Lithuania's Energy at Difficult Energy Crossroads: Planning for the Future

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Summary

On January 1, 2010 Lithuania has powered down and decommissioned the Ignalina atomic energy plant's (IAE)[1] only remaining nuclear reactor, which supplied nearly 80% of the country's electrical needs. Until late in 2007 very little attention was given as to what would happen in the aftermath of the shutdown except for considerable rhetoric that a new nuclear power plant would be built in the 2016-2018 timeframe. However, nothing was done to initiate any activity in this direction. A study conducted by independent Lithuanian-American and -Canadian researchers has shown that Lithuania has adequate energy generating capacity to power its electricity needs, if it can securely import sufficient natural gas or fuel oil supplies, and/or supplement the potential shortage with electricity imports. Costs of imported energy to replace IAE's lost power could run annually up to 400-500 mln USD in the early part of the 2010 decade and rise close to a billion USD in later years. Price of electric power to the consumer may initially be about 30% higher and subsequently, it might be higher or lower depending on the cost of imported energy resources. In either event, the cost for additional imports will be a large drain on Lithuania's financial resources and an impediment to the country's economic development.

The study examined a number of alternatives which Lithuania could develop on its own to reduce the need for energy imports. They range from using its own in-the-ground natural resources, to the construction of either a new nuclear power generating plant or the development of renewable resources, electricity and liquefied gas imports, increased use of its rivers for power generation, as well as adoption of advanced technologies to reduce power transmission losses and electricity consumption. In view of the ever increasing price of imported energy resources, the development of its own natural resources to power its electricity generating plants, large use of wind power, and power savings through technological advancements of power transmission and distribution systems might be the best and most economical way for Lithuania to attain energy independence.

Background

On January 1, 2010 Lithuania has powered down and decommissioned the Ignalina atomic energy plant's (IAE)[2] only remaining nuclear reactor. At that time, this small Baltic Republic has lost all of the IAE generated electrical power [1] which amounts to 70% of the country's current electricity consumption. From there on, the IAE, instead of being one of the largest electricity suppliers, will become one of its largest consumers [2]. As a result, Lithuania will become almost completely dependent on gas imports from Russia to power its electrical generating plants.

The decision to close IAE was made in 2004 as a condition of Lithuania's entry into the European Union (EU). At that time, Lithuania agreed to close the first of the two reactors on December 31, 2004, and the second by the end of 2009. Although Lithuania conducted studies as to

[1] Abbreviations and acronyms may be found at the end of text
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how these Chernobyl-style reactors should be deactivated, very little consideration was given as to what would happen afterwards; namely, how would this small country manage its demands for electricity when it is nearly completely dependent on a single gas supplier to fuel its remaining generators of electricity. Additionally, how would Lithuania protect itself, its economy, and its people from possible risks created by abrupt interruptions of gas deliveries or their unreasonable price escalations.

Perhaps, because Lithuania saw its entry into the EU in such a positive light, these questions weren't raised or, if they were, they didn't receive much attention. It could also be that Lithuania's general population didn't persist in asking what happens next, because they believed that their government had it all under control. After all, when the closure of the first IAE reactor was announced, Lithuania's government declared its intentions to build a replacement plant and noted that Lithuania's neighbors Latvia, Estonia [3] and later Poland [4] would partner with Lithuania in this endeavor .

Sadly, no concrete initiatives were taken to make plans for the construction of the new reactor until December 28, 2007, when the Lithuanian government formed a quasi-government corporation LEO.lt. [5], a holding company, that was jointly owned between the government of Lithuania and NDX Energija, a previously privately held company. While it was initially believed that LEO.lt's primary purpose would be to build a new nuclear reactor at Visaginas (town in Lithuania), it later became clear that this new, publicly traded company's principal interest was to maximize profits through the sale of electricity regardless of its origin. When this became public, Lithuania's newly elected president Dalia Grybauskaite requested her prime minister Andrius Kubilius and his government to dissolve LEO.lt [6]. Prime minister Kubilius delegated this responsibility to the Energy minister Sekmokas who is also now charged with initiating the construction of a new nuclear plant. The most optimistic government estimates to complete its construction are 2016-2018, leaving Lithuania vulnerable until then.

