REPORT
The promotion of electricity produced from renewable energy sources
ESTONIA, 2005

Article 3(3) of Directive 2001/77/EC of the European Parliament and of the Council (on the promotion of electricity produced from renewable energy sources in the internal electricity market) lays down that "Member States shall publish, for the first time not later than 27 October 2003 and thereafter every two years, a report which includes an analysis of success in meeting the national indicative targets taking account, in particular, of climatic factors likely to affect the achievement of those targets and which indicates to what extent the measures taken are consistent with the national climate change commitment."

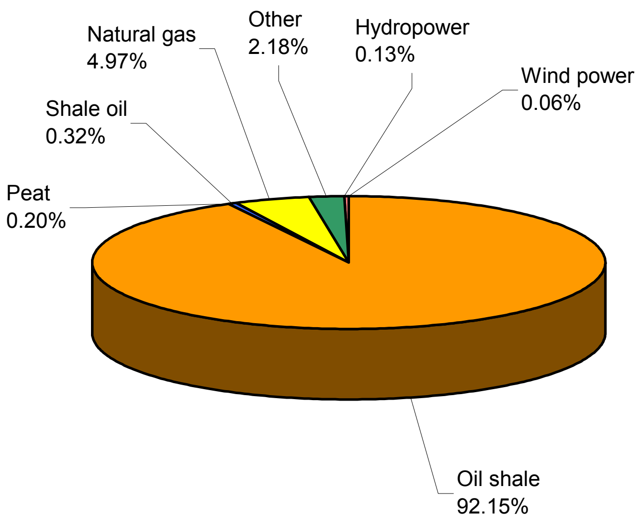
This report is based on the "Long-term national development plan for the fuel and energy sector up to 2015" (RT I 2004, 88, 601) endorsed by a decision of Parliament on 15 December 2004, on the "Development plan for the Estonian electricity sector" (RTL 2006, 7, 134) and on the initial studies undertaken to draw up those plans (http://www.mkm.ee/index.php?id=8098).

Objective

One of the objectives set out in the **long-term national development plan for the fuel and energy sector up to 2015** is that the share of electricity produced from renewable energy sources should be 5.1% of total consumption by 2010.

Production of electricity by type of fuel used

The chart below shows the breakdown of the production of electricity by type of fuel in 2003.



The environmental impact of electricity production

According to figures from the development plan for the Estonian electricity sector, in recent decades the production of electricity has been the largest user of natural water and mineral resources in Estonia and the largest generator of waste. The burning of fossil fuels (oil shale, fuel oil and natural gas) in electricity and heat production accounts for the majority of Estonia's emissions of greenhouse gases, airborne particulates and volatile organic compounds.

The volume of CO_2 emissions per square kilometre is estimated to be 157 tonnes on average globally, 1320 tonnes in the old Member States of the European Union and 1030 tonnes in the new Member States, while in Estonia the figure is 450 tonnes[1]. Emissions of CO_2 in connection with the use of oil shale constitute 67% of total CO_2 emissions. In comparison with renewable fuels and other fossil fuels, the use of oil shale as fuel has a considerably greater impact on the environment: a lower calorific value, relatively high sulphur content and extremely high ash content, resulting in far greater environmental damage from the production of electricity from oil shale than is the case from other fuels. For example, during the production of 1 kWh of electricity in Estonia an average of 1.18 kg of carbon dioxide is emitted, whilst the corresponding figure in Poland is 0.96 kg, in Germany 0.46 kg, in the European Union as a whole 0.34 kg and in Sweden just 0.03 kg[2]. The production of electricity from oil shale also comes out worst in terms of other forms of environmental pollution, depending on the fuels and technology used elsewhere.

Renewable energy resources available for electricity production

In order to determine the possibilities of increasing the share of renewable energy sources used for electricity production, a study has been undertaken for the Ministry of Economic Affairs and Communications. This study is available on the Ministry's website (http://www.mkm.ee/index.php?id=8098).

According to the study, Estonia's renewable energy potential lies primarily in the cogeneration of electricity and heat from biofuels and in wind energy, while small-scale hydro-electric energy is being developed, with a total technically usable resource of around 40 MW. Special mention should also be made of waste, above all with regard to the implementation of Directive 2000/76/EC on the incineration of waste. The competitiveness and the relative importance of solar energy are also growing. The share of renewable energy sources in Estonia's energy balance sheet as a whole is increasing.

Biofuels.

Already a large part of the felled firewood and of wood-processing residues is used in processes for converting primary energy into energy (mainly production of heat). One factor holding back the development of the cogeneration of electricity and heat from biomass is the smallness of the heating load and the fact that in districts with a favourable heating load new facilities producing only heat have already been installed. Development is also limited by the large-scale exporting of biofuels, because of which local energy producers suffer a lack of resources.

[1] The figures for CO_2 emissions are taken from International Energy Agency data for 1999.

[2] It is estimated that, as dust combustion technology is replaced by circulating fluidised bed technology, the figures for Estonia will fall to a level similar to that for Poland.

The amount of wood used for heating does indeed depend on the size and location of forest resources, but it is also affected by other factors — environmental restrictions, the allowable cut, the location of wood-processing businesses, the technology they use, the price of alternative fuels, etc. In traditional forestry, records are kept regarding commercial timber but not regarding logging waste and other low-value wood or timber growing on unforested land. For this reason there are no reliable data on firewood potential.

The largest hitherto unused source of wood fuel is logging waste, in particular spruce branches and crowns. A further unused resource is other low-quality wood. As a result of the difference in the age and species of trees in national and private forest stands, the majority of this unused resource is to be found in private forests. For example, 62% of private spruce forests are older than 60 years and grey alders cover up to 10% of the total area of stands in private forests. As only 1% of private forest owners belong to private forest owners' organisations, supplying firewood will become complicated in the future and possible only in cooperation with forestry supply companies.

In addition, it is important to note that by removing logging waste from the forest we impoverish the forest soil and thereby make the conditions worse for new forest to grow. In areas of less fertile soil there are restrictions of varying degrees when removing logging waste from the forest. In addition to being produced in the forest, waste is also produced during wood processing, although more or less all of the bark and sawdust generated in sawmills is already used and it would be impractical to consider this as an additional resource.

In Estonia biogas has been and continues to be produced from manure and effluent sludge for the production of energy, and it is collected from the Pääsküla landfill site.

