Lund University Master's Programme in Environmental Science (LUMES)

Ignalina Nuclear Power Plant:

Aspects on its operation, closure and decommissioning in relation to environmental and socio-economic conditions in Lithuania

Master's thesis

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Lund, Sweden
November 2001

This research study is dedicated to my parents,
Sisters and brother

Acknowledgments

This research study would have not been written without the months of stimulating, encouraging, fertilizing atmosphere and influence of discussions of my supervisor Prof. Sören Mattsson and my co-supervisor Dr. Christopher Rääf. I owe great thanks to both of them, who had to make out time under their busy schedule to discuss the process of this work with me. I am also thankful to all the staff of Lund University Masters' Programme in Environmental Studies (LUMES) for the knowledge and care they have provided to me during all the period of LUMES programme. I am also grateful to Prof. Diana Adliene at Kaunas Technical University for her advices and for providing me with some literature. I would also like to thank my Lithuanian friend and classmate Mr.Juozas Abaravicius for providing me with some literature and links and for the fruitful discussion regarding this topic. I gratefully acknowledge the financial support of The Swedish Institute (SI), Sweden, which enabled me to attend this programme.

Summary of the thesis

Nuclear power once appeared to promise a secure and environmentally sound contribution to energy supplies far into the future. Today, the growth of nuclear power has nearly stopped. The economy and the public acceptability of nuclear power are in question. In April 1986, unit 4 of the Chernobyl Nuclear Power Plant in Ukraine was destroyed in the worst accident in the history of commercial nuclear power, a fact that put the safety of nuclear power plants under question.

Lithuania separated from the Soviet Union in 1991 and took over responsibility for operating and regulating Ignalina NPP, which has the world's largest RBMK nuclear reactors. As all RBMK nuclear power plants, the technical design of Ignalina NPP cannot be compared with the Western light water reactors. This has to do with a less robust design of the confinement of the Ignalina NPP reactors. Ignalina NPP is providing around 80% of the Lithuanian electricity demand and some of its electricity production is exported to neighbouring countries. So, it has a great importance for the Lithuanian economy.

The Lithuanian Parliament decided on October 1999 to close down the first unit at Ignalina NPP before the year 2005. This was one of the requirements from EU to accept Lithuania as a member of the Union. This study investigates the effects of the closure on the socio-economic, and environmental situation in Lithuania. The social effect is mainly focused on the town of Visaginas where Ignalina NPP is located. The closing down of Ignalina NPP will lead to unemployment among the 5000 employees at Ignalina NPP. As a consequence of closing down Ignalina NPP, Lithuania has to use fossil fuel for its electricity production**,** which will increase the CO_2 levels drastically.

Without the financial, technical and management assistance of the international community, Lithuania will not be able to find the solutions of negative impacts of closing down of Ignalina NPP from the environment and socio-economic aspects. Successful closure will be endangered if social consequences are not being addressed adequately and timed together with the technical closure of Ignalina NPP. A Decommissioning Fund should be available not only for financing of projects related with physical closure of Ignalina NPP and for measures in the energy sector but for mitigation of social consequences as well.

Keywords: nuclear waste management, greenhouse gases, social impacts, renewable energy, electricity production

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ABBREVIATIONS

1. Ignalina Nuclear Power Plant **(Ignalina NPP)**
2. Channelized Large Power Reactor, Russian acronym **(RBMK)**
3. European Union **(EU)**
4. International Atomic Energy Agency **(IAEA)**
5. Causal Loop Diagram **(CLD)**
6. Accident Localization System **(ALS)**
7. Energy Information Administration **(EIA)**
8. Western European Nuclear Regulators' Association **(WENRA)**
9. Lithuanian Nuclear Power Safety Inspectorate **(VATESI)**
10. Gross Domestic Products **(GDP)**
11. European Bank of Reconstruction and Development **(EBRD)**
12. Combined heat and power plants **(CHP)**
13. United Nations Framework Convention on Climate Change **(UNFCCC)**
14. Spent fuel assemblies **(SFA)**
15. Storage facility of spent nuclear fuel **(SFSF)**
16. United Nations Educational, Scientific and Cultural Organiszation **(UNESCO)**
17. Finland Radiation and Nuclear Safety Authority **(STUK)**
18. Swedish Council for Nuclear Waste **(KASAM)**
19. National Energy Strategy **(NES)**
20. Low and Intermediate Level Waste **(LILW)**
21. Fuel Assemblies **(FA)**
22. Value Added Tax **(VAT)**
23. United Nations Development Program **(UNDP)**
24. The Swedish National Bpard For Spent Nuclear Fuel **(SKN)**
25. Swedish National Council for Nuclear Waste **(KASAM)**
26. International Commission on Radiological Protection **(ICRP)**

GLOSSARY

***Absorbed dose*:** "Radiation dose"- the amount of energy per unit of weight that is absorbed by a body exposed to radiation. The unit used in 1 gray (Gy); 1Gy=1 joule/kg.

Activity: The amount of decay per unit of time in a radioactive substance; expressed in the unit becquerel (Bq); 1 Bq=1 decay/second.

Effective dose: "Radiation dose". To compare radiation doses from different radiation situations, the whole-body exposure are normally calculated which could be expected to pose the same risks for severe damage as the irradiation of one part of the body. The varying radiation sensitivity of various organs and tissues must be taken into account.

Ionising Radiation: Radiation that has sufficient energy to detach electrons from atoms and molecules, i.e. sufficient to produce ions.

Radioactivity: The property of a substance to release ionising radiation.

Radioactive substance: a substance that contains atoms with unstable nuclei that become stable through decay. Ionising radiation is released as the substance decays.

Radiation: The transport of energy in the form of waves or particles.

Naturally occurring radiation (background radiation): Radiation from sources that are a natural part of the environment. This includes cosmic radiation, radiation from naturally radioactive potassium (^{40}K) in the body and external radiation from the soil and buildings.

Critical group: A group of people living near a facility that releases substances into the surroundings. This is a group that, because of living habits, age or place of residence, is assumed to receive the highest additional dose of radiation from the releases.

Collective dose: It is the sum of the doses received by all the personnel during a year time. It is measured in manSv.

Average dose: It is calculated as collective dose divided by the number of persons and it is measured in mSv.

Global warming: It is currently viewed as potentially one of the most environmental impacts arising from the greenhouse gas CO_2 produced by the combustion of fossil fuels.

H_p (10): According to ICRP 60, Hp (10) is considered as the equivalent dose in soft tissue below a specified point on the body (simulated as a sphere with a diameter of 30 cm) at a depth of 10 mm.

1. INTRODUCTION

1.1 Introduction

There is a general agreement that use of energy in the long-term perspective should be sustainable and not degrade the environment. However, the "sustainability" of energy use is an elusive concept, involving environmental and economic dimensions. Is nuclear power an economically and environmentally sustainable energy source? The essential components of any answer to this question must involve: - the input of nuclear fuel, potential environmental effects from the whole fuel cycle, including plant operation and decommissioning, and overall power production economics (World Nuclear Association Report, 2000).

In its early days nuclear power was considered as offering a potentially unlimited source of energy. The input fuel, combined with the recycling of the spent fuel, does indeed offer a possible long-term energy source. But this promise relies on new technology, the cost and precise features of which are not yet known with certainty. The reduction of operational risks from nuclear power plants has always been given top priority in plant design, and the very limited radioactive emissions from commercial plants during normal operation, since nuclear powers' inception, suggests that the environmental risks from nuclear power can be made extremely small (World Nuclear Association Report, 1999). But, still the risk of catastrophic accident causes significant public concern. The by-products of nuclear power generation also lead to a great concern for environmental sustainability of nuclear energy. Can fission by-products and long-lived wastes be handled safely and not endanger the environment? The technical evidence seems to suggest a positive answer. Ensuring this in practice, however, involves political uncertainty and some considerable perseverance (International Energy Agency Report, 2000). There is a possibility that attaining publicly acceptable safety level in plant operation and spent fuel management could render nuclear power uneconomic in comparison to other options.

In April 1986, unit 4 of the Chernobyl nuclear power plant (NPP) in Ukraine was destroyed in the worst accident in the history of commercial nuclear power. The reactor, which became operational in 1983, is a Soviet-designed nuclear plant known by the Russian acronym RBMK. Today, 15 RBMK power reactors are producing electricity in three countries: 11 units in Russia, 2 in Ukraine, and two Units at Ignalina NPP in Lithuania (International Atomic Energy Agency, 2000).

Lithuania separated from the Soviet Union in 1990 and took over the responsibility for operating and regulating the plant, which has the world's largest RBMK nuclear reactors (CEE Bank Watch Network, 1998). Ignalina NPP provides annually around 80% of the total Lithuanian electricity needs (Lietuvos Energija, 2000). The two units at Ignalina NPP have a capacity of producing 14 TWh of electricity a year (Lietuvos Energija, 2000), which provides Lithuania with most of the electricity needs and the rest is exporting to neighbouring countries. Thus, Ignalina NPP has a vital role in the electricity production and in the economy of Lithuania.

As Lithuania has the goal in its international policy to join the EU, it aims to change many of its rules and standards to achieve European Union's standards. The nuclear power plant in Lithuania has to be as safe as the other NPP in the countries of the EU. Since Ignalina NPP has RBMK type reactors, the radiation and technical safety is under question from the international organisations dealing with nuclear reactors.

According to the report of the workshop organised by the IAEA, in 1999, that had the working topic" Radiation protection at nuclear power plants", "Ignalina NPP works a lot on radiation protection issues and, according to the radiation protection results, it takes the priority over the nuclear power plants with RBMK-type reactors". However, Western European Nuclear Regulators Association "WENRA" reported in the year 2000 about RBMK reactors at Ignalina NPP and concluded, "The weaknesses have to do with a less robust design of the confinement of the Ignalina NPP reactors as compared with Western light water reactors. It is not realistic to make the Ignalina NPP confinement system comparable. Consequently, regarding mitigation of an accident, a safety level comparable to light water reactors of the same vintage in Western Europe will not be reached".

In October 1999, the Lithuanian Parliament (Seimas) decided that in line with the Nuclear Safety Account Agreement, Unit 1 at Ignalina NPP would be closed down before the year 2005 (The European Commission, 2000). Similarly, the conditions of the final closure of Unit 2, taking into account the difference in age with the Unit 1, shall be decided upon in the next Lithuanian Energy Strategy in the year 2004 (The European Commission, 2000). The European Commission interprets this decision as a commitment for closure by 2009, at the latest.

This study deals with various aspects of the operation of Ignalina NPP and the consequences for Lithuania of the decision to close it down. The consequences will be analysed from an environmental as well as a socio-economic point of view. This kind of study must be taken in any case a nuclear power plant is to be decommissioned to see not just the positive side from closing it down, but also the negative impacts from environmental and socio-economic point of view. Successful closure of the Ignalina NPP will give the EU a hope for closing the other RBMK nuclear reactors and vice versa. Looking at the constraints and impacts of closing down Ignalina NPP and being aware of them helps in putting plans for a sustainable closing down of the Ignalina NPP that may not affect the economy, society and environment in Lithuania. This is very necessary since Lithuania is a country in transition from a former plan-economy to a market-oriented economy. Any under-estimation of the cost of closing down Ignalina NPP will affect the long-term sustainable development in Lithuania in aspects related to socio-economic as well as environmental points of view.

1.2. Methodology

To achieve the general goals of this study, many questions have to be answered and further analysed. These questions are the following: Is there a net benefit for the environment of closing down Ignalina? What are the social consequences of changing from nuclear energy production to alternative methods? What are the plans for taking care of radioactive waste after closing and decommissioning of Ignalina NPP? What are the economic consequences of changing from nuclear energy to the alternatives in Lithuania? Are there enough renewable energy sources in Lithuania as alternative for closing down Ignalina NPP? Moreover, radiation risks for staff of Ignalina NPP and other staff working at alternative energy production plants are to be compared and analysed.

In Fig.1 a so called Causal loop diagram shows how this study is going to analyse the problems that may face Lithuania of either decommissioning, closing of Ignalina NPP or leaving it in operation. As can be seen from the CLD shown below, whether Ignalina NPP will be left operating or it will be shut down, there will be negative impact on one of three elements: economy, environment or international policy for Lithuania. So, in this CLD there are three elements that will gain or loose from any decision taken regarding the fate of Ignalina NPP. If proper plans will not be implemented, one or more element from the three discussed will be affected negatively. The analyses done through this study is to look for balanced solutions for different problems that may arise from the applied political decisions.

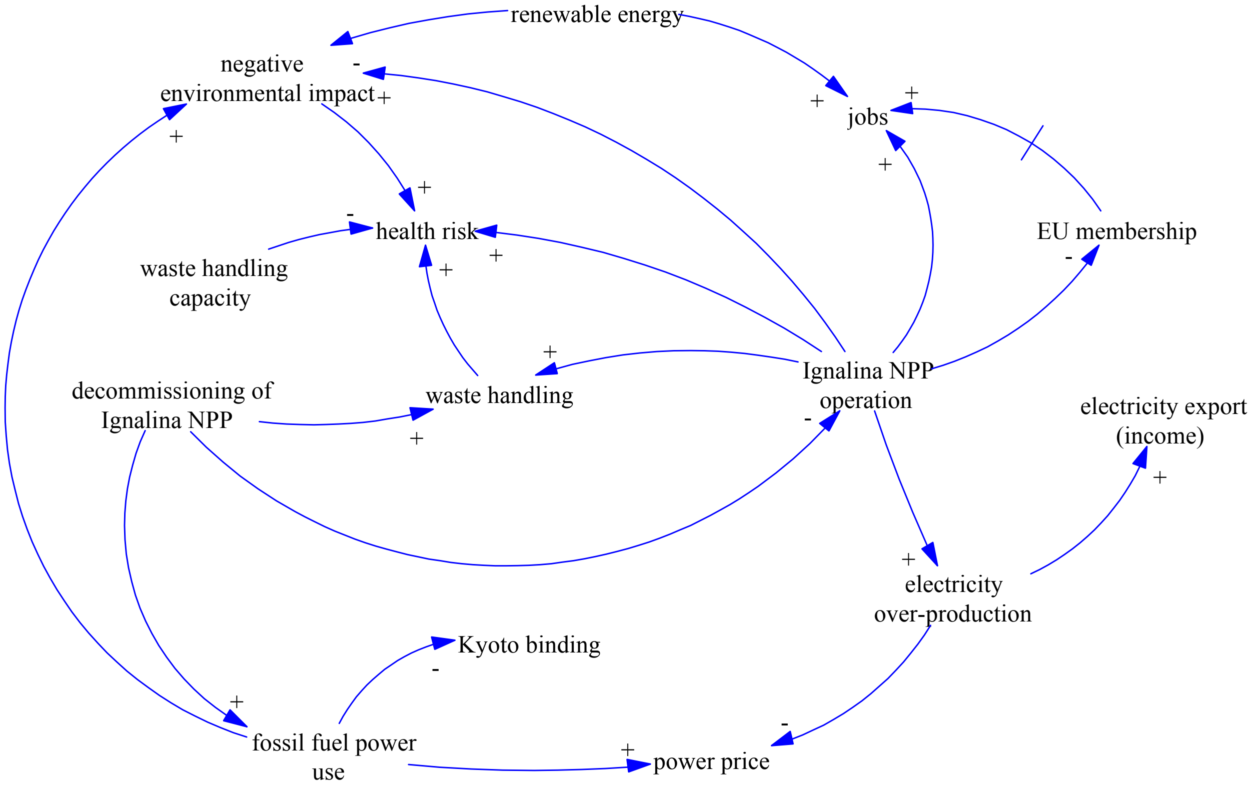


Fig.1. Causal Loop Diagram (CLD) showing the major components of three elements: environment, international policy and socio-economic side of any applied decision regarding Ignalina NPP. The (+) sign means a causal change in the same trend (either decrease caused by decrease, or increase caused by increase), and the (-) sign is a change in opposite direction.