Concern about the future and the extent of the study

Having observed all this from the North American continent and being concerned that the Lithuanian people might be facing rather disastrous electrical energy consequences due to inaction by those responsible for the planning and construction of the new nuclear plant and noting lack of public information and discussion on what energy alternatives might be available, a consortium of American and Canadian Lithuanian scientists initiated a study in 2008 with the intention to address some of these concerns and review related issues. The intention of the study was to provide an unbiased view to the public and to the decision makers of how the effects of the IAE shutdown appear from a distance and what impact it might have on the lives of the people and the country's economy. The findings were presented at Lithuania's Energy Ministry on July 4, 2009, with the ministry concurrently issuing to the public a summary of the study. Subsequently, the full study was published in Lithuania's technical trade journal "Energijos Erdve" in the September 2009 issue [7]. Several newspapers and science journals published in 2009 interviews with the authors and an article appeared in Lithuania's largest daily "Lietuvos Rytas" on November 14, 2009, resulting in 249 unsolicited readers' comments mostly supporting the findings in the study.

The study reviewed Lithuania's natural energy resources, ability by the remaining power plants to generate electric energy, current and anticipated future power needs, and expected cost increases to generate electricity without IAE. Available alternatives to generate electricity, besides building a new nuclear reactor plant, were reviewed, including the employment of new technologies to achieve major savings in energy transmission and consumption.

Overview of Lithuania's Own Resources

Lithuania has a small amount of in-ground natural energy resources. These include peat, oil, and geothermal types of energy.

Peat resources range from 30 to 35 million tons suitable for consumable use. If used to fuel existing power plants, this resource would be exhausted within approximately two years. (At present the use of peat is miniscule, and it is mostly exported for agricultural and gardening purposes [8][9]

Oil resources are estimated at an extractable quantity estimated to be about 12 million tons [10], but could be larger since exploration includes only limited areas of the country [11] . Currently, oil extraction is limited to approximately 200,000 tons annually [12]. There are no plans to increase the extraction capacity, partly due to low rates of yield and partly due to a lack of interest in opening new fields because of low or not cost effective returns. Because the fuels are of high quality, they are mostly exported for financial advantages rather than used domestically. Were the fuels to be extracted at levels necessary to satisfy all of Lithuania's power needs, the supply would be exhausted in just several years.

While Lithuania has the potential of employing low level geo-thermal resources in a few regions (13), the first geothermal terminal operation resulted in a failure due to a not very apparent reason (14). There are no known present plans to renew access to this natural energy resource.

Hydro power plants

Lithuania as a whole is a relatively flat country and is therefore marginally suited for production of hydroelectric power. Although it has many rivers and lakes, only the two main rivers, namely Nemunas and Neris are suitable for sizable economical hydro power generation.

Currently, Lithuania has one major hydro electric power plant on the river Nemunas [15], which is located on the east side of the city of Kaunas. It is rated at 101 MW (megawatt = one million watts). Its up-stream dammed basin also provides water for pumped water storage to power the electricity generators at Kruonis. The Kruonis HAE (HAE=pumped storage hydroelectric power plant) has a maximum power capacity of 900 MW and can generate electricty approximately for twelve hours at full capacity and proportionately longer at lower capacities.

There are also several smaller hydro electric power plants, with capacities some in dozens others in hundreds of kilowatts (one thousand watts). However, they do not constitute a significant contribution to the country's generated total electrical capacity.

A study of Lithuania's energy resources, published in 1997 by Lithuania's academy of sciences, [15] indicates that two new major hydroelectric plants with capacities similar to the Kaunas hydro electric power plant, could be built: one on the river Nemunas, upstream of the town of Birstonas, and the other on the river Neris, near the town of Jonava. With the addition of the two plants including generating facilities on smaller streams, Lithuania could generate at least 386 MW of power [16] or approximately 20% of its present electricity needs.