Any extensive use of biogas from farms for the purposes of energy production would require sizeable aid schemes to be put in place. The possibility has not been excluded of starting up an integrated system for treating manure in individual large farms with the aim of obtaining energy and fertiliser and reducing environmental pollution.

It should also be noted that in Estonia there have been two systems for the production and use of biogas which were in operation for up to eight years, namely at the Pärnu and Linnamäe pig farms. Both systems have been closed down on account of the limited possibilities for marketing pork and, in the case of Linnamäe, because of leaks in the digestion tank. As far as is known, the reopening of the systems has not been looked into, but the economic viability of doing so is questionable.

Estonia's resources of biogas obtained from landfill gas and effluent sludge are unquantifiable as there are no reliable data.

More extensive development of the various types of bioenergy requires project-related cost-effectiveness calculations. Establishing plantations of either energy forest or energy grass is not at present economically viable, even though existing farming techniques provide the necessary techniques for cultivating and harvesting energy grass. It is also technically possible to use straw for energy production, although in economic terms this is restricted by the distance of carriage. Wetland plants are a resource that can be used, after refining, as an additive to wood chips, for example. The possibility has not been excluded of starting up an integrated system for treating manure in individual large farms to obtain energy and fertiliser and reduce environmental pollution.

Possibilities for increasing the share of biofuels

Of the biofuels used for electricity production in Estonia, wood has the greatest economic potential. According to the long-term national development plan for the fuel and energy sector up to 2015, the total economically viable annual volume of primary energy from wood is 5.72 TWh. It is therefore essential that the economic parameters, above all price and profitability, of electricity produced from wood be studied.

Data from 2001 indicate that the volume of firewood used is equivalent to around 2/3 of the estimated reserves of wood fuel. Resources are therefore available up to an estimated volume of 865 000 m^3, or approximately 6000 TJ. Consumption data indicate that the majority of this resource is used in households. The level of waste use in comparison with the waste resources generated in the forestry-based industries is a less informative assessment, as waste is generated both in forests and in sawmills, as well as in other wood-processing businesses. It is estimated that around 75% of the wood waste resources mentioned in the forestry development plan (http://www.envir.ee/2391) are used. The estimated resources available could therefore be as much as 595 000 m^3, or approximately 3600 TJ. Waste from wood processing is already used extensively, for example in the production of wood briquettes, pellets and charcoal and as a raw material for cellulose. It can also be assumed that some of the small timber that may have been considered as part of the reserves of firewood is also used as raw material for cellulose. As a result, as far as any additional use as fuel in concerned, the resources of firewood and wood waste are close to exhaustion.

The reserves for increasing the volume of electricity and heat cogeneration are directly linked to the heating load suitable for cogeneration. Around 26% of all heat produced in boiler plants is currently produced from wood fuels. As a very rough estimate, we can assume that it may be possible for cogeneration to cover 50% of that if water boilers are replaced by steam boilers, back-pressure turbines and generators. If the number of useful hours of cogeneration capacity at full power is taken as 5300, it is possible to estimate the additional potential cogeneration capacity from wood fuels.

Calculations show that, were cogeneration to be used, a further 0.83 TWh of heat and 0.164 TWh of electricity could be produced from wood fuels[3]. This could be called the potential for replacing wood fuel boilers at boiler plants with cogeneration installations from the point of view of technical practicality. It would constitute 2.2–2.7% of forecast Estonian electricity consumption for 2010.

This assessment is optimistic rather than pessimistic, as the average capacity of a wood fuel boiler is below 1 MW_{th}. It is certainly not economically viable to replace such small boilers with cogeneration installations.

In the study on the possibilities for increasing the share of renewable energy sources used for electricity production, pessimistic basic data were applied to steam-cycle plants using wood chips to cogenerate electricity and heat in order to give an indication of what the maximum electricity price would have to be for the project to be viable — if very pessimistic basic data are applied, that price is EEK 1582/MWh for the plant to pay its way over 20 years.

[3] The average ratio of heat to electricity production in cogeneration is taken as 5:1.

Besides wood, the other fuel which could be used in the production of electricity is biogas. The output of a cogenerating plant using biogas is lower than that of one using wood chips. In the study, the viability of gas-fired plants using biogas to cogenerate electricity and heat was also determined for a certain base model which was meant to reflect the average situation in Estonia. In this model, at an electricity price of EEK 880/MWh the net present value of a plant cogenerating electricity and heat is equivalent to zero. A plant would be profitable with a higher sale price and unprofitable with a lower sale price (the simple payback period of the plant would be 10.5 years and the discounted payback period would be 20 years, to within 0.5 years).

Attention was also given to the use of biogas in cogeneration plants where the fuel is obtained from landfill sites and the costs of obtaining biogas are lower. In the case of the base model, the equivalent sale price of electricity is EEK 473/MWh, which is fully competitive with electricity produced from oil shale. With somewhat worse basic conditions the price worked out at EEK 644/MWh. A project would be viable if the price was higher and unviable if it was lower. Finally, it should be remembered that these calculations were made at real prices, which need to be multiplied by forecast inflation to obtain nominal prices.

Cogeneration plants should not have any particular problems when connecting to the electricity grid because they would be located in load centres (towns and other large settlements). This enables grid losses to be somewhat reduced, but because of the small and dispersed capacity the impact is insignificant. In order for it to be possible to regulate the electricity production of small cogeneration plants, they should be built with heat storage devices.

Wind energy.

Wind energy is one of the most important renewable energy resources in Estonia. Estonia is situated on the shore of the Baltic Sea in an area of intense cyclonic activity. The stronger winds blow in the coastal areas, particularly in western Estonia and on the islands, but the shores of Lake Peipsi are also windy. As a result of the slowing effect of the uneven relief and the forests, wind speed falls dramatically inland.

When connecting wind turbines to the electricity grid, the technical capabilities of the grid must be taken into consideration. A peculiarity of the Estonian electricity grid is the location of the large power stations in north-eastern Estonia and of the main centres of consumption in north-eastern Estonia and in the Tallinn and Tartu areas. As a result, the main 220 and 330 kV grid is situated relatively far from the areas with a lot of wind, but very little electricity consumption, on the islands, on the west coast of the mainland and on the shores of Lake Peipsi. These areas are served only by the relatively low-capacity 110 and 35 kV grid. The inconsistent power generated in the weaker areas of the electricity grid could cause serious electromagnetic compatibility problems for the wind turbines in terms of power and the quality of the voltage.