1.3. Limitation

The analyses through this study does not take into consideration the possibility of building a new Western type nuclear power plant in Lithuania to replace Ignalina NPP and could thus affect the energy strategy in Lithuania. It was difficult to find relevant updated references to this topic from books, articles or journals because most of the articles about Ignalina NPP are in Lithuanian, the language that I do not understand. I got few articles in English, and after the Sept.11, 2001 (attack on the USA), all the information regarding NPP anywhere has become confidential. It was a real obstacle in getting information directly from Ignalina officials because of that event. Because of all these constraints, I had to depend mostly on the links from the web in getting the literature and references. Moreover, I had not enough time to add more details and analysis to some of the chapters. Additionally, I had not the possibility to travel on a field trip to Ignalina NPP and see the problems in reality because of financial and visa problems. However, I tried my best to collect the good material and references to make this research study as good as possible.

2. Ignalina NPP characteristics and electricity production

2.1. Description of Ignalina NPP

The Ignalina NPP is located in the northeastern corner of Lithuania (Fig.2.), close to the borders with Belarus and Latvia(Ignalina NNP, 2001). The plant is situated on the southern shore of Lake Druksiai, 39 km from the town of Ignalina. The nearest big cities are the Lithuanian capital Vilnius (130 km away) with a population of approximately 575,000 and the city of Daugavpils in Latvia (30 km away) whose population is 126,000 (Lithuanian International Nuclear Safety Center, 2001). The plant's closest neighbour is the town of Visaginas, the residence of the Ignalina NPP personnel. The town is located 6 km from the plant and has a population of about 32,600. All distances given above are flight distances.

Fig.2. Location of Ignalina NPP in Lithuania and the political borders of countries surrounding Lithuania, U indicates nuclear power plants.

The density of the population inside 15 km radius is 14.4 persons/m^2 excluding Visaginas, and 63.1 people/km^2 including Visaginas (Ignalina NPP, 2001). Within 25 km, the density of the population is 18.6 and 35.6 person/km^2 respectively (Lithuanian International Nuclear Safety Center, 2001).

The plant uses Lake Druksiai as a natural reservoir for cooling water. The other lakes in the vicinity of the Ignalina NPP are: Visaginas, Apyavarde, Alksnas, Dysnai, and Smalves. Daugava River passes 30 km north of the plant.

The plant was originally built not only for Lithuania, but also to satisfy the needs of the Soviet Union's North-West Unified Power System. A total of four units were planned for the site. The construction of the third unit was terminated in 1989 and cancelled in 1993 (Ignalina NPP, 2001).

2.2 Climate in the area of Ignalina NPP

The Ignalina NPP is situated in the temperate climate zone. The climate is rather unstable because of the prevalent intrusion of airflows from the adjacent geographical zones. In comparison with other Lithuanian areas, this area is marked by a big variation of air temperature over the year, the colder and longer winters with abundant snow cover, and warmer but shorter summers. The average annual temperature in the region is 5.5°C. During the year, about 170 atmospheric fronts pass over the Ignalina territory from west and southeast (Lithuania International Nuclear Safety Center, 2001). The average annual precipitation with correction for moistening of draught gauge is 638 mm. The region is covered by snow for about 100-110 days per year. The average height of the snow cover is 30-40 cm. The average annual relative humidity of air reaches 80%. The average number of days with fog is 45 distributed all the year around (Lithuanian International Nuclear Safety Center, 2001).

2.3. Ignalina Structure, safety, and electricity production

Ignalina NPP consists of two units, commissioned in December 1983 and August 1987 (Ignalina NPP, 2001). Both units are Soviet designed RBMK-1500 reactors and differ from the RBMK-1000 plants operating in Russia and Ukraine not only by a higher nominal power level, but also by several improved safety features including an Accident Localisation System (ALS) (Ignalina NPP, 2001).

Ignalina NPP generates electrical power at a cost of approximately half that of alternative sources. In 1993, nuclear energy provided 88.1% of Lithuania's electricity. In 1996 and 1997, Ignalina NPP generated 85.8% and 81.3% of the country's electricity respectively (Ignalina NPP, 2001).

Extensive studies by international experts have determined that in terms of Probabilistic Risk Analysis indexes, the modified (post" Chernobyl") Ignalina NPP is comparable to Western reactors (Lithuanian International Nuclear Safety Center, 2001). This conclusion certainly does not imply that Ignalina NPP is "identical" to Western BWR's. It is a graphite moderated, channel type reactor, and in many constructional aspects differs from the single pressure vessel BWR's. The documentation of the analysis detailing the consequences of these differences is very extensive. The probability of initiating events (e.g. pipe breaks, valve failures, etc.) for Ignalina NPP is higher than for comparable western BWR's (Lithuanian Radiation Protection Center, 2001). The objective reasons for this are the higher complexity for an RBMK type reactor (a considerably larger numbers of pipes, valves and associated equipment) and the lower level of quality control for Soviet design and construction.

On the other positive side, international analysis (International Atomic Energy Agency Report, 2000) yields that Ignalina NPP is remarkably robust and that the vast majority of initiating events will not lead to fuel overheating and the release of radioactivity from fuel. The robustness also has objective reasons. These include: channels construction which limits loss-of-heat-capacity of Ignalina NPP core region, the higher vertical elevations, the larger volumes of water in the primary system and above the core region and the high redundancy by which Soviet designers compensated for lower quality control.

2.4. Energy Production at Ignalina

2.4.1. Lithuania and electricity production sources

Lithuania has a large electricity production capacity. The installed electric power capacity is around 6,000 MW. The total output of Lithuanian power plants in 1997 was 14.8 TWh of electric energy Ignalina NPP, 2001).

Ignalina NPP is generating the largest amount of electricity in Lithuania. The installed capacity of both units 1 & 2 of Ignalina NPP is 3,000 MW. However, due to safety reasons, it is allowed to operate them at 2,600 MW.

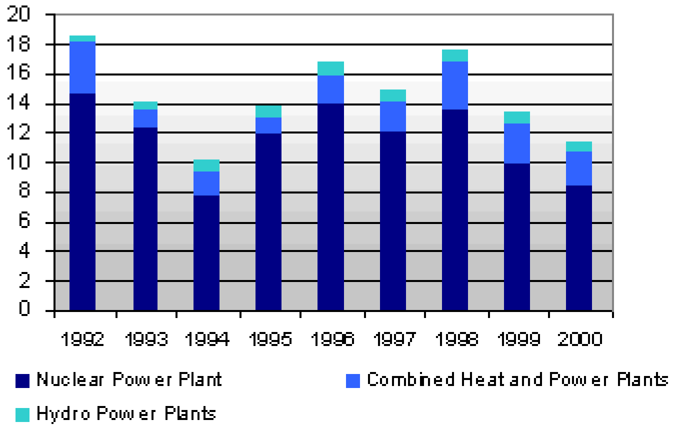


Fig.3. Electricity production in Lithuania in 1992-2000, TWh (Lietuvos Energija, 2001)

As shown in fig.3 and 4, Ignalina is the most important producer of electricity in Lithuania.

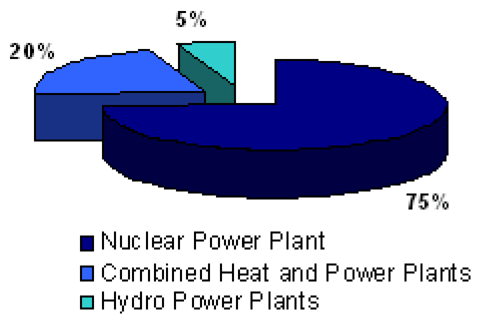


Fig.4.Structure of electricity generation during year 2000 (Lietuvos Energija, 2001)

2.4.2. Lithuania electricity export

Lithuania generates substantially more electricity than it consumes domestically (Energy Information Administration "EIA", 2001). The domestic consumption has decreased 30% since 1992 (fig.5.), but still leaving Lithuania with some excess power to export to neighbouring countries (Energy Information Administration "EIA", 2001)).

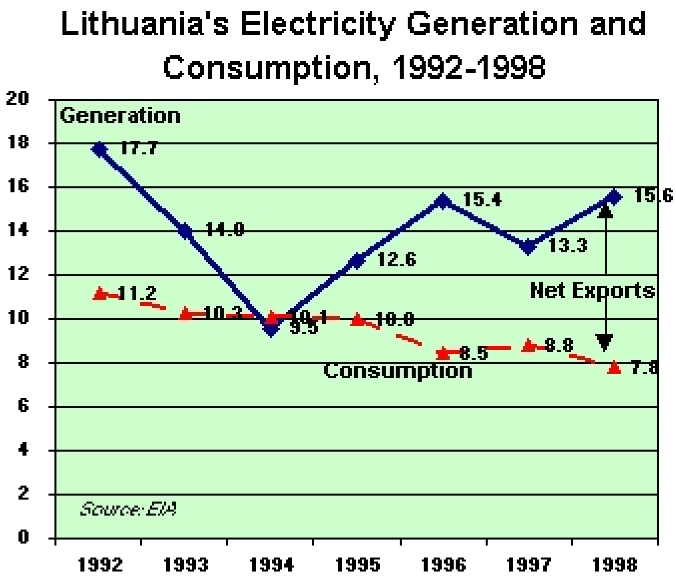


Fig.5. Lithuania's electricity generation and consumption 1992-1998, TWh (Energy Information Administration "EIA"website)

In the year 2000, Lietuvos Energija AB sold 8.3 TWh of electricity (Lietuvos Energija, 2001). From that amount, 6.8 TWh of electricity was sold to Lithuanian customers and 1.5 TWh was exported which made 18% of all electricity produced.

The geographical location of Lithuania as well as well developed infrastructure of electric power lines make it possible to export electricity to neighbouring countries. The Lithuanian energy system is interconnected with Latvia by four lines, with Belarus with five lines and with Russia (Kaliningrad region) by three lines (Lietuvos Energija, 2001). At present, the main countries importing electric power from Lithuania's are Latvia and Belarus.

Belarus has looked mainly to Lithuania to supplement its electricity needs. Belarus still owes Lithuania $56 millions for electricity supplied in 1998 and 1999 (Energy Information Administration, 2001). But after a one-year break, Lithuania agreed in May 2000 to supply Belarus with electricity again after concluding an unusual three-party agreement with Russia and Belarus. Under the agreement, Russian Energy Company "Energiya" agreed to purchase 2.2 TWh of electricity generated at Ignalina NPP for subsequent delivery to Belarus. "Energiya" will pay for the electricity with nuclear fuel for Ignalina NPP while Belarus supplies Russia with commodities as payment (Energy Information Administration, 2001).

2.6. Decision to close Ignalina NPP

On October 1999, Lithuanian Parliament (Seimas) decided that, in line with the Nuclear Safety Account Agreement, Unit 1 would be closed down before the year 2005. Similarly, the conditions of the final closure of Unit 2, taking into account the difference in age with Unit 1, shall be decided upon in the next National Energy Strategy (2004). The European Commission interprets this as a commitment for closure by 2009, at the latest (The European Commission, 2001).

3. Occupational Exposure at Ignalina NPP

In this chapter, the occupational doses are discussed and analysed. The purpose of this chapter is to show whether Ignalina NPP is a risk for its staff by analysing the data of doses absorbed during different years. Also, a comparison of the doses registered at Ignalina NPP and those registered at two NPPs in Finland are shown to see whether Ignalina NPP staff radiation protection has similar standards as in the Western European ones.

3.1. Personal Radiation Dosimetry in Lithuania

The personal dosimeter service is available in the Lithuanian Radiation Protection Centre in Vilnius. Thermoluminiscent dosimeter system by "Rados Technology" is used for monitoring of personal doses. The system is calibrated for measurements of $H_p(10)$. The system is also used for environmental monitoring (Lithuanian Radiation Protection Center, 2001).

Each radiation worker must wear a personal dosimeter during work. The dosimeters are evaluated with an interval of 3 months (Lithuanian Radiation Protection Center, 2001). However, Ignalina NPP has its own dosimetry service. The dosimeters are evaluated monthly.

3.2. Average dose to the Lithuanian population from the natural sources of ionising radiation

The average annual effective dose from natural sources of ionising radiation in Lithuania is 2.2 mSv. The following sources (Table 1.) are included: indoor radon- 1 mSv, cosmic radiation- 0.35 mSv, soil and building material materials- 0.5 mSv, and radionuclides in human body- 0.34 mSv (Lithuanian Radiation Protection Centre Report, 2000).

3.3. Average dose to Lithuanian population due to operation of nuclear energy installations

The dose due to nuclear energy installation is constrained by means of limitation of releases of radioactive materials from these installations. The concept of dose constraints is used for these reasons. It means that dose constraints are determined for each source and are used for optimisation of radiation protection. All the possible exposures from all the controlled practices are taken into account. The sum of all these doses shall be lower than the dose limit. When dose constraint is used, the doses to members of critical groups due to the use of even few sources do not exceed dose limits. According to ICRP 8, the critical group is a hypothetical group of people who are most likely to be the most exposed to radiation. The dose constraints for members of critical groups due to installation of nuclear energy are 0.2 mSv/year (Lithuanian Radiation Protection Centre, 2001). In Sweden, the dose constraint is 0.1 mSv/year for operational nuclear power stations (Western

European Nuclear Reactors' Association, 2001). The dose constraints due to international recommendation should not exceed 0.3 mSv/year.

It is calculated that the annual dose to Lithuanian population due to the operation of nuclear energy installations does not exceed 1/100 of the dose limit for the public and is about 0.01mSv (Lithuanian Radiation Protection Center, 2001).