Wind and solar power

Lithuania, situated on the Baltic coast, has reasonable amounts of wind energy at or near the shoreline capable of powering wind-driven electrical generators [17]. The currently installed wind generating capacity is approximately 52 MW. Additional wind generators are being planned to be built in later years [18][19].

Due to its northern location, Lithuania is only marginally suited for using current solar technology to produce electricity [17][20]. Most solar applications are for thermal heating purposes [21]. However, should newer photo-voltaic technologies become capable of producing more cost effective solar cells, then their use for power generation may become economically justifiable [22]

Renewable energy resources

Lithuania has large amounts of idle farm land that could be used to grow renewable energy resources, such as wood and/or calorie rich agricultural plants. Currently the largest national renewable resources are wood, wood residue from manufacturing, and straw from agriculture. They could amount to nearly one million tne (ton oil equivalent) annually [23]. An equally large, if not larger, energy resource could be obtained through the programmed growing of energy producing plants on some 500,000 hectares of idle farm land [24]. While it is not apparent which type of plant growth these lands would support, it is clear that energy yield from such additional plant growth could yield at least another million tne of primary energy (energy contained in organic matter, chemical energy, potential water energy, etc) on an annual basis [25].

Production of biogas from municipal waste and communal refuse for energy generation is still in its ‘infancy’ in Lithuania [26]. While there is a potential of generating some energy from these sources, very little is known about their available amounts or their potential contribution to the energy balance.

Power generation sufficiency

Lithuania’s current power generating capacity was examined, with and without IAE production. It was concluded that Lithuania’s non-nuclear electric power plants and limited imports could provide sufficient capacity to meet all Lithuania’s electrical needs during the next 15 to 17 years.

The analysis included generation capabilities of electrical power plants using gas and/or oil, the output of hydroelectric facilities, electricity imports (such as from Finland and/or Sweden), and the growing contribution of wind power generation [27]. The analysis indicate that Lithuania in 2010 to 2013 could produce at the very minimum 2130 MW of power if natural gas was available and 1505 MW if only oil was used and without including the Kruonis HAE contribution. Imports of 300 MW from Finland or other sources would raise these values to 2430 MW and 1805 MW, respectively (Peak power output of Kruonis HAE could add 900 MW for a period not longer than 12 hours within a 24 hour period or for longer time spans at lower power generation levels). However, Kruonis HAE, upon emptying its reservoir, would subsequently have to use for pumping operations at least the same amount of energy that it delivered to the system previously, preferably during low power demand periods. In time spans between the years 2017 and 2026, the available power generation capacities, including 350 MW imports, could increase the system capacity to 3190 MW if gas was available, and 1942 MW if powered only by oil and without Kruonis HAE contribution.

Power needs were examined for three different economic scenarios: pessimistic, stagnant, and optimistic [28]. The pessimistic scenario is based on 3% drop from the 2006 economic activity level until 2011, followed subsequently by no growth until the end of 2012, and thereafter an annual growth of 1%.. The stagnant scenario is based on the economic activity level staying at the 2006 level until 2011 followed by 1% growth thereafter. The optimistic scenario assumes 1% growth from the 2009 economic level until 2011, a 2% annual growth from 2012 to 2016, and 3% annually thereafter.

The above scenarios indicate [29] that the national power demand during 2010 and 2013 will range from 1800 to 1900 MW for the pessimistic case; 1850 to 1950MW for stagnation, and 1950 to 2050 MW for the optimistic activity level. For the years 2017 to 2026, the power demand projections under the pessimistic scenario could range from 1850 to 1950 MW; 1980 to 2080 MW under stagnation conditions, and 2300 and 2800 MW in an optimistic scenario.. Although power requirements for an optimistic scenario were calculated, one does not realistically expect it to occur due to the anticipated prolonged economic downturn [30] [31].