In most windy regions of Estonia, the electricity grid is weak, short-circuit power is very low and there is a very strong flicker. In this respect the Lake Peipsi area is better off. The Estonian distribution network was designed and built for the needs of one-way electricity supply. The connection of small power stations, including wind power stations, to the distribution network would turn that particular part of the network into a network with multiple supply points, and this would create a number of technical and economic problems for the network operator, including problems related to relay protection and other automatic equipment. The most significant of these are the modernisation of the relay protection and other automatic equipment in the network in connection with the creation of multiple supply points and the increase in short-circuit current, preventing production by any part of a small power station that is separated from the network because of abnormal operation, and the question of whether the (relay) protection and other control devices of small power stations meet the requirements of the network. If wind turbines that have electron transducers with low flicker emissions are in use and if effective filters are used to suppress harmonic emissions, the limiting factor will be the transmission capacity of the networks and the capacity of grid transformers to regulate the voltage. These problems are particularly acute in periods of minimum load when the wind turbines are nonetheless operating at maximum output. In our case, the planned wind farms should be connected to the 110 or 330 kV electricity grid.

Having regard to the present state of the electricity grid it is possible to install wind generators in Estonia amounting to 90–110 MW, but that would involve a qualitative degeneration in the performance of the grid. Without negative side-effects wind turbines could be put up to generate 30–50 MW. In addition to the grid considerations, wider use of the wind resource is restricted by the relatively small power load and the large unit capacity and poor manoeuvrability of plant in the existing power stations. The problem is alleviated by the Estonian electricity grid's strong link (connection capacity) with the Latvian and Russian grids, which makes it possible to cover unevennesses in wind energy. The technical limit on the connection of wind generators to the Estonian grid is 400–500 MW. That, however, would require investment in electricity networks and power stations, to ensure the transfer and regulation of wind energy and the necessary reserve capacity.

Possibilities for increasing wind power that can be connected to the grid

The following possibilities for overcoming the constraints arising from the quality of the voltage in weak networks would enable an increase in the wind power that can be connected to the grid:

◦ strengthening the network by installing additional lines, which would be a direct way of preventing voltage quality problems caused by wind power. However, constant installation of new lines could involve so much additional expenditure as to render the wind project unprofitable;

◦ regulating reactive power with electronic control devices, which could, in some cases, be significant for counteracting the impact of wind power on the quality of the voltage;

◦ load management could be an effective measure to overcome wind power-related voltage constraints — the weak network effect will be minimised by managing the load of consumers located close by and matching it to the output power of the wind generator. However, it is not usually possible to manage load with sufficient speed or in sufficiently small steps to combat flicker, and so load management is better suited to keeping the voltage within certain limits. Also, loads suited to load management are not always available — either there simply are not any in the vicinity or there are technical problems involved in using them or the owners do not want to cooperate. For these reasons, load management is, generally speaking, not an option in Estonia at the current time. However, it is conceivable that wind power facilities could be set up along with the appropriate businesses whose load could be managed. At the same time this combined approach would reduce network losses and improve the quality of the voltage;

- wind energy diffusion — this concept could be used in large wind farms, where the wind-farm voltage control system could immediately send a signal to the farm management system to reduce or increase power depending on the mains voltage.
- energy storage, including such technologies as pumped-storage power stations, accumulator batteries and flywheels. These are expensive to use, but the costs may drop in the future, in particular those of accumulator batteries.

The dependence of competitiveness on the amount of investment

When studying the impact of the unit cost of investment in wind generators on their competitiveness, it should be remembered that the unit cost ensuring profitability is different at different times, as the power grid is constantly changing. The aim was to determine the maximum unit investment ensuring competitiveness for each (five-year) planning period. It is clear that the higher the marginal costs of electricity production in the grid, the greater the investment for entering the market with wind generators can be. This also applies to wind conditions — the better they are, the more expensive the wind turbine can be.

Analysis of the competitiveness of wind energy and the reduction of CO_2 emissions

International experience and previous calculations have shown that it is not possible to adopt wind power without economic incentives. Competitiveness would be increased on the one hand by lower investment costs together with a higher purchase price for the electricity generated and on the other by environmental taxes which would render fossil fuel-based technologies more expensive and by higher fuel prices. It is clear that, because of new investment and other factors, the price of electricity in Estonia will rise in the future, although at the same time the environmental savings achieved with wind generators will decrease as new technologies pollute considerably less. In the long term, other, currently expensive, renewable-energy technologies will be developed and become cheaper, in turn providing competition to wind energy. One factor which dramatically increases the competitiveness of wind generators is the CO_2 tax, which makes electricity generated from fossil fuels more expensive. By increasing the CO_2 tax to a sufficiently high level, it would be possible to ensure that wind turbines are introduced even without subsidising their investment costs or production.

Necessary subsidies

The easiest way of subsidising wind-generated electricity is through an obligation to purchase at a reduced price, which is also the method applied in Estonia. A large number of model calculations were made to assess the size of the subsidy needed for generators operating in different wind conditions to be profitable, the results of which are presented in the figure below. It should be borne in mind that the amounts presented in the figure have been obtained on the basis of fixed investment costs, fuel prices, environmental taxes and other basic data. All the amounts will need to be recalculated if any of these factors change. The number of possibilities stretches into the thousands and the topic would need a separate study.

