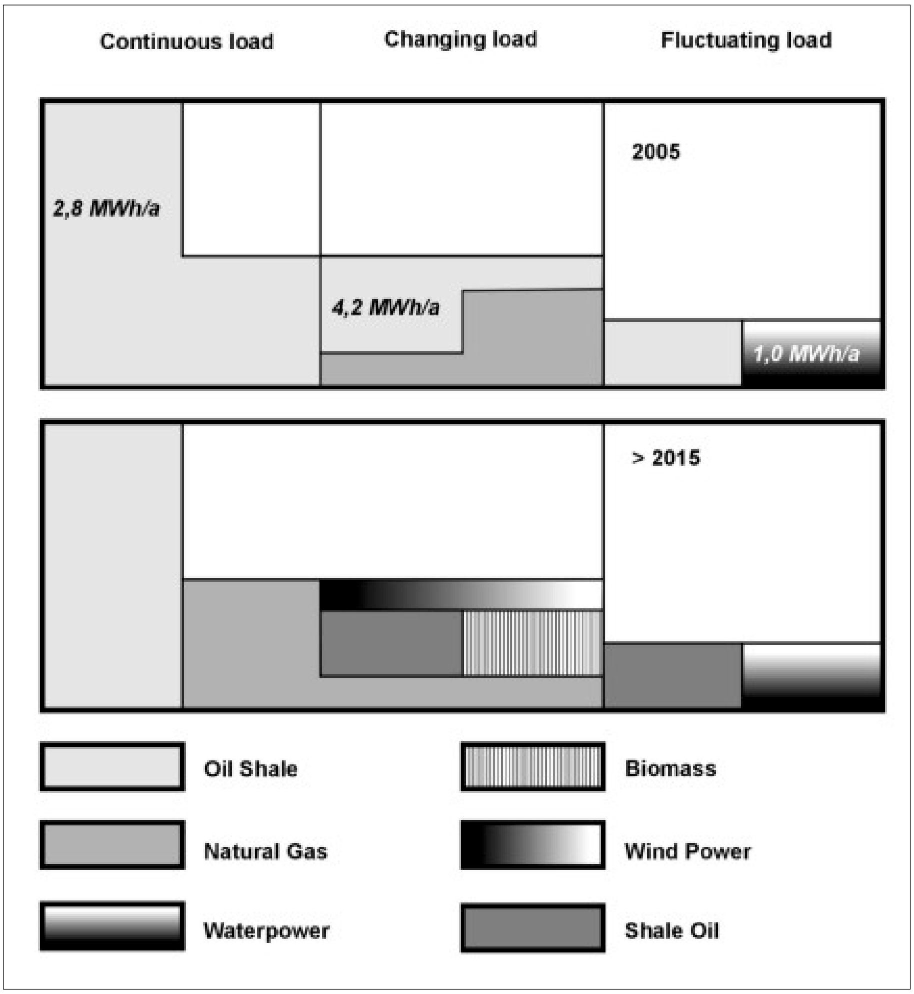


Figure 6. Fuels in electricity balance

WILL SHALE OIL CONTINUE TO BE SURPRISING?

Estonian shale oil industry has stood for 76 years and experienced many critical situations. The last quarter of the year 1998 was the most difficult time when some plants installed with *Kiviter* retorts were closed because of the fall in the crude oil price quoted in Rotterdam below 10 USD per barrel. The crude oil price is three times higher now, and the rate of exchange has increased as well. The price of heavy fuel oil, the measure of shale oil price, was 45–50 USD/t at the end of 1998, but it is 150–160 USD (2700–3000 Estonian kroons) per ton today. This price exceeds the prime cost of our shale oil by a factor of more than two times.

Celebrating 80 years of Estonian oil shale industry.
I. Öpik with leading persons of Estonian Oil Shale Ltd., 1996

At a seminar on the Estonian strategy of energy policy, Tallinn, 1997