The analysis in the study indicates that if sufficient natural gas is available for generating electricity, all power needs could be satisfied until 2026 [32]. However, if gas supplies were disrupted, power generation using fuel oil would be short by some 300 to 400 MW, assuming that power production would be confiined only to "Lietuvos Elektrine" and the Mazeikiu power plants, hydroelectric generating facilities, and windpower. Inasmuch as peak power demand in Lithuania is only for a few evening hours during the winter months [33][34], the shortage could be eliminated by additional power generated by the Kruonis HAE. Such a demand shortage could also be eliminated by importing power in the range of 300 to 350 MW from Finland or Sweden [35]. Furthermore, generating electricity with fuel oil could be equivalent to the generation with natural gas, if all other power plants were equipped to use fuel oil. For this reason, it would be important to prepare all power plants to burn fuel oil as quickly as possible. This flexible form of power generation does not take into account additional contributions by some other power plants using renewable energy sources such as wood, biofuels, municipal waste, peat, etc. Currently, use of such materials for electricity generation are negligibly small.

The cost increment (in U.S. dollars) of power generation using either natural gas or fuel oil, upon closure of IAE , was also examined. The cost assessment is based on estimated variations in the prices of natural gas, fuel oil, and imported electricity during the years from 2010 to 2013 and from 2014 to 2016. Gas prices are expected to vary from $250 to $400* per 1000m^3 during the period 2010 to 2013, and from $350 to $550 per 1000m^3 during the period 2014 to 2016 [36]. Fuel oil price estimates range from $444 to $592 per ton during the time period 2010 to 2013, and $518 to $814 per ton from 2014 to 2016 [37]. Comparable price of electricity imports are estimated to range from $70 to $90 per MWh during the years from 2010 to 2013, and $80 to $100 per MWh in the 2014 to 2016 time frame [38].

The calculated costs to replace the IAE generated power for Lithuania's internal use during the years 2010 to 2013 are $283 million if natural gas is used and $457 million when using fuel oil at their respective highest unit prices. At lowest unit prices, the cost penalty for gas generated electricity could be from zero to $5 million, and $267 million for fuel oil. Comparable replacement costs during the 2014 to 2016 time frame are estimated at $618 million for gas and $865 million for oil at the unit highest prices and respectively $104 million and $387 million at the lowest unit prices [39] .

In all cases examined, the generation of electricity with natural gas is considerably less expensive than using fuel oil. Cost estimates showed that it would be more expensive to import electricity when gas prices are less in pricel than $250/1000m^3. This study also indicated that producing electricity with oil would always be more expensive than importing electricity.

The Need for a New Strategy (Approach)

Lithuania, to assure its economic viability, should consider taking bold and practical steps to ensure itself of sufficient supplies of electricity now and in the future. Due to extremely downturned economic conditions and high risks of interruptions of energy supplies from Russia, the published "2007 Energy Strategy for Lithuania" [12} is outdated and does not provide an adequate 'road map' to address Lithuania's essential energy security needs. Therefore, a new and updated strategic plan should be developed which would more effectively and realistically focus the country's efforts on achieving the following goals:

1. Sufficient energy generating availability to satisfy the country's electricity needs and security;

2. Maximized energy independence through diversification of resources for generating electricity;

3. Assurance of competitive electricity prices to facilitate maximum local employment;

4. Achieving considerably increased efficiencies in power generation, transmission, distribution, and particularly at the user level;

5. Re-evaluate need for ties with Russia's IPS/UPS power system and interconnection with its distribution network. Eliminate such interdependencies whenever the risks involve the country's independence of any kind;

6. As one of the first priorities, advance the time table for the establishment of "electrical power bridges" with the European Union for importing and exporting electrical energy;

7. Integrate Lithuania's electrical system more fully into the Baltic Power Ring and in synchronism with the EU UCTE system

The revised strategic plan could also consider the following additional issues:

- Re-evaluate Lithuania's current and future electrical needs under best and worst economic conditions;

- Evaluate all currently available energy generating facilities and select those that are most beneficial for upgrading them to maximum operational efficiency;

  - Evaluate the potential of all available practical and cost effective energy resources to power generating plants and risks of their continuous availability on the basis of:

    - Practicality, value, and limitations of available local resources;

    - Value, benefits and problems with imports;

    - New power generating technologies and resources to complement local power resources;

    - Comparison of relative costs of all above

  - Establish and enact rigorous programs to integrate electricity supplies from various sources including imports in order to maximize energy savings at generation, transmission and consumer (user) levels that would be best for the national economy and lowest consumer cost;

  - Develop a plan and implementation schedule leading to Lithuania's independent control of power generation, distribution, and its eventual integration into the EU system.