Table 1. Comparison between annual doses from natural sources and nuclear energy installations (Source: Lithuanian Radiation Protection Center, 2001)

Source of ionising radiation	*Annual dose in mSv*
Mean dose from natural sources	2.2
Indoor radon and radon daughters	1
Cosmic radiation	0.35
Soil and building material	0.50
Radionuclides in human body	0.34
Mean dose due to operation of nuclear installations	0.01

3.4. Estimations of annual absorbed dose to the working staff at Ignalina

In the year 2000, there were 3269 employers (Table 2.) dealing directly with ionising radiation at Ignalina NPP (Lithuanian Radiation Protection Centre Report, 2001). Additionally, 575 special task workers were also working temporarily at the Ignalina NPP.

The average dose for all workers of Ignalina NPP in the year 2000 was 2.8 mSv. Regarding the effective dose in the year 2000 at Ignalina NPP, 63% of the effective dose are in the range of 0-0.5mSv, 7% in the range of 0.5-1mSv, 13% in range of 1-5 mSv, 6% in range of 5-10 mSv, 4% in range of 10-15mSv, 6% in range of 15-20 mSv, and 1% in range of 20-25mSv (Lithuanian Radiation Protection Centre website, 2001). Table 2 below summarizes results of monitoring of occupational exposure of workers working with source of ionising radiation at Ignalina NPP on the year 2000.

Table 2. Average annual effective doses of workers at Ignalina NPP in the year 2000 (Source: Lithuania Radiation *Protection Centre Report of the year 2001)*

Area of activity, occupation	**Number of workers**	**Average annual effective dose, mSv**
Ignalina NPP (inside workers)	3269	
	2728	0-5
	197	5-10
	296	10-20
	48	More than 20
Ignalina NPP (outside workers)	575	
	422	0-5
	40	5-10
	113	10-20
	0	More than 20

Source: VATESI Annual Report 2000

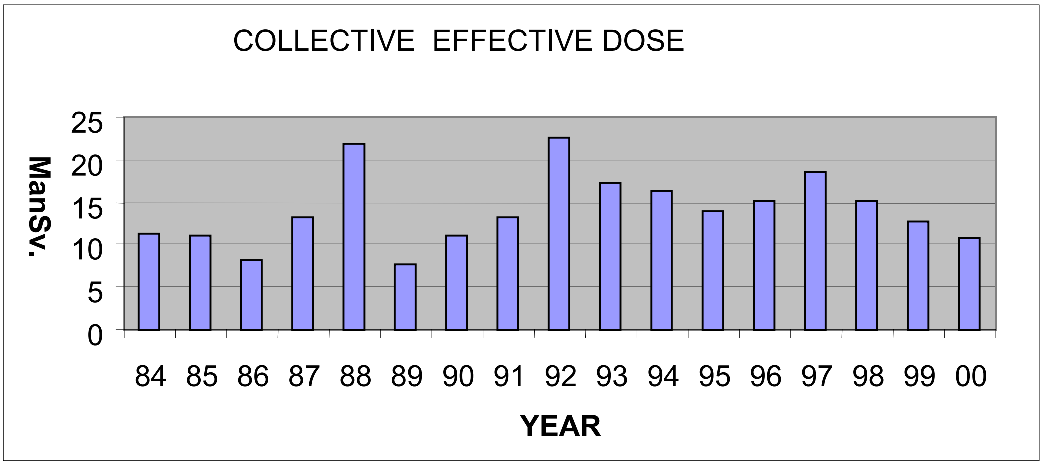


Fig.6. Collective effective doses at Ignalina NPP includes own staff and outside workers, when working at Ignalina

To understand the importance of Fig.6, the definition of what collective effective dose indicates is necessary. Collective effective dose is the product of the mean effective dose and the number of exposed persons (Kimball's Biology Pages, 2001). Even though the mean dose to the people in a certain exposed group is small, there is still a probability that some or more of these individuals may develop late effects, e.g. cancer, due to radiation exposure. According to Kimball's Biology

Pages (Fig.7.), there is considerable evidence that at moderate amounts of a carcinogenic substance, the response is linear (A). However, at very low amounts of some chemicals, there may be a threshold (B) below which the agent has no effect. For other chemicals, and probably radiation, it is likely that even the tiniest dose will have an effect (C), but the population exposed must be large enough to observe it. Note that at zero doses, the line does not intercept the origin. This is because even unexposed individuals show a spontaneous level of response (e.g., tumours).

At very high doses, the rate of response may increase faster than the dose (E) as, for example, the probability of a single cell suffering from two mutations increases. On the other hand, very high doses may kill off damaged cells before they can develop into tumours (F) (Kimball's Biology Pages).

Source:(Kimball's Biological Pages, www.ultranet.com/~jkimball/BiologyPages/C/CancerRisk.html)

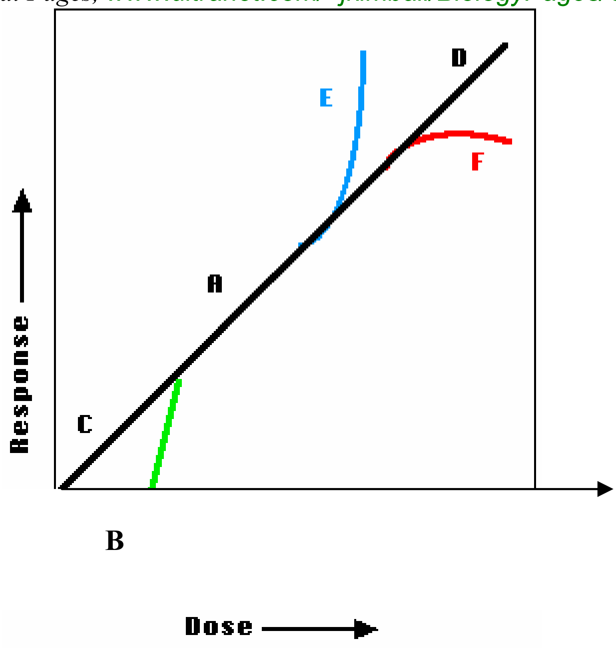


Fig. 7. Radiation-induced response

Moreover, it may be of interest to compare the collective doses from Ignalina NPP with collective doses to workers at Western European NPPs. This will give us an answer to the question whether the radiation safety measure of the employees at Ignalina NPP is as good as the ones at Western European NPPs. For comparison, two NPP in Finland are considered, Loviisa and Olkiluoto NPPs. The figure below (Fig.8.) shows the collective radiation dose at the Finnish sites.

Source: Finland Radiation and Nuclear Safety (STUK)

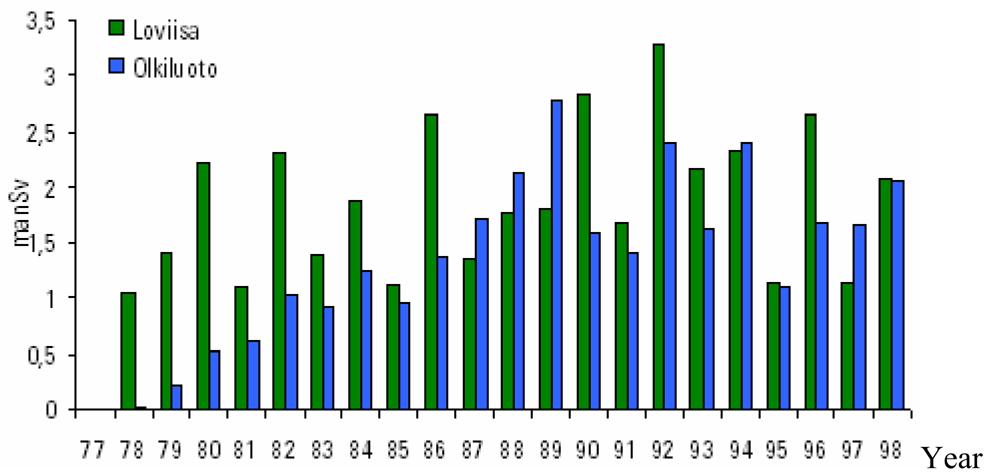


Fig.8. Collective doses for workers at Loviisa and Olkiluoto NPPs (1977-1998).

The collective dose for workers at each of the two NPPs (Fig.8.) was not exceeding 3.3 manSv per year during a 20 years period (Finnish Radiation and Nuclear Safety Authority "STUK", 2001). Even in 1989 where the collective dose at Ignalina NPP the lowest within the last 16 years. However, it is still higher than the highest collective dose registered (3.3 manSv) at Loviisa NPP in 1992 (STUK, 2001). Even if we consider that in Finland the dose from natural sources has been subtracted from the measured doses, the radiation protection of the personnel at the Finish NPP seems to be better than at Ignalina NPP. But here the operational parameters of the NPP have to be taken into account as well as the number of employees at the different NPP (Table 3.)

Table 3. Comparison of annual electricity production, number of employees, collective dose, and collective dose per unit electric energyproduced, at Ignalina, Loviisa and Olkiluota NPPs in the year 2000.

	Annual electricity production (TWh)	Number of employees	Collective dose*/ man Sv	Collective dose per unit electric energy produced/man Sv/TWh
Ignalina NPP	14	5000	10	0.71
Loviisa NPP	3.8	1000	2	0.53
Olkiluota NPP	7.0	1300	2	0.29

3.5. Summary

Radiation protection for Ignalina NPP staff has been improving in the last few years. However, in spite of that effort, the occupational exposure is higher than that in the Western European NPPs. This is partly because a larger number of employed personnel are working at Ignalina NPP than at Western European NPPs. The plant is also larger in capacity than comparable Western NPPs. One way to achieve the radiation protection level like that at Western NPPs is by improved training in radiation protection. When decommissioning Ignalina NPP, special care has to be taken to protect the decommissioning staff during the performance of the decommissioning process.

4. Regional and Local effects of Ignalina NPP on the environment

Before going into details about the effects of Ignalina NPP on the regional and local environment, the development of radioecological research in Lithuania is to be mentioned briefly. This is to give the reader an overview about the driving forces that was behind promoting the development in this field of science.

4.1. Background of radioecological research in Lithuania

Before 1986, radioecological research was conducted mainly in research institutes, such as the institutes of Physics, Geology, Botany, and Vilnius University of Construction (Lithuanian Radiation Protection Center, 2001). Public health institutions of the Ministry of Health were performing measurements of radionuclides with the aim of estimating their possible influence on humans. Many results of such research, especially regarding concentrations of radionuclides in foodstuff and drinking water, were secret and could not be easily accessed (Lithuanian Radiation Protection Center, 2001).

4.2. Effect of Chernobyl accident and Ignalina on the radiotion environment in Lithuania

All the available equipment was used for the measurements of radionuclides from the first days after Chernobyl accident. Though only one Ge(Li) spectrometer was available in Lithuania, the measurements of radioactive contamination of pasture grass, milk, and other foodstuffs were performed (Lithuanian Radiation Protection Center, 2001). Level of radioactive iodine in thyroids of people, which were coming from different places of Lithuania, served as indicator of the geographical distribution of radioactive contamination of the Lithuanian territory.

A few facts given below illustrate results received in connection with Chernobyl contamination of Lithuania. The content of ^{137}Cs on the ground was less than 1-2 kBq/m^2 before Chernobyl accident (Gudelis A., 1998). The radioactive cloud from Chernobyl passed over the southern, southwestern and western parts of Lithuania. Later "spots" of contamination have been detected. Small "spots" of ^{137}Cs have been detected in the southern and southwestern parts of Lithuania. The highest ^{137}Cs concentration has been found in the southern and western Lithuania near the lakeshores (Gudelis A., 1998).

Increase of concentrations of radionuclides in foodstuff after Chernobyl accident is also observed as it is shown in the figures below (Fig.9.). These concentrations are continuously decreasing.

An increase of the concentration of ^{137}Cs in meat, fish and vegetables occurred after the Chernobyl accident (Fig.9. and Table 4). Thus it is difficult to say whether Ignalina NPP had any influence on this matter. However, Sr/Y-90 concentration was observed to rise in Lithuanian environment even before Chernobyl accident.

Results of an evaluation of the doses due to main foodstuffs show that natural K-40 is responsible for more than 99% of doses. Doses, which are caused by artificial ^{137}Cs and Sr/Y-90, are 0.5 and 0.7 μSv, respectively (Gudelis A., 1998). Monitoring of radioactive nuclides in main foodstuffs is continued.

Results, received by different research institutions in Lithuania, show that Chernobyl contamination of Lithuania and doses burdens are similar to the ones in other neighbouring countries to the west and north from Lithuania. These results also show that the contribution from the normal operation of Ignalina NPP is very small compared to the contributions from the atmospheric nuclear weapons tests (Lithuanian Radiation Protection Center, 2001).

One of the most important problems in radioecological research is quality assurance of the measurements (Lithuanian Radiation Protection Center, 2001). This problem is especially important due to the fact that results received by some laboratories are used for decision what actions shall be taken with the food. Though contamination of foodstuff is permanently decreasing and in many cases is well below the action level (600 Bq/kg), the wild mushrooms, particularly the ones exported from Russia, Belarus and Ukraine, may cause health problems (Gudelis A., 1998). It makes the quality assurance and continued surveillance even more important.

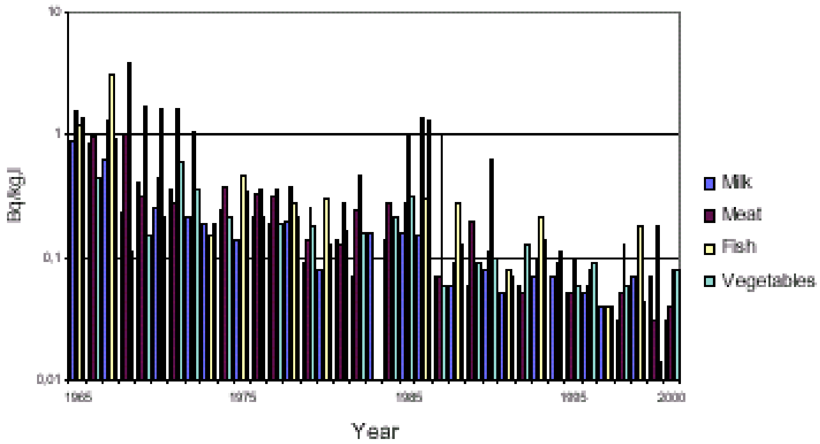


Fig.9. Concentration of ^{137}Cs in main foodstuffs in 1965-2000

The mean annual concentrations in air of some artificial radionuclides observed at 3.5 km southeast from Ignalina NPP are presented in table 4.