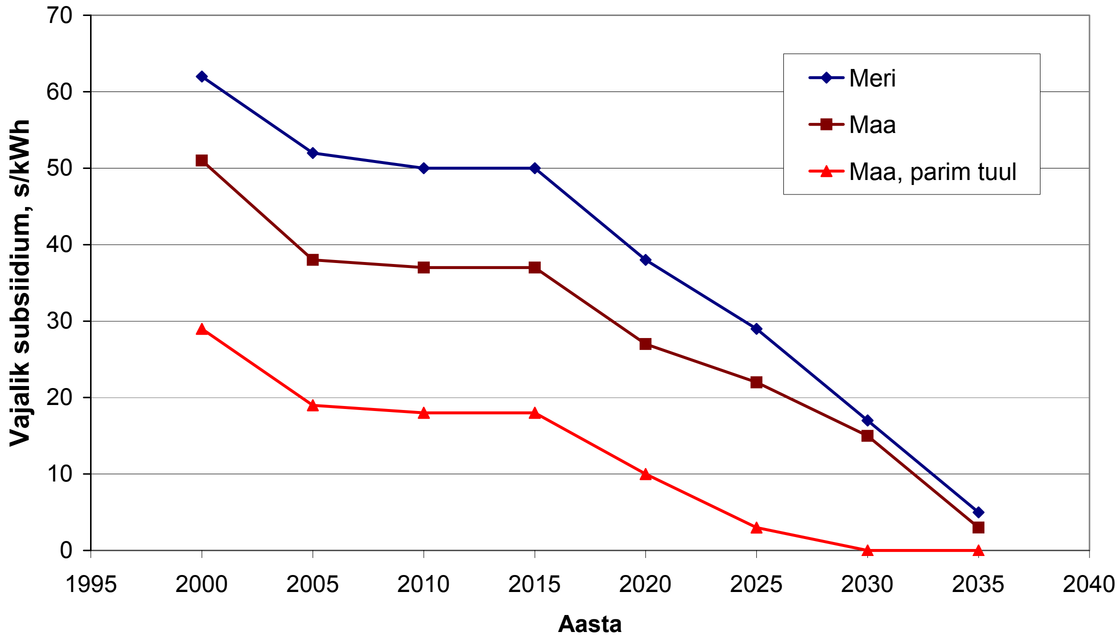


Chart:

x-axis: Year
y-axis: Necessary subsidy in Estonian sents/kWh
Key: Sea
Land
Land, optimum wind conditions

Reducing CO_2 emissions

In order to assess the reduction in CO_2 emissions, a comparison needs to be made of model calculations where some include wind generators and some do not but where the conditions are otherwise identical. The calculations show that in 2010, with 50 MW of wind turbines in good wind conditions on the coast, CO_2 emissions from power generation will fall by 0.11 Mt and that in 2025, with 150 MW of wind turbines on the coast and 150 MW in coastal waters, CO_2 emissions will fall by 1.0 Mt. (According to data from the Ministry of the Environment, CO_2 emissions in Estonia in 2004 amounted to 18.532 Mt.)

Possibilities of using wind turbines

Although in the summer months the daytime load increases by around 200 MW compared with the load during the night, it would not be environmentally friendly to use wind turbines to cover this difference as that would force the oil-shale-fired power stations to continue operating extremely uneconomically at minimum capacity. With the increase in the load in the autumn and winter periods, a serious problem in the case of sizeable wind turbine capacity would be starting up the supplementary blocks at the Narva power station. It takes 14–16 hours to start up blocks which are in cold reserve, i.e. around the same amount of time that can elapse between the peaks in wind turbine capacity. This means that the so-called cold reserve cannot be used to compensate for fluctuations in wind turbine capacity and a greater number of blocks will have to be kept in operation as a so-called rotating reserve. The consequence of this is a further increase in the fuel consumption and emissions of thermal power stations. It is important to note that the speed at which it is permitted to change the load of an oil-shale block in operation is only up to 2.5 MW per minute.

In the absence of hydro-electric plants, the problem that will always restrict the use of wind resources in the Estonian electricity grid is the need to compensate for the rapid and large fluctuations in power from wind turbines. If thermal power stations are used for this purpose (in particular large oil-shale-fired stations), fuel costs will increase and the environmental impact and economic viability of wind turbines will decrease.

This problem can be eased by exporting and/or importing electricity, depending on the possibilities and willingness of neighbouring electricity grids and on the conditions in the electricity market. A restructuring of the production capacities of the Estonian grid would also help, but that will take an extremely long time. In the longer term, the storage of electricity may prove to be a solution.

The pluses and minuses of using wind energy

The advantages of using wind energy are as follows:

- it is a renewable and clean type of energy;
- it is a large (in terms of Estonia's needs practically unlimited) resource, in particular having regard to the possibilities of setting up wind farms in coastal waters;
- the resource used (wind) is free of charge;
- low capital expenditure (not unit costs!) for the plant because of its low capacity and the relative simplicity of the construction work — this enables wind turbines to be constructed quickly (in half a year) using both municipal and private funds;
- the automation of wind turbines reduces staffing needs and operating costs;
- the technology is developing and improving;
- relatively good availability of the software and know-how for designing and operating wind turbines;
- sufficient interested parties;
- an increase in employment by using local labour in the construction of wind turbines and if it proves possible to manufacture equipment or parts in Estonia;
- few negative effects on the environment.

The disadvantages of using wind energy are as follows:

- because of the nature of wind turbines, the volume of electricity they produce is sporadic and the timing is very irregular;

- the need for reserve capacity to compensate for wind turbines at times of no or little wind — the construction of wind turbines only slightly reduces the need to build other types of controllable power stations;
- the need for controllable capacity to smooth out the fluctuations in output arising from changeable wind speed — there is currently no such capacity in the Estonian grid, and increasing controllable reserve capacity would increase costs in the grid;
- using fossil-fuel-fired power stations to compensate for the fluctuations in power from wind turbines increases environmental pollution;
- difficulties in electromagnetically connecting wind turbines to the grid (voltage fluctuations, flicker, harmonics);
- the low usage rate of the nominal capacity of wind turbines compared with other power stations — in Estonia generally under 30%;
- high unit capital costs (EEK/kW);
- primarily as a result of the two previous disadvantages, the relatively high cost price of the electricity generated; the low degree of competitiveness on the open electricity market of the fluctuating electricity output from wind turbines, and the need for aid mechanisms;
- a potential negative impact on the Estonian economy — purchasing the equipment will increase the foreign trade deficit, subsidies will increase the price of electricity for consumers and, if foreign capital is involved, the subsidies raised from Estonian consumers will be taken out of Estonia;
- the lack of experience and know-how in Estonia regarding the construction and operation of wind turbines.

Conclusions

In order to make generators located in optimum wind conditions on the coast more competitive, the investment cost will have to fall to a level of EEK 7000–11 000/kW.

In order to ensure competitiveness, the investment cost of generators located on the coast in good wind conditions will have to fall to a level of EEK 5000–8000/kW.

The unit investment in a wind turbine constructed in coastal waters should be in the range EEK 8000–11 000/kW in the coming years.

If the sale of wind-generated electricity to the grid is not subsidised, in order to bring the best wind generators into operation in 2005, their construction will have to be supported to the extent of up to EEK 7000/kW. The construction of a 1 MW wind turbine thus needs aid of up to EEK 7 million.