Alternatives and/or Their Combination to Generate Sufficient Electricity

In view of ever increasing energy prices and possible eventual scarcity of primary energy resources, Lithuania would benefit in the long run by maximizing self-sufficiency. Appropriate cost benefit analysis, economic effects on balance of payments, and assessments on impacts on employment and economic wellbeing should be the basis for prioritizing specific developments. Ideally, it appears that renewable energy sources, such as organic, wind, and solar resources could cover approximately 60 to 70% of the total national needs. Hydropower could supply approximately 20%. Remaining energy needs could be supplied by combinations of electricity, gas and fuel oil imports, and/or by use of small nuclear power plants. Inasmuch as there are a number of ways to address the potential energy resource problems, the following alternatives or their combinations could be considered:

1. **Renewble resources**. Even if the decision is made to build a new large capacity nuclear power plant, Lithuania should pursue, on a faster and considerably larger scale energy self-sufficiency than called for in EU Directive 2009/28/EC, the development and use of

renewable resources as means to minimize the need for fuel imports [40]. This option would also help reduce unemployment and curtail the outflow of financial resources.

If this alternative was selected, Lithuania could develop a large scale program to grow plants and/or trees containing high energy value. To support this, Lithuania could consider utilization of some 500 thousand+ hectares of idle agricultural land. Credible literature suggests that each hectare of land could yield bio-growth sufficient to provide approximately 2 tne of bio-fuels [41}. As a result, Lithuania could produce on its own from organic resources approximately one million tne or 11.630 TWh of primary energy. Futhermore, new technologies are rapidly emerging to process organic materials into bio-fuels with the potential of increasing energy yields above the 2 tne per hectare of land.

2. **Wind energy.** Wind maps of Lithuania indicate an average wind speed of 6-7 m/sec in its coastal regions and somewhat higher in the Baltic Sea shelf [17]. Assuming wind turbine operation 30% of the time, a total of 500 5MW windmills would produce approximately 6.5 TWh of electrical energy, or about 2/3 of the country's needs. If a decision were made to employ wind turbines at this magnitude, Lithuania could begin their manufacture, either on its own or jointly with the other Baltic countries. This could help employ not only a large number of skilled workers but also technicians and scientists.
3. **Pumped power storage**. If wind power was selected as a major energy contributor, it would be essential to have on stand-by a sufficient number of power generating/supplying sources while the wind was not blowing. Major power contributors for such events could be the Kruonis HAE, electricity imports, and generating plants powered by gas, fuel oil, and/or renewable organic resources. Significant energy reserve increases could be secured by increasing the fill capacity of the Kruonis HAE water reservoir. This could be rather inexpensively done by raising the height of the containment wall of Kruonis HAE. Construction of additional pumped storage facilities would also help absorb excess wind generated power when the wind is blowing and assure more adequate reserves during wind dormant periods or otherwise produce export income.
4. Hydroelectric power. Lithuania would benefit, both financially and economically, by building at least two new Kaunas HE size hydro electric power plants: one on the river Nemunas and the other on the river Neris [15]. Such two new power plants in conjunction with several smaller hydro generating plants on other rivers could add at least 286 MW of power. This could boost the total power generated by all hydroelectric plants to 387MW or approximately 17-20% of Lithuania's peak power demand at virtually no recurring cost to generate this uninterrupted additional energy. While some environmental objections might be raised concerning the effects on ecology due to flooding of some local upstream areas and thereby effecting