Table 4. Mean annual concentration in air of some artificial nuclides observed at 3.5 km from Ignalina NPP (Source: Gudelis A. Institute of Physics, Lithuania 1998)

Year	^{137}Cs	^{134}Cs	^{131}I	^{95}Zr	^{95}Nb	^{60}Co	^{54}Mn	Events
1978	13	-	-	41	80	-	1.1	
1979	15	-	-	-	-	-	-	
1980	10	-	-	49	61	-	0.3	Chinese test on October 16
1981	34	-	-	750	1300	-	16	
1982	7.1	-	-	-	-	-	0.2	
1983	4.4	-	-	-	-	-	-	First reactor of INPP put into operation in December
1984	1.0	-	-	-	-	19	46	
1985	0.4	-	-	-	-	11	23	
1986	6100	3400	4.5×10^4	45	68	5.6	10	Chernobyl accident on April 26
1987	13	5.2	-	-	-*	2.1	2.2	Second reactor of INPP put into operation in August
1988	8.2	2.2	-	-	-	0.9	0.8	
1989	2.8	-	-	-	-	0.7	0.7	
1990	2.4	-	-	-	-	0.8	1.0	
1991	4.1	-	-	-	-	0.9	1.2	
1992	4.4	0.09	-	0.2	0.6	1.0	1.5	
1993	3.0	-	-	0.6	0.7	0.16	0.18	
1994	3.5	-	-	-	-	0.19	0.19	
1995	3.8	-	-	-	-	0.04	0.04	
1996	3.6	-	-	-	-	0.13	0.05	
1997	1.1	-	-	-	-	0.25	0.11	

** The (-) sign indicates that the value is under the detected levels*

The first reactor of the Ignalina NPP was put into operation at the end of 1983. By that time, the ^{137}Cs concentration in surface air became close to the detection limit of $1 \mu Bq/m^3$. Beginning with 1984, the new kind of radionuclides appeared in the Ignalina NPP environment (Table 4). The activation products ^{60}Co, ^{59}Fe, ^{58}Co, ^{54}Mn, ^{51}Cr had been registered time after time, and correlation with a wind direction respective to the Ignalina NPP during the sampling period was very clearly seen. Initially, the concentration of activation products was measured as high as tens and, in some cases, even hundreds of $\mu Bq/m^3$. For instance, the maximum activity concentration of ^{60}Co, ^{54}Mn and ^{51}Cr was detected on 3-6 April 1985 and totalled to 111, 980, 274 and 1760 $\mu Bq/m^3$ (Gudelis A., 1998).

Because of significant radioactive contamination due to Chernobyl accident, the new stage of radioecology in the vicinity of Ignalina NPP environment began after the April 26, 1986. As a result the radioisotopes of iodine ^{131}I, ^{132}I together with ^{132}Te, as well as the other short-lived fission products such as ^{140}Ba, ^{140}La and ^{136}Cs were detected for the first time near Ignalina NPP in aerosol and fallout samples (Gudelis A., 1998).

4.3. Ignalina NPP and the environment

When operating and maintaining the NPP, large quantities of radioactive wastes are accumulated and stored in the NPP depositories. When the station is working normally, water and air purified of radioactive substances enters the environment (Lithuanian Radiation Protection Center, 2001). Radioactive pollutants increase when carrying out maintenance, or in the event of an accident.

The main permanent source of artificial radionuclide pollution in Lithuania is Ignalina NPP. In recent years, Ignalina NPP has been operating at half its capacity, so the amount of radioactive emissions into the atmosphere has decreased. The amount of pollution originating from Ignalina NPP is much lower than that originating from natural radioisotopes, nuclear weapons, and the Chernobyl NPP disaster. The most acute problem is the storage of liquid radionuclides waste within Ignalina NPP. Leakage of radioactive waste has been found in water flowing into the Druksiai Lake from Visiginas. Large amounts of radioactive materials have accumulated in the sediment on the bottom of the lake, and aquatic plants in the waste canal as well as near the canal have been found to be contaminated (Lithuania UNDP Report, 1996).

The accumulation of radioactive material in the impact zone of Ignalina NPP is measured by the NPP's own services. Moreover, under the auspices of the Lithuanian Monitoring Programme, the environment around Ignalina NPPs is monitored by the Central Environment Research Laboratory and by the Institute of Physics in Vilnius (Lithuanian Radiation Protection Center, 2001). At the end of 1993, with the help of Sweden, two automated gamma-monitoring stations were put into operation, one situated in the prevailing wind direction, and the other opposite that wind (Lithuanian Radiation Protection Center, 2001). These stations constantly measure the intensity of gamma radiation, and regularly transmit data into the central computer at the Environmental Protection Department. At the Institute of Physics base near Druksiai Lake, there is an operating model of the automated and meteorological observation system. At this operating model, wind speed and direction, air temperatures at two altitudes are measured, and air stability class determined. Based upon observation data, calculations of radionuclide dispersion in air are made in real time.

All the gaseous radioactive waste produced in Ignalina NPP is emitted into the atmosphere via a 150 m high ventilation pipe (Motiejunas S., 1996). The quantity of aerosol radioactive substances emitted is not high as the gas passes through storage chambers and filters on its way out.

Most active of all releases into the air are radioactive noble gases. As registered, 96-97% of the radioactive gases emitted by Ignalina NPP are ^{41}Ar (Motiejunas S., 1996), whose half-life period is 1.83 hours. ^{41}Ar appears in the reactor when neutrons activate stable ^{40}Ar contained in the air and in cooling water. The most significant product is ^{133}Xe whose half-life is 5.2 days. This radionuclide accounts for about 3% of the inert gas activity. Other xenon and krypton isotopes make up less than 1% of the radioactive emission.

Table 5. Ignalina NPP releases to air (Source: S.Motiejunas report)

	1985	1986	1987	1988	1989	1990	1991	1992
Radioactive inert gas (GBq)	$4940x10^3$	$3173x10^3$	$1593x10^3$	$2098x10^3$	$1768x10^3$	$2390x10^3$	$1768x10^3$	$703x10^3$
^{131}I (GBq)	80.6	147	34.5	38.5	2.7	4.3	10.1	1.18
"Long-living"radionuclides (GBq)	38.5	8.5	3.0	3.3	1.7	9.8	10.6	2.15

Noble gases do not enter the biological chain, and quickly spread in the atmospheric air. These gases only cause external irradiation and, therefore, their effect on the environment is not very significant.

Other radionuclides, which have entered organisms via food, water and air can be assimilated and remain in the tissue for a long period. Iodine isotopes are especially radiotoxic, the most significant being ^{131}I (half life 8.1 days). Over the last few years, releases of this nuclide from Ignalina NPP have decreased considerably (Table 5).

Meanwhile, the impact on the environment by Ignalina NPP itself was not clearly seen since the collection of air and fallout samples were permanently carried out at only one location. Approximately 120 samples air and 12 fallout samples were gathered yearly but usually only few of them contained activation products typical of Ignalina NPP. It was evident that comparing with the starting period (1984-1985) the releases became less by two orders of magnitude. The occurrence of activation products was recognised several times at Braunschweig and other European stations when easterly wind prevailed. Considering trajectory calculations, Ignalina NPP might have been the most probable source of these events (Motiejunas S., 1996). However, simultaneous detection of the same activation products at the near site (3.5 km southeast) and remote one (Braunschweig) did not take place, evidently due to insufficient sensitivity of the method and relatively low releases, reducing the probability to detect certain radionuclides in different directions at the same period of time. The activity concentration of both ^{60}Co and ^{54}Mn in air near the Ignalina NPP was similar in the early nineties, thus the activity ratio $^{54}Mn/^{60}Co$ was close to 1 (Motiejunas S., 1996). However, the ratio was found to be close to 4 when radionuclides under consideration were detected in Berlin on 9-15 June 1992.

In order to estimate the extent of artificial radionuclides accumulation in the Ignalina NPP environment, some investigations were carried out. Deposition of ^{60}Co and ^{54}Mn released to the atmosphere was calculated taking into account meteorological data and measured concentration in fallout. According to these calculations, the total amount fallen onto the surface of lake Druksiai in 1992 was 4.0 MBq and 3.2 MBq respectively (Gudelis A., 1998). The same work also dealt with concentration of fission and activation products in the bottom sediments and hydrophytes. Investigations on land ecosystem revealed certain sites located both in directions of prevailing winds and close to the lake. The deposition of ^{60}Co in the mat was found to be 24 Bq/kg. Furthermore, 228 soil samples around Ignalina NPP from the upper 5 cm layer at the sites with known coordinates were taken in 1996. Available moss samples from the surface of $1m^2$ at the same location were taken too. The total number of moss samples was 77. No activation products were detected in the soil samples. The mean deposition of ^{137}Cs in soils was 0.9 kBq/m^2, allowing to conclude that the whole investigated territory was slightly contaminated with ^{137}Cs which mainly represents consequences of global fallout. However, three anomalous sites were ascertained as contaminated directly by Ignalina NPP. The activity ratio $^{137}Cs/^{134}Cs$ was estimated to be between 2 and 9 at these locations (Gudelis A., 1998).

5. Emergency Preparedness for nuclear accident at Ignalina NPP

5.1. Ignalina and Radiation Safety

In October 2001, The IAEA organised a workshop under the working title “Radiation protection at nuclear power plants”. According to this workshop, Ignalina NPP works a lot on radiation issues and, according to the radiation protection results; it takes the priority over the nuclear power plants with RMBK-type reactor (IAEA, 2000).

One of the most instructive indicators of the safety operation is the number of emergency shutdowns of the Ignalina NPP Units (Table 6). The downward trend of this indicator (Table 6) is not too evident. The fact that the number of emergency shutdowns increases every second year may indicate that Ignalina NPP emphasis is laid on short-term emergency prevention programmes (VATESI report, 2000).

Table 6. Number of emergency shutdowns at Ignalina NPP (1984-2000) (VATESI report, 2000)

YEAR	Unit 1	Unit 2	Ignalina NPP
1984	32	0	32
1985	3	0	3
1986	8	1	9
1987	0	6	6
1988	3	8	11
1989	1	0	1
1990	5	1	6
1991	1	3	4
1992	2	4	6
1993	1	1	2
1994	5	3	8
1995	1	1	2
1996	5	2	7
1997	2	0	2
1998	3	1	4
1999	1	2	3
2000	2	3	5

Even though the radiation protection and radiation safety at Ignalina NPP is comparatively high compared to the other RMBK-1500, there is still a need for emergency preparedness (WENRA, 2001). So, the following discussion regards the emergency preparedness to any nuclear accident at Ignalina NPP.

5.2. Emergency evaluation calculation

The earlier on-site Emergency Response Plan has been thoroughly reviewed and modified in line with Western NPP standards. Accident classification and alarm criteria have been developed according to the IAEA's RMBK guidelines, and following a final review from Lithuanian International Safety Center, they will be included in the plan. The new plan is using the completely reconstructed Emergency Operation Centre. This plan is under revision frequently to accommodate for the experience gained (Western European Nuclear Regulators' Association, 2001).

Early in an emergency, there is a need for quick rough release predictions in support of planning of the emergency response.

5.3. Main organs responsible for emergency in case of an accident to Ignalina NPP

The Lithuanian National Department of Civil Defence has developed an emergency plan for the protection of Lithuanian inhabitants, based on Lithuanian legislation and other regulations ("Plan for protection of Lithuanian Republic population in case of accident at the Ignalina NPP"). Every year, government authorities repeatedly analyse, improve and finally approve the context of this plan (VATESI, 2001). The immediate actions of civil defence in case of an accident include: organisation of warning and communication, management, radiation protection, evacuation, medical aid, protection of cattle and plants, fire protection, keeping the public order, logistics, and civil security forces.

In 1994, Lithuania joined the 1986 IAEA Convention regarding operative information about nuclear accidents and established procedure of presenting such information (VATESI, 2001).

The roles and obligations of different institutions (Fig.10) in case of an accident at the Ignalina NPP are determined by numerous legislative details. One of the main institutions is the Lithuanian Nuclear Power Safety Inspectorate (VATESI), which in case of accident shall:

- Accumulate information on the situation in the Ignalina NPP;
- Make analysis and prospect situation on the plant site, evaluate possible release of radioactive substances to the environment;
- Informs the Prime Minister, the Department of Civil Defence, Ministers of Health and Environmental Protection, Nuclear and Radiation Safety Advisory Committee, other Governmental structures about conditions at the plant and radioactive release;
- Provide information to the public on the current emergency situation, and operation of liquidation activities;
- Inform and advice the Emergency Situation Commission;
- Inform the International Atomic Energy Agency (IAEA) and neighbouring countries as required by Convention and bilateral agreements. VATESI shall present to IAEA and neighbouring countries the following information: time, exact place and nature of the accident, possible or determined cause of the accident, general characteristics of radioactive release, as well as quantity composition and amplitude of radioactive release (VATESI Annual Report, 2000).

Source: VATESI (http://www.vatesi.lt/en/img/avarinio_len_2_d.jpg), 2001

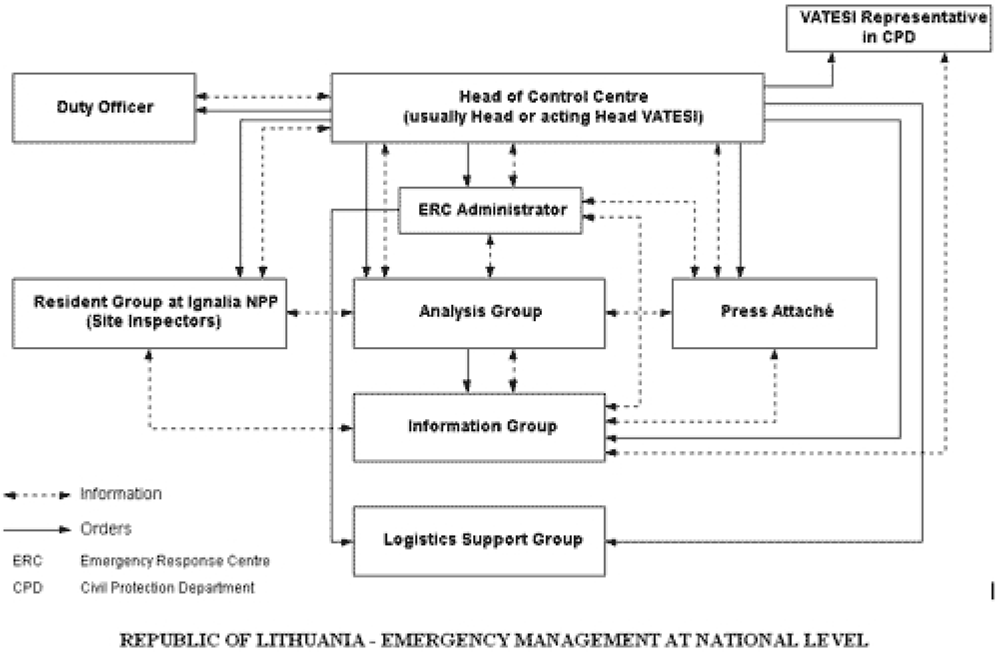


Fig.10. Republic of Lithuania- Emergency Management At National level

5.4. Criteria for radiation protection of inhabitants in case of accident at Ignalina NPP

According to VATESI, the radioactive accidents at Ignalina NPP are divided into three types: local, regional and general accidents. In case of a radioactivity release to the atmosphere, the following exposures are possible:

- External exposure from passing radioactive cloud;
- Internal exposure by inhalation of radioactive aerosols;
- Contact exposure in case of radioactive materials being caught on open body or clothes;
- General external exposure of people by radioactive substances, fallout on the ground, building and surfaces;
- Internal exposure of people ingesting food and local water contaminated by radioactive substances.