A CO_2 tax of at least USD 100/t_{CO_2} would enable generators located on the coast in optimum wind conditions to enter the market in the near future, and a change in the tax would have little impact until 2015. From 2020 the necessary tax level would fall to USD 25, after which it would continue to fall to zero. The pattern would be similar for generators located in other wind conditions.

Looking at the economic situation in Estonia, the idea of a CO_2 tax of USD 100 seems utopian but, taking into consideration ever stricter environmental demands around the world and Estonia's accession to the European Union, this figure may become realistic sooner than expected.

Taking into consideration the fact that OÜ Jaotusvõrk and OÜ Põhivõrk have received applications amounting to almost 400 MW for wind turbines to be connected to the grid, the construction of a number of wind parks can be expected in the coming years, in particular on the Pakri peninsular, around Virtsu and Audru, in Saaremaa and on the north coast.

To sum up, it can be said that time is on the side of the adoption of wind turbines in Estonia: investment in the power grid will raise the price of electricity, fossil fuel prices and environmental taxes will increase, the cost of wind turbines will fall and their technical specifications will improve. Other changes in the power grid, in particular the construction of rapidly controllable gas turbines, should also ease the entry of wind turbines into the market. However, the lack of hydro-electric plants in Estonia to compensate for the sudden changes in power from wind turbines dramatically reduces any potential environmental gains and, taking into consideration the structure of the electricity grid and, in particular, its low transmission capacity in windy areas, there will be no shortage of technical and economic problems in implementing wind energy.

The environmental impact of using wind energy

As a rule, the use of wind energy enables emissions of greenhouse gases and other pollutants to be reduced. In the case of wind turbines connected to the general electricity grid, this reduction in emissions depends on the type of power station used to compensate for the rapid changes in the power from wind turbines. If hydro-electric plants are used, there are no problems. However, if plants burning fossil fuels are used, the relationship between the electricity output of the wind turbines and the reduction in emissions is no longer linear, as the fuel costs of fossil-fuel-burning plants in continual transient operation are considerably greater than those of plants with a stable load. By using the large Estonian oil-shale-fired power stations to compensate for the changes in power from wind turbines, emissions of air pollution decrease by considerably less than would have been thought by using linear dependency. In order to obtain any environmental effect, controllable capacity will have to be purchased from neighbouring electricity grids.

The negative impact of wind turbines on the environment is primarily concerned with their possible harmful effects on birds, in particular as they are located on birds' migratory routes in western Estonia. The density of the bird population and the fertility of the birds could also fall in the vicinity of wind parks. Assessments made on the basis of other countries' experience in this regard are quite contradictory.

The audiovisual impact on nearby human settlements is also considerable, including the hitherto insufficiently studied effects of infrasound. However, it is possible to reduce these impacts dramatically through the suitable positioning of wind turbines relative to populated areas.

Hydropower

Estonia's hydro-electric resources are modest. Although Estonia belongs to a relatively water-rich area in terms of average runoff (250 000 m^3/km^2 per year), the use of hydropower is complicated by the fragmentation of the water resources. Of the 7308 watercourses in Estonia, with a total length of 31 019 km [Loopmann, 1979], 94% are less than 10 km in length. Only 10 rivers (Võhandu, Pärnu, Põltsamaa, Pedja, Kasari, Keila, Jägala, Navesti, Emajõgi and Pedetsi) are more than 100 km in length. Less than 50 rivers have a flow rate exceeding 2 m^3/s and only 14 have a flow rate exceeding 10 m^3/s. The rivers that are the most abundant in water are the Narva (with a flow rate at its mouth of almost 400 m^3/s), Emajõgi (71.8), Pärnu (64.1), Kasari (27.6), Navesti (27.2) and Pedja (25.4) rivers. Some data on the larger rivers are presented in Table 10.1. The topography is level. The relative elevation of landforms does not generally exceed 20 m, rarely reaches 50 m and only exceeds that in a few exceptional cases. Despite this, there are a number of river reaches with concentrated falls that are suitable for generating hydropower, and the majority of these have been used before.

The first rivers that should be mentioned are the coastal rivers in northern Estonia which flow over a limestone escarpment — the Purtse, Kunda, Selja, Loobu, Valgejõe, Jägala, Pirita and Keila rivers — each of which could produce several hundred kW of power. In the hydrographic basin of the Gulf of Riga, the greatest potential is to be found in the Pärnu river, in the middle reaches of which there are a number of places with concentrated falls where the capacity could reach several megawatts. Conditions in the Kasari river are generally unfavourable owing to its low marshy banks, although there are still some small falls of around a couple of hundred kilowatts in its lower reaches. In the hydrographic basin of Lake Peipsi, there are escarpments with a capacity of around 100 kW in many rivers (Suur Emajõgi, Väike Emajõgi, Suislepa, Ahja, Võhandu, Piusa, etc.). The potential of the Põltsamaa (Paala) river is considerable, in particular around the town of Põltsamaa itself. There are small falls suitable for use in many rivers across the country.

According to *Eesti Entsüklopeedia* [the Estonian Encyclopaedia], the theoretical resources of hydropower in our rivers amount to around 300 MW.

Much smaller than the theoretical resources are the technically usable resources, which are determined primarily by the existence of concentrated drops (rapids) and the possibilities of using them. Then the economically viable resources must, in turn, be distinguished from the technical resources, and these depend on many factors that change over time, such as fuel and electricity prices, national energy policies and environmental requirements. In current conditions, possible hydro-electric power stations can be included as part of the economically viable resources if the cost price of what they produce does not exceed EEK 1.2/kWh.

When assessing Estonia's hydropower resources, it makes sense to study the resources of the Narva river separately, as they are comparable with the total resources from all the other Estonian rivers and their use is of interest in terms of large-scale power engineering. On the other hand, however, a large proportion of the Narva river's potential is used by the Narva hydro-electric power station (125 MW), which is under Russian control. According to international best practice, the electricity generated by hydro-electric power stations operating in frontier rivers is divided between the countries in proportion to the part of the catchment area that is in their territory. Since approximately one-third of the catchment area of the Narva river is situated in Estonian territory, the Estonian state should have the right to a corresponding share of the electricity generated at the Narva hydro-electric power station.