For forecast of radioactive consequences and planning protection of residents, three phases of accident are distinguished:

A- Early phase: from the beginning of accident until finishing of release of radioactive substances to the environment (information of radioactive plume at the ground). This phase could last from several hours until several days. In this phase, radioactive fallout products cause external exposure from the passing of populated areas by the radioactive cloud and internal exposure from inhalation of radioactive substances being in cloud.

B- Intermediate phase: from formation of radionuclide deposition until all protection measures for residents are taken. Depending on the scale and nature of accident, this phase could last from several days until one year. In this phase, external exposure is caused by radioactive substances, which deposited from clouds on the ground and buildings, and formed radioactive deposition. Radioactive substances enter the body by ingestion of contaminated food and water.

C- Late phase: Lasts until the time when no further remedial protection measures are necessary. All restrictions at the contaminated territory are recalled, but domestic monitoring is fulfilled. External and internal exposures are caused by the same reasons as in the intermediate phase.

Criteria for radiation protection of inhabitants are given in Tables 7 and 8 for the early and intermediate phases of accident respectively. These recommendation criteria were elaborated based on recommendations of International Radiation Safety Commission and approved by the head physician-hygienist by the Republic of Lithuania (Lithuania International Nuclear Safety, 2001). Neither of the remedial measures listed in Tables 1 and 2 are used if predicted doses are below the lower limits.

Measures could be postponed or taken depending on real radiological situation and local conditions, if predicted doses exceed the upper limits. Measures listed in these tables must be taken if predicted doses are above the upper limits. Permanent and temporary permissible levels of radioactive contamination of food are given in Table 9. Temporary permissible levels could be used only for the contaminated food and not longer than 30 days from the beginning of the accident.

Table 7. Radiation safety criteria for inhabitants at the early phase of an accident (Source: Lithuanian International Nuclear Safety, 2001)

Prognostic dose for 10 days, mSv	Lower limit (mSv)	Upper limit (mSv)	Lower limit (mSv)	Upper limit (mSv)
Measures to ensure radiation protection of inhabitants	If all body is exposed	If lungs, thyroid gland or any other body organs are exposed		
Sheltering, protection of respiration organs and all body	5	50	50	500
Iodine preventive measure				
Adults	-	-	50*	500*
Children and pregnant woman	-	-	50*	250*
Evacuation				
Adults	50	500	500*	5000*
Children and pregnant women	10(1)	50(5)	200*	500*

**Used for thyroid gland*

Table 8. Radiation safety criteria for inhabitants at the intermediate phase of an accident (Source: Lithuanian International Nuclear Safety, 2001)

Prognostic dose for 10 days (mSv)				
Measures to ensure radiation Protection of inhabitants	If all the body is exposed		If lungs, thyroid gland or any other body are exposed	
	Lower limit	*Upper limit*	*Lower limit*	*Upper limit*
Limitation for use of drinking water and foodstuff	5	50	50	500
Evacuation of inhabitants	50	500	-	-

Table 9. Permanent and temporary permissible levels of radioactive contamination (Source: Lithuanian International Nuclear Safety, 2001)

Type of food	Group of nuclides	Permanent levels (Bq/kg)	Temporary levels (Bq/kg)
Milk/babies food	^{239}Pu, ^{241}Am	1	10
Other food		10	100
Milk/babies food	^{90}Sr, ^{131}I	100	1000
Other food	^{90}Sr	1000	1000
Milk/babies food	$^{134/137}Cs$	1000	10000
Other food	$^{134/137}Cs$, ^{131}I	1000	1000

5.5. Evacuation Plan for inhabitants of Lithuania in case of nuclear accident at Ignalina NPP

A division of the Lithuanian government carries out the evacuation of local inhabitants. The Governmental Emergency Situation Commission makes proposals with regard to evacuation based on actual situation, radiation forecast and inhabitant's protection criteria. The Governmental Emergency Situation Commission controls the evacuation through municipal administrators and the municipal emergency situation commissions. More than 53,000 people should be evacuated from 30 km zone (VATESI website, 2001). Residents of Visaginas should be evacuated first. Taking into account predominate wind directions, two evacuation routes are prepared. The first evacuation route will be in the western and northwester directions. The second evacuation route will be in southern and southwester directions. Near the 30 km zone boundaries, the intermediate evacuation points would be established.

According to VATESI reports, inhabitants would be evacuated by personal/private and public transportation. Depending on the radiation situation, evacuation would be performed in two ways:

- In case when there is no radioactive contamination, by using the same transport.
- In the case of radioactive contamination, the evacuation is planned to take place in two stages. From home to an intermediate evacuation point and then further by transport to other districts or cities. The reason for the intermediate place in evacuation way is to be able to monitor the contamination levels of people.

Activities of the intermediate evacuation points are coordinated and controlled by municipal emergency situation commissions. Main purposes of intermediate evacuation points are to control departure from and arrival to contaminated territory, keep registration of evacuated inhabitants and transportation, fulfil domestic control of people, animals and transportation means, ensure necessary medical aid, perform sanitary treatment of people and decontamination of vehicles.

6. Closure and decommissioning

6.1. Closure and decommissioning of Ignalina NPP

The proposed closure of Ignalina NPP is highly controversial. Local politicians object on the ground of the country's dependence on the plant for electricity, the prestige associated with nuclear power and the plant's economic importance.

The position of Ignalina NPP as the country's prime electricity supplier means that Lithuania has to build 2,600 MW of generation capacity in addition to the extra generation needed as a result of economic growth. The problem is compounded by technical difficulty of closing the plant down, which is highly complex.

Lithuania is in even more difficult position because it cannot rely on electricity to be provided by most of its neighbours due to diplomatic instability. Yet another complication is the replacement of generation capacity by Belarus. If Ignalina NPP closes, Belarus would have to acquire an alternative source of supply. It is unlikely that Lithuanians would feel comfortable if the Belarus' erected their own nuclear facility.

Lithuania also has a quandary in the cheapness of Ignalina NPP supply. The plant produces electricity at a much cheaper rate than any of the alternatives, if one disregards the decommissioning and decontamination costs. The most likely replacement technology would be natural gas, but even this is comparatively expensive. It may also be subject to security concerns if the fuel is supplied from Russia or EU countries.

Lithuania will have to bear a cost of decontamination and decommissioning. These costs could easily amount to more than a billion Euros (Lithuania's Ministry of Economy, 2000).

6.2. Decisions of Lithuanian authorities

In 1997, Lithuania began updating the National Energy Strategy (NES). After the careful consideration of technical, economic and political factors in the whole energy area, in October 5, 1999 the Seimas (Lithuanian Parliament) of the Republic of Lithuania approved the National Energy Strategy submitted by the Government of the Republic of Lithuania (National Energy Strategy of Lithuania, 1999). According to this, Unit 1 of Ignalina NPP is to be shut down by 2005 taking into consideration the terms of the long-term and essential financial aid of the European Union, the group of G-7 states and other states as well as international financial institutions (National Energy Strategy of Lithuania, 1999).

The Seimas /Parliament/ also proposed that the Government should develop consequent compensatory power and social infrastructure projects without delay. According to these projects, the above-mentioned financial aid would be efficiently applied to restore the energy production of the Republic of Lithuania.

The decision about Unit 2 is to be made by 2004. International Community welcomed this decision of Lithuanian government. However, the decision of decommissioning of Unit 1 of the Ignalina Nuclear Power Plant was met with mixed feelings in the Lithuanian society. In some cases the decision is treated as a result of political pressure from Brussels, more favourable to EU than to Lithuanian economy.

Taking this into account, Ignalina NPP has developed a number of engineering projects to be implemented, so that the preparation for Unit 1 decommissioning specified in the National Energy Strategy, may be carried out. The projects on pre-decommissioning activities are related to the spent nuclear fuel storage, solid and liquid radioactive waste management, heat power plants renovation, decommissioning process management as well necessary documentation development such as the final decommissioning plan, decommissioning projects and others (Ignalina NPP, 2001).

In accordance with the Law on decommissioning of Unit 1 of the state enterprise of the Ignalina Nuclear Power Plant issued by the Seimas in May 2, 2000, all preparatory activities on Ignalina NPP Unit 1 decommissioning should have been performed by January 1, 2005. Based on preliminary calculations, the proposed projects will cost about 200 million EURO and cover only a preparatory period of decommissioning, and thus, do not solve any social issues (Lithuania's Ministry of Economics, 2001).

6.3. Is the decision of closing down Ignalina NPP for environmental security or a political issue?

The decision of decommissioning of Unit 1 of the Ignalina Nuclear Power Plant was met with mixed feelings in the Lithuanian society (Abaravicius J., 2001). There was much discussion and a difference of opinion about this issue. There have been allegations in the political debate of Lithuania that this nuclear power plant is to be closed only as a result of political pressure from Brussels. Some even assumed that EU countries did not want to have any competition from cheap energy produced in Lithuania. The Ignalina NPP working in full capacity generates 14 TWh of electricity per year. Annual electricity demand for Lithuania is 11 TWh per year. Evidently, there might be quite good export possibilities resulting in economic benefits for Lithuania. But Mr. Gunter Verheugen, member of the European Commission, does not agree with such statements. "The simple fact is that Lithuania inherited the wrong machine. The former Soviet Union built two RBMK-type reactors on Lithuanian soil. This is the core of the problem," said Mr. Verheugen in the Donor's Conference for decommissioning of Ignalina NPP held in Vilnius, 20 June 2000(Verheugen, 2000).

EU officials usually emphasize in their arguments to convince Lithuania to close down Ignalina NPP, other than the radiation protection aspects, that the Ignalina NPP was constructed to serve the energy needs of a larger Soviet Union and to supply plutonium to the military projects of the country (Integracijos Zinios, 2000). Besides, the installation is oversized; it is out of proportion for the Lithuanian needs as well as for the capability of Lithuania to maintain it. Its true costs have never been realistically calculated, but the costs of decommissioning, social restructuring programmes have been calculated. The plant is still being run with an oversized staff. Commercial accounting has hardly been introduced into its management.

The EU position is that if Lithuania had inherited a nuclear power reactor of another design the European Union would never have demanded its closure. A number of candidate countries might join the European Union with reactors of other design types. Lithuania cannot do the same, as the RBMK type of reactor is generally regarded as unsafe according to WENRA.

6.4. Present importance of Ignalina NPP to the energy sector development

Around 80% of total electricity Ignalina NPP covers demand in Lithuania. Besides that existing capacities of thermal power plants (Lithuanian PP - 1800 MW, Vilnius CHP - 365 MW, Kaunas CHP - 158 MW, etc.) have limited abilities for energy production and are kept as "cold reserve" in case of emergency (Piksrys S., 1998). The maintenance costs of these thermal plants are high while its operations are inefficient and unprofitable. For these reasons customers are forced to pay for keeping of existing overcapacities. The reduction of energy cost as share of Gross Domestic Products (GDP) mainly could be achieved by improvement of energy efficiency in all sectors of national economy.

Domination of nuclear energy in electricity market hinders necessary investments for the implementation of energy efficiency programmes and sustainable alternatives (cogeneration, modernization of existing thermal plants, renewable, etc.).

6.5. Social Impacts

A weak point in the process of decommissioning of high-risk nuclear reactor units is related to social issues. The closure of Unit 1 before the year 2005 (and the future decision concerning Unit 2) will arise serious economic problems for Lithuania and social problems for the region where Ignalina NPP is located. International assistance for technical closure of Unit 1 is somehow committed and hopefully will be far better developed in the near future. But social issues and the future of the town of Visaginas are still not well reflected either in the Government’s programmes or in the commitments of international donors (Ignalina NPP, 2001). Over 95% of Ignalina NPP's staff live in Visaginas town and Zarasai. Being a mono-industrial area overwhelmingly dependent upon Ignalina NPP, non-Ignalina NPP employment is very limited in these municipalities. Visaginas, which was developed in parallel with Ignalina NPP, is completely dependent on Ignalina NPP as the only employer. Visaginas has 33,800 inhabitants (about 1% of the total population of Lithuania) and about 5,000 residents are employed at the Ignalina NPP. The vast majority of work force in Visaginas is employed in services related to Ignalina NPP. The specific character of the town has been determined by the ethnic composition of its population since people from ethnic minorities make up to 86% of the residents (Ignalina NPP, 2001). The region of the Ignalina NPP is categorized as socially and economically depressed.

Due to Ignalina NPP restructuring, lay-offs in the plant count for 5% of job cuts in the year 2000 (Ignalina NPP, 2001). This process is expected to continue until the physical closure of the Unit 1, counting for approximately 9000 unemployed persons (if no proper measures for the new jobs will be taken) till the year 2005. To avoid serious social consequences, a programme of social impact mitigation should be created and implemented early in the process. Neither the local municipality nor the Lithuanian Government can implement these highly expensive programmes without international assistance. According to primary investigation prepared, the regional social problems can cost around 190 million USD over 10 years (Lithuanian UNDP, 2001).

The big concern is to create jobs for young people growing up in the region. Some of them will be more mobile and take jobs in other parts of Lithuania. The regional authorities are discussing ways they can make the region attractive for foreign investors. The EU can help them to do this, with special funds, and can help in sharing Western experience to solve this problem.

6.6. International Context

The Government of Lithuania regards the decommissioning process as an issue that can only be solved in an international context. The preamble of the Law of decommissioning reflects this: "Lithuania has inherited Ignalina Nuclear Power Plant, which was constructed to solve energy supply problems of a large part of Eastern Europe, and therefore the closure of the plant is not only Lithuania's, but also an international problem. The adoption of the present Law is based on the National Energy Strategy"(National Energy Strategy of Lithuania, 1999). The National Energy Strategy (1999) is set explicitly in the context of preparing for accession to the European Union. Former Lithuanian Prime Minister Andrius Kubilius underlined that " it was not Lithuania that created this problem, and Lithuania should not be left alone to tackle it. This is a part of Lithuanian heritage, hanging like the millstone round our neck and taking its toll on our economy. To leave Lithuania in the lurch would be an act of political and moral irresponsibility" (Kubilius A., 2000). According to Kubilis, without the key financial assistance of the international community Lithuania will be incapable of putting the decision of decommissioning of the Ignalina NPP into effect.