There is also a significant unused resource in the Narva river — the Omuti rapids with a capacity assessed to be in the range 15–30 MW. The engineer U. Sihiveer has shown that it would be possible to construct a hydro-electric power station at Omuti with a capacity of as much as 60 MW by using a 23 km channel to direct the Pljussa river to the start of the Narva river, the Vasknarva gradient. The soundness of the idea has been confirmed by professors H. Velner and U. Liiv. However, the idea could only be brought to reality as a joint Estonian-Russian project. And in the case of a purely Estonian plan to construct a power station, there would certainly be problems relating to the fact that it is a frontier river. Therefore the Omuti hydro-electric power station has to be regarded as a possibility only in the longer term.

As it is a frontier river, the use of the resources of the Narva river is subject more to political factors than technical or economic factors.

To sum up, the technically usable resources of hydropower in Estonian rivers without the Narva river can be assessed as being up to 30 MW with an average annual output of up to 200 000 MWh, of which 10–15 MW with an annual output of 70 000–100 000 MWh would be economically viable in the near future. Of that, a level of almost 3 MW with an average annual output of almost 17 000 MWh has already been obtained. In addition, there are the Omuti rapids with a technical (and also economic) resource of 15–20 MW and an annual output of 100 000–150 000 MWh, as well as one-third of the capacity of the Narva hydro-electric power station, i.e. 40 MW and 250 000 MWh.

The investment necessary to construct a hydro-electric power station depends to a very great extent on specific natural conditions and, in the case of power stations or mills to be reopened, on how much remains of the hydro-electric structures and what state they are in (the cost of structures makes up 40–60% of the total cost of a hydro-electric power station). Therefore any assessment of capital expenditure requires extensive analysis in each individual case. However, the results of these analyses constitute business secrets and are generally confidential.

According to confidential assessments drawn up by experts, the unit capital expenditure required for potential hydro-electric power stations is generally EEK 15 000–35 000/kW, a figure which would guarantee the power stations a payback period of around 6–10 years which, bearing in mind their 50–60-year life span, is entirely reasonable. It would be possible to reduce capital expenditure by up to 20% by simplifying the automatic equipment, although that would in turn increase annual running costs.

Capital expenditure could be reduced dramatically by manufacturing the hydro-electric turbines locally. Experience shows that this would be possible with small turbines with a capacity of up to 20 kW. Capital expenditure could also be reduced substantially by renovating old turbines, where they still exist. However, the life expectancy of such turbines is much lower at just 10–20 years.

The construction of pumped storage plants is to be recommended from a technical point of view, e.g. to even out the work of wind farms, but they are not economically justifiable in the current conditions in Estonia. Environmental problems would also arise.

The pluses and minuses of hydro-electric power stations.

The advantages of using hydropower are as follows:

- it is a renewable and clean type of energy;
- it does not waste resources — water that has passed through the power station is still fit for use;

- the technology is well-developed — small-scale hydro-electric power stations are relatively simple and very reliable and have a long working life (usually more than 50 years);
- there is a long tradition of hydropower, and parts of many hydro-electric structures are still in existence;
- sufficient experience, know-how and interested parties;
- the cost price of hydropower does not depend to any great extent on inflation;
- the low operating costs and almost total automation of small-scale hydro-electric power stations;
- low capital expenditure and the relative simplicity of the construction work, which enables small-scale hydro-electric power stations to be constructed quickly (in six months to two years) using both municipal and private funds and relatively simple equipment and by small, non-specialised construction companies;
- being located throughout the country, they would enable transfer losses to be reduced and the quality of the voltage improved;
- they are very manoeuvrable. Of course, small and micro-scale hydro-electric plants do not support frequency regulation. However, some of them would enable a certain amount of manoeuvrable capacity to be created to smooth out the fluctuations in power from wind turbines — this applies, above all, to that part of the capacity of Narva hydro-electric power station that belongs to Estonia, but also to the restorable Linnamäe hydro-electric power station on the Jägala river (which has a reservoir large enough for daily regulation) and to the possible future Omuti station;
- benefits in terms of regional development: as former water mills are restored, bridges and reservoirs are also restored, opportunities for recreation, tourism and fishing are opened up, and employment in rural areas increases;
- generally few harmful effects on the environment (in contrast to large hydro-electric power stations).

The main disadvantages are as follows:

- large unit capital expenditure and the relatively high cost price of the electricity generated. On the other hand, the use of new corrosion-resistant materials, the simplification and standardisation of hydro-electric plant and the use of electronic control devices to the greatest extent possible, and the continued rise in the price of organic fuels substantially increase the competitiveness of small-scale hydro-electric power stations. Particularly good figures are obtained from restoring former plants. Such contemporary technological advances as fibreglass pressure pipes, inflatable dams, immersible compact sets, etc. are also worthy of mention;
- a certain dependence on the seasons and the climate, although in Estonia considerably less so than in the case of wind or solar energy;
- the fragmented and limited nature of the resources.

Environmental impact.

With correct planning and design, small hydro-electric plants have relatively little harmful impact on the environment. On the contrary, small-scale hydro-electric plants even out the flow rate of rivers and improve their water exchange and aeration, and thereby also their sanitary status. Ensuring that there is the correct minimum flow rate behind the dam and that there are fish passes means minimal impact on aquatic fauna, including on the migration of valuable fish in coastal rivers. Small reservoirs increase the resistance of rivers in times of drought and cold, diversify the landscape and open up new recreational possibilities. Reservoirs more than 2 m deep do not dry up in summer or freeze through in winter, thereby guaranteeing habitats for fish and bottom-dwelling fauna even in extreme conditions and preventing the wells in the surrounding area from drying up in times of drought. Many restored water mills could become tourist attractions. In order to preserve waterfalls of natural beauty (such as Jägala and Keila), the experience of, for example, Finland could be applied, where many power stations located in such places are closed in the summer tourist season and in spring and autumn are in operation only on workdays. The use of noise barriers and modern equipment enables noise levels to be kept to a minimum. With careful design, hydropower plants can be blended into their surroundings. Instead of concrete dams, soil or stone should be preferred and, if necessary, hidden head races, underground pressure pipes and so on should be used. Weirs can be made to look like natural cataracts, etc. There is plenty of experience in this regard in Western Europe, as there also was in pre-war Estonia. Land loss resulting from flooding can be reduced by constructing dykes.