Mr. Joachim Jahnke, Vice President of the European Bank of Reconstruction and Development (EBRD), stated at the Donor's Conference in Vilnius that "the closure of Ignalina NPP means that Lithuania honours its international obligations, but also that it cares for the safety of its own citizens and of Europe as a whole. It also means, however, that Lithuania needs a lot of international support in addition to its own resources"(Janke J., 2000). The question is how big this support should be and what stages it should cover. What is necessary now is the preparation for the closure of Unit 1 and later Unit 2, requiring all the costly decommissioning facilities that enable the safe management and storage of nuclear waste during the first stage of the plant's decommissioning. What is further required is a solution to the problems in the energy sector as a whole through certain alternative investments, and even more importantly, its restructuring and privatisation.

The Government of Lithuania is committed to continue its investigation of the advantages offered by various power generation modes. Inter-connection of the Lithuanian power grid with the Western European Network is expected to increase security of supply and access to the international energy market (Piksrys S., 1998). The trade-off between future investment in the rehabilitation of existing conventional power plants, which suffered a long period of under-investment, on the one hand, and in the establishment of the combined heat and power plants (CHP), on the other hand will be important elements in this investigation. The Government will follow the principle that there is a need to establish combined heat and power production in the context of the rehabilitation of existing district heating systems, to integrate natural gas network into Western networks and improve energy efficiency. The Government will urgently outline and, in the very near future further detail, the regulatory framework for the production, distribution and consumption of power, gas and heat.

6.7. Integration into the European Union

Obviously, the decision on the specific date of the decommissioning of Unit 1 of the Ignalina NPP is inseparable from the restructuring and modernization of the Lithuanian power sector as a whole. Lithuanian government seeks for other options of electric power generation. Lithuanian integration into the European Union calls for the simultaneous integration of Lithuania's power sector into the common electricity market of Europe. In compliance with the EU acquits of the power sector, Lithuania has already adopted the major decisions on the restructuring of the power sector and in the short run the government plans to carry out the necessary steps which would allow to liberalize and open it for private capital as well as to establish all the mechanisms of the power market. The paradox, however, is that although Lithuania takes all these necessary legal and administrative measures leading towards a single EU power market, there is no technical connection linking Lithuania with central Europe "Lietuvos Energija, 2001".

A quick and efficient unification of the Lithuanian power system and the European power grid by building the power transmission lines between Lithuania and Poland is the government's top priority (Integration news, 2000). This would help to moderate the economic consequences of the shutdown of the Ignalina NPP. The decommissioning of the Ignalina NPP, the reforms of the power sector, and accession to the European power grid should be considered equally important and interrelated processes. But in some cases it is clearly evident that EU officials prioritise the question of the decommissioning, and the questions of energy sector development as well as energy export are not treated as important as they actually are (Integracijos Zinios, 2000). Therefore, some Lithuanian politicians, so called "Euro sceptics", see such EU position as unwillingness to see Lithuania as a possible competitor in European energy market.

Finding the alternatives to the Ignalina NPP, in most cases, brings at the forefront an issue of commercial and investment projects. Lithuania has a fairly well developed energy sector. Western investments and definite involvement in the privatisation of the Lithuanian energy entities could significantly contribute to the modernisation of the Lithuanian energy sector and moderate the economic consequences of the decommissioning of Ignalina NPP.

6.8. Decommissioning of Ignalina NPP and its effect on the environment

The closure of Unit 1 will undoubtedly cause a relative increase in emissions to the atmosphere, compared with nuclear power, of about 5 million tonnes/year, compared with emissions in the year 2000 of 0.7 million tonnes of CO_2 (National Energy Strategy of Lithuania, 1999). All these calculations are based on too optimistic growth projection, which do not take into effect the downturn in 1999. So, less energy will be used than predicted. Industrial energy use is expected to reduce as it gets used more efficiently than in Soviet times. Energy use is not expected to grow until households get wealthier and can spend more as a proportion of their incomes on electrical goods.

The EU Environmental Directives will be in force by 2004 and will not allow use of oil containing 5% of sulphur as it is nowadays (The European Commission, 2001). Therefore, gas will be the main fuel in use, reducing emissions in boiler houses and power plants.

Table 10. Comparison of different quantities of greenhouse gases in some of Baltic countries in 1998 (*Source: National Energy Strategy 1999)*

Country	CO_2 tonnes/capita	SO_2 tonnes/capita	NO_x tonnes/capita
Lithuania	6,7	31	21
Sweden	6,5	12	46
Finland	12,2	39	58
Denmark	12,3	35	55

There may be a relative increase in emissions of greenhouse gases by the change from nuclear to thermal power generation when Unit 1 will be closed. In absolute terms (which is what affects health and global warming) there will be reduction in emissions because energy use overall has decreased and sufficient other measures are being taken to meet Kyoto targets. However, in the longer term after the closure of Unit Two, assuming good growth in the economy and more energy use by households, emissions will grow again especially from transport (National Energy Strategy of Lithuania, 1999).

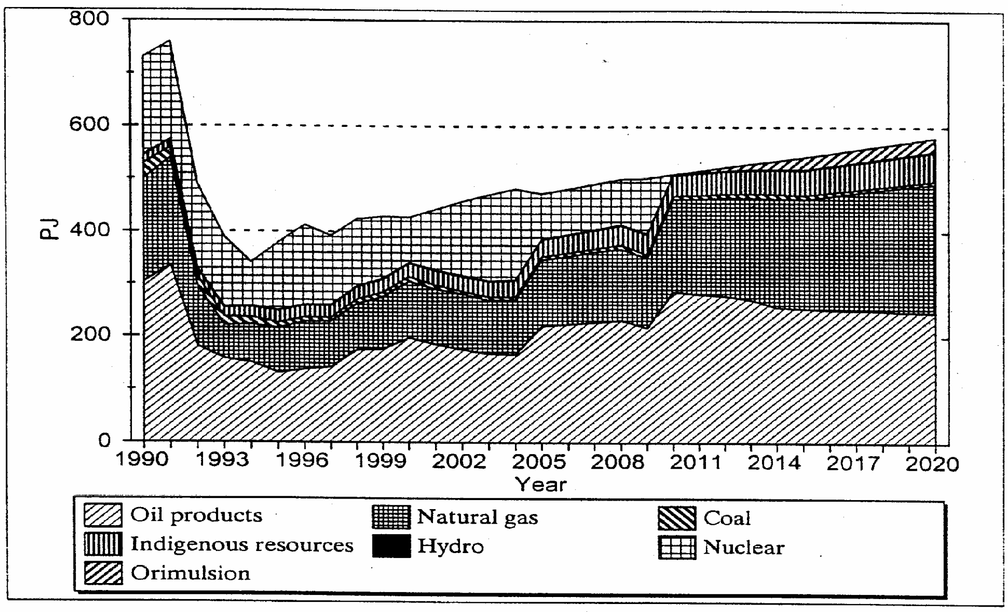
Lithuania has ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 (CE Bank Watch Network, 1998). The main obligation of the UNFCCC (stabilise CO_2 emissions, maintaining 1990 level of emissions in 2000 and further reduction) will be easily achieved if Ignalina NPP will operate. Implementation of the main requirement laid in the Kyoto protocol of this convention (to reduce emissions of greenhouse gases by 8% below 1990 level by the year 2008-2012) therefore depends on the fate of Ignalina NPP.

In the case of Ignalina being shut down (Scenario a), emissions caused by the fossil fuel burning, will increase considerably and the achievement of the UNFCCC requirements will become problematic. The second scenario will easily fulfil this requirement. So, in case of the first scenario, it is necessary to increase the use of natural gas and renewable, replacing higher sulphur oil.

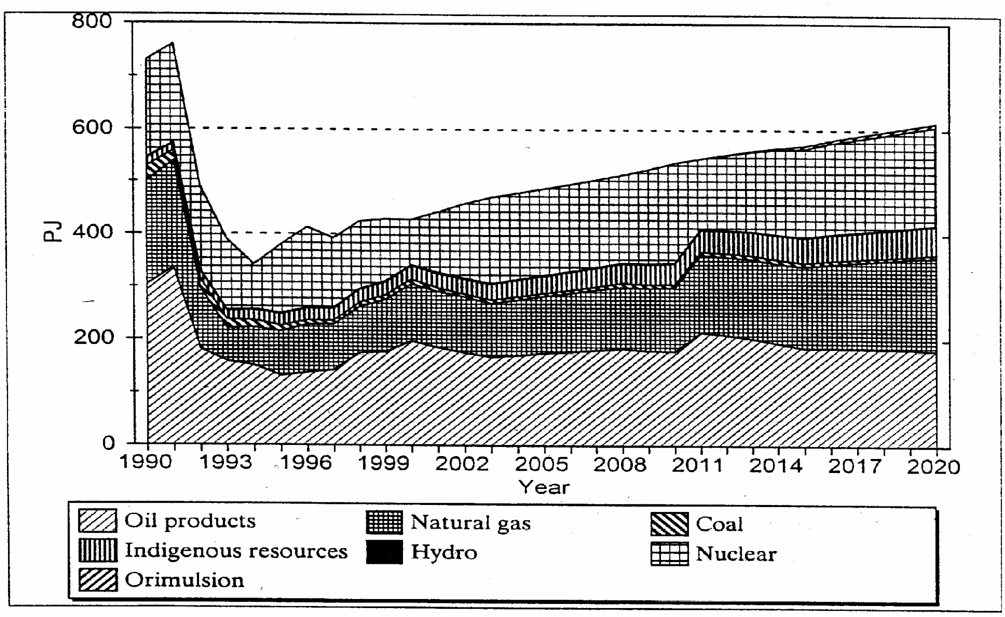
According to National Energy Strategy 1999, two different options for the primary energy demand are shown in the fig below (Fig.11.). The most probable scenario corresponds to two life time options for the Ignalina NPP operation: 1) unit 1 will be kept in operation until 2005, unit 2- until 2010, 2) in both units the technological channels will be changed and the power plant will be in operation until the end of the planning period.

In the first case after the closure of the Ignalina NPP (Fig.11.), total primary energy demand is about 5% less because of higher efficiency of the power plants that would replace the nuclear power. However, total fossil fuel demand is about 30% higher (in comparison with the second option). Natural gas and heavy fuel oil will compensate for this increase. At the end of the planning period, natural gas constitutes 50% of the primary energy consumed for electricity production, heavy fuel oil- 40% and orimulsion – 10% (National Energy Strategy of Lithuania, 1999).

In the second case, nuclear energy, natural gas and oil products dominate at almost equal shares in the primary energy balance. Other fuel forms (coal, orimulsion (a fraction of "bad" oil), indigenous and renewable energy sources) constitute only about 12% at the end of the planning period. Nuclear energy will prevail in the balance of fuel consumed for electricity production. Its shares will decrease to 65%. During the planning period, consumption of the heavy oil will decrease gradually.



a)



b)

Fig.11. Primary energy productin (basic scenario): a) both units of the Ignalina NPP are decommissioned by 2010, b) Ignalina NPP is kept in operation until the end of planning period

6.9. Summary

The proportion of nuclear power in the total electricity production, in Lithuania is one of the highest in the world – as Ignalina Nuclear Power Plant generates over 80% of electricity produced in the country (Ignalina NPP website, 2001). However for Europe it raises a great anxiety, as the reactors model and technique used are of the same type that caused the catastrophe in Ukraine at the Chernobyl NPP. Doubts of reactor safety are one of the main barriers or the Lithuanians road to EU membership. One of the requirements of the European Commission for gaining the membership is to implement an early shutdown for Ignalina Nuclear Power Plant.

The international context of the problem is evident. The closure of Ignalina means that Lithuania honours its international obligations and cares for the safety of its own citizens and of Europe as a whole.

7. Waste Management of Ignalina NPP

Before writing about the nuclear waste produced by the Ignalina NPP and the risk from high activity nuclear fuel waste, it is necessary to point out the steps that are usually applied in any nuclear fuel waste management. Different categories of waste are also defined and the source of their existence is discussed here.

7.1. Theoretical background:

Radioactive waste, like any toxic industrial waste, is safe when properly managed. The radionuclides decay and the radiation actually disappears with time. Depending on the type of waste, this time varies from a few seconds to thousands of years. The activity of radioactive wastes decreases with time. The lifetime is characterised by the “half-life” period, during which activity is assumed to half its value (World Nuclear Association, 1999). For example, after ten half-lives, only one thousandth of the initial radioactivity remains.

Nuclear wastes result whenever nuclear fission is used. Nuclear fission occurs when a nuclear reaction takes place, splitting the atom and emitting thermal heat. The nuclear reaction can be either induced or spontaneous and a “nuclear reaction” takes place. The thermal energy from that nuclear reaction is used to make electricity. One form of nuclear waste is the by-product of making electricity at commercial nuclear power plants.

Thus, at a nuclear power plant, fission takes place under carefully controlled conditions inside the nuclear reactor. Nuclear fission generates energy, including heat. The heat is used to make steam, which turns turbines to induce electric power. Like the coal is the fuel burned to make steam at coal-fired plants, uranium is the fuel used to make steam at nuclear power plants.

Approximately once a year, one-third of the nuclear fuel inside a reactor is removed and replaced with fresh fuel. The used fuel is called “spent fuel”. It is highly radioactive and is the primary form of the high-level nuclear waste. It must be isolated carefully for thousands of years because its high radioactivity has the potential to harm people and the environment (SKN Report 29, 1988). During that time, the spent fuel will decay to a level of radioactivity that is about the same as natural uranium-ore deposits.

At Ignalina NPP, as in most NPPs worldwide, when spent fuel is removed from a reactor, it is first usually put into a water pool. The water serves as a radiation shield and coolant. Storing the spent fuel in pools is intended only as a temporary storage until a permanent disposal place is found. An alternative to storing in pools, some spent fuel can be stored above ground in concrete or steel called “dry casks” (World Nuclear Association Report, 1999). But, still, these storage approaches are temporary measures until a permanent disposal plane is found. A part of the fuel can also be recycled. The chemical process by which uranium and plutonium are recovered from the spent fuel is called “reprocessing”. Some countries forbid reprocessing of nuclear waste and Sweden is one of them. Lithuania is also not either reprocessing the spent nuclear fuel at Ignalina because it has no technical means to do that. Commercial reprocessing of spent nuclear fuel is carried out in several nuclear energy using countries like France and Russian Federation (World Nuclear Association Report, 1999). The highly radioactive materials that are extracted from used fuel at reprocessing plants represent more than 95% of the waste (in term of activity) resulting from the generation of electricity. A typical large nuclear power plant produces about 30 tonnes of spent fuel a year, which, if reprocessed, results in about three cubic meters of high-level waste in the vitrified form (World Nuclear Association Report, 2000). This could be a solution for the nuclear waste at Ignalina NPP, but the fear of using this for military nuclear weapons makes this solution unattractive.

Intermediate- and low-level wastes are also generated during nuclear power production. Radioactive products of nuclear fission can contaminate water used as coolant or the equipment of the power station. Liquid wastes result from the decontamination of equipment and buildings, as well as from laundry and shower effluents. The off-gases, e.g. radioactive noble gases such as xenon and krypton, and various short-lived gaseous products, are to a large extent absorbed on filter cartridges in the different ventilation systems. The cartridges are further treated as solid waste.To decrease its volume, the liquid waste can be treated by evaporation after which the concentrate is collected at the bottom of the evaporator. Ion exchange resins may be used for lowering the content of radioactive elements of the liquid waste (International Commission on Radiological Protection “ICRP”, 1997).

The solid radioactive waste at a nuclear power plant also includes towels, paper, and metals used during the maintenance of the power plant.A typical large 1000 MW nuclear power plant produces a quite variable quantity of such waste, depending on local conditions, with an average of about 100-600 m^3 per year (World Nuclear Association Report, 2000).

7.2. Radioactive waste from Ignalina

Ignalina NPP produces around 99.6% of the radioactive waste in Lithuania (Ignalina NPP website, 2001). The rest of Lithuanian radioactive waste is produced from medical practices, industry and agriculture and makes up only few cubic meters per year. Radioactive waste at Ignalina NPP consists of solid and liquid waste, ion exchange resins and a small quantity of used lubricants. The spent fuel is stored in special water pools, located in the same building as the reactors as mentioned in the previous section. For the unit 1, the water pool where the nuclear fuel is stored was expected to be fully loaded by the year 1998, while for the unit 2 it was expected to be fully loaded by the year 2000. The responsible authorities at Ignalina NPP recognised that further operation of the Ignalina NPP will only be possible if a new storage will be constructed. Totally, there are around 13,000 units of spent nuclear fuel rods stored in water pools. Recently, the interim storage of the spent fuel is under construction on the bank of Druksiai Lake, near Ignalina NPP. The spent fuel will then be stored in special casks for 50 years (Ignalina NPP website, 2001).

There is still no solution to the problem with the long-term management of the nuclear waste at Ignalina NPP. This will create additional environmental and economic problems.

Among the most important issues to be solved is to minimise the volume of the nuclear waste. Around 700 m^3 of Low and Intermediate Level Waste (LILW) are produced annually at Ignalina NPP, whereas Western plants produce about 100 m^3/year (WENRA reports, 2000).

7.3. Ongoing projects to improve nuclear waste management at Ignalina

"Siemens Nuclear Power GmbH" has received an order for the supply of a waste treatment facility from the operator of Ignalina NPP. The facility will be used for processing and environmental compatible storage of low- and medium- activity liquid wastes from the two 1500 MW-units Ignalina 1 and 2. The project covers the design, supply and erection of a cementation plant and an interim storage facility. The value of the contract amounts to around EURO 10 million (FRAMATOME ANP, 2000). The waste treatment project, which had been awarded to Siemens Nuclear Power following an internationally invitation to tender, will be financed by a commercial bank loan with Hermes export credit guarantee (Ignalina NPP, 2001). The construction project will be implemented in cooperation with six local subcontractors.

Around 2,500 m^3 of low- and medium- activity liquid wastes, primarily evaporator concentrates and ion exchangers' resins are in storage in the Ignalina NPP (VATESI, 2000). They have been accumulating since the middle of the 1980's from operation and maintenance of the two Soviet-design RMBK units and the waste is to be treated in the new facility for interim storage and later placement in a final repository. For that purpose, they will be transformed in a cementation process into solid, water-insoluble form and subsequently placed in environmentally compatible interim storage.

The facility will also be required for the management of liquid radioactive wastes that will arise in the course of upcoming decommissioning of the first unit.

Water pools are only temporary ways of storage; therefore the international competition for the spent fuel storage was announced. The winner of the contract was the German company GNB and they are to deliver 20 CASTOR and 40 CONSTOR steel containers for the storage of the spent nuclear fuel. The total cost of the contract is about 30 million DM (Ignalina NPP, 2001). According to the contract, in the year 2001 (this year), the company should deliver 18 containers of CONSTOR type. The first container, CASTOR, was sent to the storage site constructed nearby Ignalina NPP on May 12, 1999. Some part of the spent nuclear fuel has already been placed in all available containers of CASTOR type and was taken to the spent nuclear fuel storage site.

For the CONSTOR container, the weight of an empty container is about 70 tonnes, with spent nuclear fuel- about 84 tonnes (Ignalina NPP, 2001). The container is located on a special platform at the site. One of the most important works connected with the future decommissioning of the Ignalina NPP is the unloading and the location of the spent nuclear fuel in the storages.

Ignalina NPP experts affirm that the available number of containers will not solve the problem of the spent nuclear fuel. Based on the assumption that in the case of unit 1 at the end of the year 2004, and a unit 2 close down in year 2010, around 350 additional containers in addition would be required (Ignalina NPP, 2001). The spent nuclear fuel can be stored in the containers CASTOR and CONSTOR for 50 years, after which it is necessary to transfer it out to the final burial place (depository). In Lithuania, however, such place is not planned yet (Balek V., 2000).

7.4. Decommissioning of Ignalina NPP and interim spent nuclear fuel storage facility

In order to ensure safe handling of spent fuel at Ignalina NPP, unload of all spent fuel from the reactors during the decommissioning of Ignalina NPP must be carried out as well as to remove the fuel consecutively from the interim storage. It is necessary to design the storage facility of spent nuclear fuel (SFSF) for a total of 17,850 spent fuel assemblies (SFA) (Ignalina NPP, 2001). The storage facility should be commissioned in stages as determined by detailed studies.

For unit 1 to be decommissioned, the first turn of SFSF for 1530 SFA should be put into operation not later than 2004 (Ignalina NPP, 2001). Then starting from 2006, part of the storage facility for 1,530 SFA should be put into operation annually (Ignalina NPP, 2001).

According to Ignalina NPP publications, first phase of Ignalina NPP decommissioning consists of preparatory activities that include preparation of necessary documents, which are required in accordance with standard procedures of Lithuanian Republic. During the next phase, which starts from the shutdown of unit 1 reactor, it is necessary to unload all the fuel that is in the reactor into the pools. To provide the resources to unload the whole core region of the reactor, it is necessary to empty the space in the pools for about 1,660 SFA by that time.

From a technical point of view, existing storage facility will allow to take care of spent fuel from both units until October 2004, taking into consideration additional purchase of 12 containers of CONSTOR type in order to use the capacity of the existing facility entirely. The capacity of the existing facility is not enough for the decommissioning process. Therefore, starting from October 2004, the new spent fuel storage facility should be put into operation. Its capacity should be enough for removal of fuel from unit 1 in the second decommissioning phase.

7.5. What does the Lithuanian government do to find solutions for the waste management problems in Lithuania?

Lithuanian government has recognised the problem of the nuclear waste, especially after the law of decommissioning of unit 1 was passed on May 2, 2000 (VATESI, 2000). Experts have written their reports to the government of Lithuania about the predicted values of decommissioning residue. The decommissioning residue of the Ignalina NPP constitutes of: Primary mass of 130,000 tonnes, secondary mass of about 83,000 tonnes and operational waste of 18,000 tonnes (VATESI, 2000). This made the issue urgent and the Lithuanian government took a decision of setting up an organ that handle out such problems and is called Lithuanian Radioactive Waste Management Agency. The statute of the organisation that is to be a state company was drawn up at the end of year 2000. The top priority of the Agency is to work out the general strategy of radioactive waste management in Lithuania. This Agency may also do research on the possible plans for long term storage in underground (500 m) which has also been done in Sweden and Finland.

8. Renewable Energy Potential as an alternative for nuclear power and fossil fuel

No technology is absolutely safe or without environmental effects. In case of decommissioning Ignalina NPP, Lithuania has to depend on the fossil fuels and/or on the renewable energy in its energy production.

Burning coal in power stations is still the major source of electricity worldwide, and is going to be the major source for Lithuania as well after a decommissioning process of Ignalina NPP.

A 1000 MWe light water reactor uses about 25 tonnes of enriched uranium a year, requiring the mining of some 50,000 tonnes of uranium ore (Uranium Information Centre, 2001). By comparison, a 1000 MWe coal-fired power station requires about 2.3 million tonnes of black coal per year (Uranium Information Centre, 2001). This creates 7 million tonnes of CO_2 and many other gases such as SO_2, depending on source of the coal per year (Uranium Information Centre, 2001). Additionally, solid wastes from a coal-fired power station can be substantial and cause environmental and health damage.

If Ignalina NPP is closed down, Lithuania will rely mainly on imported fossil fuels. This will cause local and global environmental problems. To reduce the risk from potential fossil fuels usage, renewable energy supply in Lithuania should be investigated. In this part, the available renewable energy sources as well as their implementation potentials are analysed. Moreover, some suggestions are given to use the renewable energy sources available in Lithuania in more efficient ways. Also, throughout this research, it will be shown that many renewable resources are not efficiently used for energy production.

8.1. Biomass

8.1.1. Plant biomass utilization as solid fuel: The plant biological mass (wood residues, straw, energy plants) is one of the most significant renewable energy sources in Lithuania. The annual potential of the wood fuel is approximately 3 Mm^3 (i.e. 18GWh). About 2 Mm^3 (i.e. 12GWh) of the firewood and timber waste (i.e. approximately 60-70% of the total potential of the wood fuel) is used for the energy requirement. About 20-25% of this amount is used in the central heating boiler houses, the total power of which is 100 MW (Dagys & Jarmokas, 1998). The rest part is used in the small-decentralized heating equipment, the efficiency of which is lower. About 4 million tonnes of the straw is gathered annually in Lithuania, where just 0.5 million tonnes could be used as fuel. Recently, 5 boiler-houses using the straw as a fuel with the total power of 3.5MW are operating in Lithuania (Lithuanian Renewable Energy Server, 2001). Only 1% of the straw resources are used for the energy needs. About 1 mm^3 (6GWh) of the food fuel is still not used. For this purpose, the boilers with the total power of 300 MW should be installed and reconstructed. Straw has great possibility to be used as fuel (about 0.5 Mtonnes). For this purpose, the boiler-houses using the straw with the total power of 300 MW and thermal generators should be installed. The energy potential of straw and wood fuel is about 0.67 Mt (Lithuanian Renewable Energy Server, 2001).

Besides, about 30,000 hectares of the land are not fertilized enough for agriculture use in Lithuania. Also, there are about 20,000 hectares of peat bogs of which the exploitation will soon be finished. The plantation of the energy plants or quickly growing trees can be increased. With the average yield of 10 tonnes/ha of the dry biomass, 500,000 tonnes of biomass can be harvested annually

(Lithuanian Renewable Energy Server, 2001). There is possibility to use silt from the water treatment plants to fertilize these plantations. Such investigations were started in Lithuanian Institute of Forestry. As the resources of the straw as a fuel are not sufficiently used in Lithuania at the present, the air heater of the 500kW power for the grain dryers, premises and greenhouses must be created in the production field. The furnace for the burning of the wood waste of 0.5, 1.0, and 2.5 MW power will be designed and its production will be started in the future.

8.1.2. The liquid bio fuels and oils: Biofuel is defined as fuel extracted from wood and may also include branches and twigs that are left behind from timber felling activities. Energy forests and recycled wood (lumber from demolished buildings) can be grouped under this subheading. When wood from an energy forest has been harvested, it is shredded into chips that are then used as fuel. The wood may contain small concentrations of ^{137}Cs originating from e.g. the global fallout in the 1960 and 70s. However, these levels are enriched when the fuel is processed into chips. Chips from the above mentioned materials could therefore contain rather high levels of ^{137}Cs (KASAM, 1998).

The rapeseeds in Lithuania are the main source of these bio-fuels in Lithuania. It is currently grown in an area of 37,400 hectares, but the area that can be increased up to 180,000-240,000 hectares without the violation of the agricultural practices. Around 50,000 hectares of the rape is sufficient for the vegetable oil, thus the remaining amount of 540-720 thousands of the rapeseeds can be used to produce 178,000-238,000 tonnes of the bio fuels and oils (Lithuanian Renewable Energy Server, 2001).

About 34,000 tons of ethanol is produced annually in Lithuania, but Lithuanians are capable of producing 68,000 tons. The ethanol produced from agricultural products could be used as a source of petrol production in “Mazeikiu Nafta” Oil Company (Lithuanian Renewable Energy Server, 2001).

8.1.3. Biogas: The resources of the organic materials that can be used for the production of biogas are constantly accumulating and regenerating in the agricultural production. The most important of them are the animal manure and the organic waste of the food processing industry. The economy of such units has to be evaluated. Today, there are 26 complexes for 6,000-30,000 pigs in Lithuania and these have shown to be profitable (Lithuanian Renewable Energy Server, 2001). The total number of pigs kept in Lithuania is 339,000 (Lithuanian Renewable Energy Server, 2001). There are 343 farms housing more than 200 pigs that belong to the communities and the private farmers. The total number of the pigs kept there is 162,000 pigs. There are 704 farms with more than 50 cows or cattle, and the total amount of cattle is 270,000 in Lithuania. The annual energy potential of the manure accumulated in the pig complexes is 15 millions m^3 (105 PJ or 90 GWh) of biogas; it is 7.2 million m^3 of biogas (or 43.2 GWh) in the private farms and the farms of the communities; and it is 65.2 million m^3 of biogas (319.2 GWh) in the cattle farms of the same category (Lithuanian Renewable Energy server). The total energy potential accumulated in the mentioned farms is 87.4 million m^3 of biogas per year or 520 GWh (Lithuanian Renewable Energy Server).

The reduction of the demand of the agricultural products in Lithuania decreased the use of the arable lands by 0.5 million hectare (Savickas & Vrubliauskas, 1997). This area could be used to grow energy plants. The usage of the green mass in the anaerobic processing during the summer would maximise the energy potential of the biological digesters installed in the farms. The produced biogas could be used to dry the hay and the grain as well as it can be used to fertilize the soils.

The lack of big investments in this field of research may delay using the biogas as a significant source of energy in Lithuania.