However, despite the general level of friendliness to the environment, it should be remembered that a river is a complete system where every change to be made requires caution. The impact of reservoirs is not always unequivocal. Reservoir water is warmer than average and contains less oxygen, which can lead to a reduction in the abundance of cold-water fish (such as grayling and trout) whilst being well-suited to warm-water plant-eating fish. Raising water levels may cause problems in land improvement. The water level in main ditch outfalls at drainage sites can only rise to a certain level. Further problems may arise if water intakes are located on the river for other purposes or if there are cascade spillways.

Factors hindering use.

The following should be mentioned as the principle obstacles to the use of hydropower:

- relatively high unit investment, particularly in the construction of new plants, as a result of which the cost price of electricity at the switchgear of small hydro-electric plants is relatively high despite the low operating costs. According to assessments by experts and return calculations concerning specific levels of output, the cost price of electricity at the switchgear of restored plants would be EEK 0.6–1.3/kWh and at the switchgear of new plants EEK 0.85–1.7/kWh;
- funding difficulties — because of the relatively small size of the projects, it is hard to obtain long-term soft loans;
- the lack of experience and skills, and difficulties in obtaining relevant consultancy;
- gaps in legislation — above all the provisions regulating the use of water resources need to be made more precise, e.g. water use in the event of cascade spillways of hydro-electric plants constructed on the same river. For example, there were once eight water mills and

power stations in operation on the Jägala river, ten on the Ahja and Võhandu rivers, 12 on the Õhne river and as many as 25 on the Piusa river;

- difficulties in resolving questions of ownership;
- political barriers to full utilisation of the resources of the Narva river, related to the fact that it is a frontier river — negotiations with the Government of the Russian Federation are necessary to ensure that the resources are used in accordance with international best practice.

Possibilities for increasing the use of hydro-electric power stations

The connection of hydro-electric power stations to the grid does not lead to any significant technical problems. Their output power does not fluctuate and it is sufficiently easy to predict the amount they will generate in the short term As a rule, hydro-electric plants are located in areas where the distribution network is well-developed. A slight problem when connecting to a weak network could be the need for reactive power from asynchronous generators. In order to alleviate this, capacitor batteries are usually connected to the generator switchgear.

The connection of small hydro-electric plants to the distribution network would turn that particular part of the network into a network with multiple supply points, thereby causing a number of technical problems of which the most significant are the need to modernise the relay protection and automatic equipment as a result of the creation of multiple supply points and the increase in short-circuit current, avoiding having the portion of consumers that are disconnected from the network during abnormal operation supplied by small power stations, and the question of whether the relay protection and other control devices meet the requirements of the network.

All the same, being spread throughout the country they enable transfer losses to be reduced and the quality of the voltage improved. They are also very manoeuvrable, so enabling a certain amount of manoeuvrable capacity to be created to smooth out the fluctuations in the power from wind turbines.

The total capacity of hydro-electric power stations in Estonia today is almost 3.5 MW with an average annual output of almost 19 GWh, which would comprise some 0.2–0.3% of consumption in Estonia in 2010. Taking into consideration the future plans of a number of firms and businesses, and the recent pace of commissioning of hydropower of around 0.3–0.4 MW per year, it is to be expected in the next few years that a number of former power plants and water mills will be restored with a total capacity of more than 5 MW and an average annual output of around 39 GWh, comprising some 0.5–0.7% of consumption in Estonia in 2010. It is realistic to expect that the total capacity of hydro-electric plants will have risen to 9–10 MW by 2010 and their average annual output to 45–55 GWh, which will comprise 0.6–0.9% of consumption in Estonia in 2010. With favourable climatic conditions, hydro-electric power plants could generate up to twice as much electricity. If relations with Russia develop in a positive manner, resources of 40–60 MW and an annual output of 200–300 GWh could be added from the Narva river. In 2010 this could account for 2.8–5.0% of consumption in Estonia. In principle, it would therefore be possible in water-rich years for hydro-electric power stations to cover the entire obligation for the generation of renewable electricity, at the same time dramatically broadening the possibilities of using wind generators.

The limiting factors in this regard may prove to be environmental (primarily fish conservation) requirements.

The investment in developing the electricity grid to increase the share of hydro-electric power is relatively small and will have no practical impact on the price of electricity. In other regards (the obligation to purchase at a favourable price, tax relief, subsidies, etc.) the impact will be similar to that of increasing the share of other forms of renewable energy. The installation of one MW in hydro-electric power stations (just as in other power stations using renewable energy sources) would reduce the CO_2 currently emitted from the Estonian grid by around 5000 tonnes per year, SO_2 by around 50 tonnes, NO_x by 5 tonnes and ash by 60 tonnes [Raesaar, 1996]. These figures will certainly fall in the future in connection with the increase in the efficiency of new thermal power stations and in the cleanliness of combustion processes and with the probable increase in the use of natural gas.

Summary

On the basis of the information presented in this report, the following realistic solutions exist to achieve the stated objective regarding the amount of electricity to be generated from renewable sources by 2010:

Hydropower

To increase the current capacity of hydro-electric power stations by almost 3.5 MW to 10 MW, which would enable 45–55 GWh of electricity to be generated annually with an average quantity of water, thereby constituting 0.6–0.9% of consumption in Estonia in 2010. The necessary investment is in the range EEK 165–195 million.

Cogeneration of electricity and heat from biomass

To use the technically practical potential for replacing wood fuel boilers at boiler plants with cogeneration installations, by installing an electricity capacity of 31 MW. On the basis of cogeneration from wood fuels, this would enable up to a further 830 GWh of heat and 164 GWh of electricity to be produced. This would constitute 2.2–2.7% of the forecast Estonian electricity consumption in 2010. The necessary investment is in the range EEK 650–900 million.

In addition there is electricity produced from biogas. Currently one gas-powered generator using landfill gas from Pääsküla produces 6–7 GWh of electricity per year. This figure can be multiplied several times if landfill gas and biogas obtained from effluent sludge, manure and the food waste accruing in larger towns are factored in. Allowing for a total addition of 3 MW, it can be assumed that 25 GWh of electricity will be generated in this way by 2010, equivalent to 0.3–0.4% of consumption in Estonia. The required investment is EEK 55 million (landfill gas) to EEK 140 million (biogas).

Electricity generated from black liquor is also to be regarded as renewable electricity. According to official data, 11.2 GWh were generated in 2001. This would amount to 0.1–0.2% of consumption in 2010. As the cellulose and paper industry develops, this figure may increase substantially.