8.2. Hydropower

Hydropower does not lead to any radioactive releases or waste (KASAM, 1998). The activity does not affect the human radiation environment more than traditional construction work and indoor or underground work. Anyone working in the underground generator facilities at hydropower plants can be exposed to e.g. increased concentrations of radon and daughters of radon. The collective dose for Norwegian hydropower workers has been calculated to be approximately 2 manSv/year (KASAM, 1998). Approximately 110 TWh of electricity is generated annually, leading to 0.02 manSv/TWh or 0.2 manSv/GWyr (KASAM, 1998). Also, there is a risk due to breakage of ponds and water floods.

Hydro energy is a well-developed source of energy. Hydro energy is not exploited enough in Lithuania if comparing with the experience in developed countries and bearing in mind the EU requirements (that member countries are required in 2010 to cover 12% of their energy demand using renewable energy sources). Today, the share of renewable energy sources in total energy balance for Lithuania is only 7% and refers mainly to wood and hydro energy resources (Lithuanian Renewable Energy Server). It means that EU requirement could be met by extension of hydropower energy use in Lithuania. Only about 14% of available technical hydro energy resources are being utilized in Lithuania. Their share in total energy balance is only 1% and in electricity balance the total hydro energy potential is only 3% (Lithuanian Renewable Energy Server, 2001). The technical or real hydro energy resources consist of 2,7 kWh/year (Lithuanian Renewable Energy Server, 2001). About 2,2 kWh/year or 80% of all resources fall on the share of the two biggest rivers: Nemunas and Neris (Lithuanian Renewable Energy Server). The share of all middle and small rivers (there are 470 small and middle size rivers are available in Lithuania) is about 0,5 kWh/year or 20% (Lithuanian Renewable Energy Server, 2001).

8.3. Geothermal Energy

Geothermal energy is stored in the form of heat in bedrock or is generated by radioactive decay. To harness geothermal energy, hot water or steam is extracted from deep boreholes. People have used hot groundwater for bathing and heating for thousands of years. Geothermal energy has been used to produce electricity for approximately 100 years (KASAM, 1998). The occurrence of radioactive substances in hot springs has been known since 1911. Today, geothermal energy is used primarily in Iceland, Italy, Japan, New Zealand, Russia and the USA. It is also used in smaller scale in other countries e.g. Sweden. Nearly 50% of the heat supplied to Lund's district heating system can be attributed to geothermal energy (KASAM, 1998).

Radioactive substances in uranium's decay chain dominate the activity in geothermal flows. From the point of view of radiation protection, the greatest interest has been focused on ^{222}Rn, which dissolves in water and then disappears into the air during distribution to users. In Iceland, 2-10 kBq/m^3 (2-10 Bq/litre) ^{222}Rn has been found in the water from hot springs. This can be compared with the Swedish limit of 100 Bq/litre for water from municipal water works on private wells to be considered potable. The average figure for radon releases is 150 TBq/GWyr and the collective effective dose caused by this is estimated at 2 manSv/GWyr. The annual dose per person, 1 km from a plant producing 100 MW of thermal energy is approximately 0.01 mSv. Radiation doses to personnel at the deep boreholes can be significant unless the facility is equipped with good ventilation (KASAM, 1998).

Solid radioactive waste only occurs on a small scale in the form of material transported up with water from the bedrock earth energy is already in use in Lithuania. Private users in Vilnius and Klaipeda have installed capacity of 114 kW from aquifers up to 100 m. Vydmantu geothermal heat plant (in Kretinga district) is one of the ongoing projects in this field and the construction is still not completed yet. Moreover, Klaipeda geothermal demonstration plant is planned to be built soon.

8.4. Solar energy (Photovoltaic)

Photovoltaic is considered as the world's most promising renewable energy species as stated in the "World Solar Program (1996-2005)". In Lithuania, where an electric distribution network is well developed, photovoltaic equipment should be gradually connected to the grid. At the present, there is no photovoltaic system.

Development and use of solar energy technology is hampered by a very high cost of installed electrical effect that is several times higher than that of conventional electric energy. At present, the cost of installed 1 W-power solar cell is 2-3 US$ and the cost of installed 1 W-power in solar elements reaches 5-10 US$ (Shuksteris & Kiveris, 1996).

Studies in the field of local manufacturing solar cells create opportunities for the development of new and effective solar cell production technologies. The self-manufactured technology principles were commenced to be applied in solar cell technology within the framework of "Solar and alternative renewable energy sources for agriculture (1996-1999). It is essential to continue scientific research on new organic materials suitable for solar energetic. For example, three-component chalcopyrite semiconductors may become very effective material in solar element technology.

The widely used monocrystalline silicon technology for solar cells has been manufactured in Lithuania. The approach is able of producing technology resulting in higher efficiency (15%) of solar cells and by one third diminishing their production costs (Shuksteris & Kiveris, 1996).

8.5. Wind power

Electricity produced by wind power does not lead to any radioactive releases and generates no radioactive waste other than that which arises from material extracted and used for producing components and when components are scrapped.

Recent wind power technology makes it possible also to produce directly warm water for heating of houses. Many West European countries (Denmark, Germany, Netherlands and others) are already using this kind of energy source to improve their countries environmental conditions. However, wind energy resources and possibilities of their use are very specific for various countries. Therefore, experiences of separate countries cannot be mechanically transferred into another ones for application. Implementing wind energy is associated with great investments; therefore wind power application may be initiated only through scientific and economic investigations.

In 1991, the closed joint stock company "Vejas" designed the first electricity generation wind plant in Lithuania. Later, the Closed Joint Stock Company "Jegaine" was founded and continued this activity. Several power facilities were designed each being of 60 kW range, one of these was built in Kaunas (Lithuanian Renewable Energy Server, 2001). In the Klaipeda district, one power plant was built. However, not all plants could work successfully because of series of technical problems that have arisen concerning wind power efficiency, operational reliability and other issues. Solution of these problems requires investigations of wind energy climate aspects, data on the wind energy distribution depending on wind velocity profiles and other data.

Initial wind energy resources evaluation was carried out in Lithuania. Calculation methods were developed using one-year's meteorological data, which were registered. The investigation showed that wind energy may be used and that it is technically feasible to develop this resource further in Lithuania. However, taking a decision to implement wind power energy requires fundamental research to ensure efficient operation of wind power plants and reliability of structures in airflow. Before wind turbines building begins, measurements of wind energy parameters must be carried out using special instrumentation lasting not less than 6 to 12 months as required by legal regulations. It allows suitable choice of wind power facilities, preparing optimal operation regime and timetables, forecasting power generation and evaluation of economic indicators. Moreover, it is necessary to examine variation of wind parameters, wind gust forming wind velocity profiles. Unevenness of surrounding grounds, the levels of building in nearby areas, wind flow formation, natural and urban obstacles are to be studied carefully before taking any decision on this matter.

8.6. Renewable energy policy in Lithuania

The studies of indigenous energy resources, which were formed in Lithuania during recent years show that the statement of the European Union, to cover approximately 12% of the internal energy demand of each country by renewable energy sources, could be implemented (National Energy Strategy of Lithuania, 1999).

Pilot projects implemented in recent years justify the possibility to accelerate utilisation of indigenous energy resources particularly for the heat supply. In 1996, 196,000 toe of indigenous and renewable energy resources (3.1% of internal primary energy consumption) were consumed. Installed capacity for incineration of wood waste at present reaches approximately 90 MW.

However, the use of these resources is rather low because of the high price that is sometimes exceeding the price of imported fuel oil. Without a developed infrastructure of indigenous fuel production and use the production costs are high. Market relations were not formed in local fuel production sphere. Non-favourable taxes policy (royalty tax, VAT, pollution charges, etc.) had influence on the growth of indigenous fuel prices.

Measures, provided by the Lithuanian Energy Efficiency Programme, stimulate much faster utilisation of indigenous and renewable energy sources. In comparison with the year 1996, the utilisation of these resources was increased in year 2000 by 1.7 times and it is forecasted that till 2020 (Table 11) it will increase approximately by 4.8 to that level in 1996.

Table.11. Forecast of consumption of indigenous, renewable and waste energy resources (Source: National Energy Strategy, 2001) (N.B. ktoe = 1000 tonnes of oil equivalent)

Resource	Suggested consumption, k toe/year		Necessary investments
	2000	2020	(Till 2000, million $)
Wood waste and fire-wood	300	500	8.4
Municipal waste	132	220	73.5
Peat	40	120	3.6
Straw	2.6	134	0.6
Biogas	2.4	12	3.2
Solid household and industrial waste	-	100	-
Wind energy	0.52	6.3	4
Solar energy	1.0	300	1.2
Geothermal energy	18	18	26.7
Small hydro power plants	1.7	6.5	-
Total:	498	1417	121.7
% Of total primary energy		14.8%	

It is the most efficient to use indigenous energy resources for local heating purposes (except for hydro and wind energy).

Following the EU provisions and seeking to reduce the volume of fuel import and to use as much as possible all local resources as well as to create new working places Lithuania will continue the utilization of indigenous energy resources. The extension could be achieved by the following means:

- Economic, legal and organizational means promoting the use of wood, peat and other kinds of indigenous fuel;
- A wider utilization of other energy sources (hydro, waste energy, biogas, municipal waste, solar and geothermal energy), using the experience gained in the pilot projects.

Regarding the solar energy programs, the most important ongoing project is the "Development of Lithuanian Solar Program 2000-2005 and its implementation in the World Solar Program 1996-2005" (Lithuanian National Solar Program 2000-2005, 2001). The program is coordinated by the Institute of Lithuanian Scientific Society and funded by UNESCO.

The envisaged budget grant for renewable energies implementation and research is equal to that recently assigned to atomic energetic (Lithuanian Renewable Energy Server, 2001). However, more investments from the government are needed for developing projects in this field. Further development of renewable energy implementation will depend on long-term stable programs involving political, legislative, administrative, economical and market aspect, as well as employment policy, agriculture, researches, technologies and others.

8.7. Summary

Lithuania has many renewable energy sources that can be used for environmentally sound energy supply. However, these resources are not enough to provide Lithuania with the sufficient energy supply for the near future, which means that during a transition period Lithuania must rely on imported energy which mainly origin from fossil fuels. Use of these renewable energy sources reduces the import of fossil fuels and may consequently, also reduce, the expenses in energy sector. Implementation of renewable energy use in Lithuania creates more jobs that will reduce the unemployment in the country in the energy sector; employment will be an important issue especially when the employees of Ignalina will be jobless after the decommissioning of Ignalina NPP.

More investments in the renewable energy field in Lithuania are needed to enhance the development in this field. The government alone is not capable to invest in this field due to the tied budget. Therefore, private sector has to participate in investment and especially the energy companies. Foreign investments in this field are available, however they could be bigger. The fact that Lithuania is not a member of the EU and that it has borders with Russia and Belarus are constraints for encouraging foreign investments in this field since this kind of investment is a long-term one. Officials in Lithuania hope that joining the EU will attract more foreign investments in this field.

9. General conclusion

Whatever decision or action the Lithuanian government will take regarding the issue of the Ignalina NPP, it will have an impact on one or more of the following: policy, economy and the environment.

In case of decommissioning of Ignalina NPP, the electricity production will decrease and the prices of electrical power will increase since Lithuania will be obliged to import fossil fuel for electricity production. Decrease in electricity production means that no export of electrical power will be possible and this will lead to negative impacts on Lithuania's economy. Additionally, many people employed at Ignalina NPP will loose their jobs and this will have a lot of social impacts on them and their families. Furthermore, the closing of Ignalina NPP leading to import and burning of fossil fuel for electricity production means that releases of CO_2 and other chemical compounds that have negative impact on the environment will increase. Lithuania will also have difficulties in meeting the requirements of Kyoto protocol in reducing CO_2 levels. As a consequence of CO_2 increase, such impacts of problems as global warming and climate change will increase, contributing to more global and local environmental effects. The risk of nuclear accident at Ignalina NPP will decrease, leading to less health risks. Closing of Ignalina NPP, Lithuania will have better chances to join EU as this organisation put closing and decommissioning of Ignalina NPP as a requirement for the country to join the EU. This may increase the opportunity for Lithuanians to find jobs in the EU countries and will encourage European and other investors to invest in the Lithuanian economy and in the renewable energy sources projects. Renewable energy as alternative to nuclear energy will be a necessary addition to the fossil fuel to produce electrical power. The continued operation of Ignalina NPP will lead to large amounts of nuclear wastes and will arise the necessity of safe handling and final depositories as well as planning for environmentally sound way for nuclear waste management in Lithuania.

In case of leaving Ignalina NPP operating, electrical power production will be like it is nowadays i.e. a large scale production leading to relatively cheap electricity cost for the inhabitants and available amounts for export. This will increase the income for the economy of Lithuania. Moreover, employees will keep their jobs at Ignalina and unemployment will not increase. Some impacts on the environment will be obvious because of the release of radiotoxic elements and gases to the environment. Also, a certain health risk to some of the employees at Ignalina may occur as a consequence of being subjected to relatively high doses of ionising radiation. Leaving Ignalina NPP operating will help Lithuania in achieving the requirements of Kyoto protocol. But on the other hand, this will be a big obstacle for Lithuania in joining the EU membership. Leaving Ignalina NPP operating, the research for finding potential renewable energy for electricity production will not be enhanced and encouraged. This is because such research needs a lot of investments, and the investor will not find it profitable to invest in this field because of the cheap electricity produced from the nuclear power at Ignalina NPP.

The social question is to be well discussed not just on the local level, but also from an international perspective. If the international community want to implement long term sustainable development plans for Lithuania, it should supply the municipalities that mainly depend on Ignalina in their employment with the financial as well as the management plans of the region's economy. Also, international institutions should provide Lithuania with the assistance to establish a new energy strategy after decommissioning of the Ignalina NPP. The financial assistance that the EU has offered till now is not sufficient to overcome the difficulties in the economy sector Lithuania will face after closing down Ignalina.

Renewable energy can partially become an alternative for the nuclear power produced at Ignalina NPP after shut down. However, a lot of investments are needed to apply the projects dealing with renewable energy policy implementation. Before joining the EU, Lithuania will face difficulties in attracting the investors in this field since projects in the renewable field are only profitable in the long term and not in a short one. Furthermore, the unstable political situation in some of the countries surrounding Lithuania makes it difficult for the investors to make investments in this field in Lithuania.

The radiation safety at Ignalina NPP is adequate according to the international experts, and Lithuania has also some degree of emergency preparedness in terms of plans and measures for any nuclear accident at Ignalina NPP.

Research about the topic can be continued especially in the follow-up of the social and economic problems that may arise in the region of Ignalina. The research can be done even before decommissioning of the Ignalina NPP in order to implement protective measures and means to avoid detrimental socio-economic impacts on the inhabitants of the region. Also, this research should be continued by carefully analysing possibilities of building a new NPP that fits the international standards from the technical point of view and to see whether this can provide a good mean for the economy and energy sector for Lithuania and the surrounding countries.

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