Wind energy

By adding the 123 GWh annual output of 50 MW of wind turbines (1.7–2.0% of 2010 consumption), the required figure of 5.1% for renewable electricity can be achieved. Investment totalling around EEK 950 million is needed to construct wind turbines and connect them to the grid, whilst around EEK 30 million of controllable capacity will have to be purchased annually.

Wind energy has the greatest potential and it would be entirely possible to meet the 5.1% target with wind energy alone. In order to achieve this, 140–170 MW of capacity would need to be constructed by investing EEK 2460–2740 million in wind turbines and their connection to the electricity grid, by building approximately 80 MW of gas turbines for around EEK 640 million, and by modernising the primary and secondary capacity regulators of four blocks at Narva power station for around EEK 120–180 million.

Other

The most important thing would be an agreement with Russia on jointly running the Narva hydro-electric power station, which would give us the possibility of using a 41 MW hydro-electric unit. The electricity generated would then amount to around 200 GWh, or 2.8–3.3% of 2010 consumption. In addition, the acute problem of compensating for power from wind turbines would also be eased somewhat.

The burning of biofuels in conjunction with oil shale in the new fluidised-bed boilers at Narva power station would require biofuels (wood, straw, etc.) to be received, put into short-term storage and prepared for combustion, as well as the construction of feed devices, which could be an option once the oil-shale boilers have achieved a sufficient degree of reliability. However, the distance of carriage of biofuels may prove to be too great in economic terms. Problems can also be foreseen with the procurement of fuel, as the wood fuel market is more or less exhausted, and the appearance of one new, large consumer would in the first instance raise the price of fuel and there would probably also be fuel shortage problems. The only realistic option for procurement of additional fuel could be the cultivation of energy forest or energy crops. Even this would increase the price of fuel and require time for preparations to be made. The latter factor also restricts the broader development of the cogeneration of electricity and heat from biofuels.

5.1% of Estonian domestic electricity consumption can be covered from renewable energy sources by 2010 if 300–360 GWh of electricity are generated from them. For this quantity purchase-price subsidies amounting to EEK 90–144 million will have to be paid.

Measures taken

The use of renewable energy sources in the production of electricity is regulated by the Electricity Market Act, which entered into force in 2003 and was amended in 2004 (RT I 2003, 25, 153; 2004, 18, 131; 86, 583).In order to encourage the use of renewable energy sources in the production of electricity, the following provisions have been introduced:

1. the obligation to develop the network (§ 66);
2. the definition of renewable energy sources (§ 57);
3. requirements concerning generation from renewable energy sources (§ 58);

4. the conditions for determining the share of electricity to be generated from renewable energy sources if they are used together with fossil fuels (§ 58);
5. a certificate of origin (§ 58);
6. the obligation to purchase electricity generated from renewable energy sources (§ 59);
7. network services to be provided under the same conditions (§ 65);
8. non-discriminatory network charges for transmission and distribution (§ 71);
9. informing consumers of the fuels used to generate electricity and of their environmental impact (§ 75).

The share of electricity generated from renewable sources in total domestic consumption in 2004 was less than 1%, despite a 2.7-fold increase in the generation of hydropower and wind energy from 7 GWh in 2002 to 19 GWH in 2003. By the end of 2005 the share of electricity generated from renewable sources in total domestic consumption was 1.2%.

A draft act amending the Electricity Market Act has now been prepared and submitted to the Government for further discussion. This draft act provides for a new, more effective scheme for encouraging the use of renewable energy sources.

The present Act obliges network operators to purchase (at a price of EEK 0.81/kWh) all the electricity generated by a producer of renewable energy to the extent of the operator's network losses. The main problem with this scheme is that a network operator who does not have a licence to sell electricity cannot buy more electricity than the amount equivalent to his network losses. This is primarily a source of uncertainty for the large so-called wind parks which are connected (or wish to connect) to the grid — at times of low electricity consumption (for example summer nights) network losses are small and so the purchase obligation is also small. In 2002, when the Act was drafted, it was not possible to predict such a rapid development of large wind parks and so the aid scheme currently in place no longer really works towards achieving the stated objective (neither from the point of view of the wind parks nor from that of the scheme itself). Similarly, the current Act does not provide for any kind of aid to promote effective cogeneration, despite this being one of the main objectives of Directive 2004/8/EC (support for efficient cogeneration and thereby increasing the security of supply and saving primary energy, by using in a sensible manner the heat created in the generation of electricity or vice versa and producing electricity together with heat).

The draft act sets out an aid scheme for renewable energy producers and cogenerators which would enable the producer to use the purchase obligation as before or to sell the electricity produced itself and be given aid for the electricity sent to the grid and sold. All producers of renewable energy may benefit from one of these two aid options for the electricity they generate.

The purchase obligation is placed on the seller specified by the grid operator, as the grid operators themselves may not be involved in purchases and sales. Electricity produced from renewable energy sources will continue to be purchased at the price of EEK 0.81/kWh.

In addition to the use of the purchase obligation, renewable energy producers now have the possibility to be given aid for electricity sent to the network and sold. This should encourage producers to become actively involved in selling, as in this way they can earn significantly more than by using the purchase obligation (the reference price for the power stations in Narva is currently EEK 0.41/kWh, meaning that, together with the aid, it would be possible to earn EEK 0.41+0.50 = EEK 0.91/kWh).

The duration of the aid scheme has also been extended to 12 years from the start of production (the current Act sets out that the aid scheme will remain in place for 7–12 years but not beyond the end of 2015).

The general aid scheme also includes one restriction on producers using wind as a source of energy from 2009, in that aid will be paid to them or they will be able to use the purchase obligation until such time as the production in Estonia in a calendar year exceeds a certain limit (probably 30 GWh), after which the producers must sell electricity at market price without using the purchase obligation or aid. Separate records will be kept for each calendar year. The linking of the obligation to purchase electricity generated from wind power or the payment of aid to annual production is a result of the technical particularities of the Estonian grid — there are no power stations in the grid that can be rapidly regulated to balance out the electricity produced from wind power.

One clarification has been added, in that the producer specifies the supply that it wishes to sell using the purchase obligation. Producers who produce electricity from renewable sources in a power station with a production capacity of less than 1 MW may sell their electricity in the form of open supply.