wildlife, they need to be contrasted with potential energy shortages, huge money expenditures for purchase of fuel or gas, continued economic stagnation and unemployment, and as a result, the potential of increased emigration of its most productive population segment. In the end, a country without population does not need land. It should also be noted, that Latvia is generating well over 60% of its energy needs from three sizable hydro electric dams on the river Dauguva. It is not apparent that Latvia's ecology has experienced devastation on account of these dams. As a side benefit, areas above the dams usually experience considerable economic benefit from water based tourism, recreation and sport events, as well as increased water supplies for agricultural, fishing and consumption purposes.

5. **Nuclear energy**. Lithuania's energy and to a large extent political independence are dependent on the ability to produce its own energy. Large scale nuclear power reactor fills this need well. However, in light of several other alternatives, building a new nuclear plant the size of IAE (1500 MW), raises numerous questions, such as: 1) Is there a vital need for a large nuclear power plant when there are other alternatives, some of which are less capital intensive and some less expensive on a kWh basis; 2) Will Lithuania, in its very uncertain economic condition be able to attract the needed capital to build a very capital intensive facility?, 3) If built, will the Lithuanian user be able to pay the high price of amortization? 4) Will such a facility be able to compete on price with the electricity provided by nuclear plants being built by Russia in the Kaliningrad region and by Byelorussia just east of Lithuania's border[42] [43], 5) Long term problems involving storage and safety of used radioactive materials have neither been addressed and the associated costs been aired nor accepted by the public, 6) Can funding be justified to maintain large and very expensive stand-by power generating facilities over the active life of the nuclear reactor?, 7) Will the large reactor distract Lithuania's drive towards energy self-sufficiency?

A nuclear plant built by Lithuania seems to be incompatible with the EU mandate to achieve energy self-sufficiency of at least 20% by 2020 and higher levels thereafter {40]. Also, since the large reactor must be operated at or near full capacity at all times, it is not clear what would be done with excess energy unless facilities were available to store it or exported it as electricity is being generated. As was the case with the IAE, excess energy was sold to Byelorussia and Russia at prices approximately ½ of the IAE's internal costs. These losses were leveled on the Lithuanian consumer by increasing electricity prices. .

It appears that whatever plans existed for building the new nuclear reactor have up to now lacked openness and transparency [44][45]. Lithuania's public has not been adequately informed nor invited to comment on the types of power generation it would prefer to support.

The public seems not to be aware of the complexities and true costs of building and operating a large reactor, the extent of time for its construction, cost burdens and safety of storing used nuclear materials over many years, the risks of massive power disruptions when the reactor shuts down, etc.

However, what is known is that more than a dozen countries are developing new methods of using nuclear materials to more efficiently generate electricity [46]. The Pebble Bed Modular Reactor being developed in China and South Africa is one example. This reactor will be powered by nuclear fuel molded into ceramic balls rather than typically used expensive and difficult to store uranium fuel rods . China has already built and is operating such a 200 MW prototype reactor. Other nuclear entities are developing “generation IV” reactors. They are designed to burn previously used nuclear fuels. Their use would bring about significant financial benefits to the plant operator and assure them nearly unlimited fuel supplies. It appears that by the late 2020s these new developments in power generation would obsolete the reactors built between 1980 and today.

Lithuania's government sources forecast completion of the new nuclear power by 2016-2018. However, those dates seem to be based more on optimism than reality for the following reasons:

- Available information indicates that orders for critical components, such as large forgings for nuclear power plants, are backlogged and deliveries on some long term delivery contracts won’t be made until early 2020 [47];

- Lithuania has yet to finalize the specifications for its new reactor. The request for formal bids won’t likely be published until well into 2010. The evaluation of bids and the selection of the winner, assuming that financing would be found, may be as late as 2011;

- Recent reports of nuclear power plants built by Finland, Bulgaria and France indicate that it takes approx.3 years from the date of contract award to the first steps in construction [48].

- Time to build the reactor in Finland is now estimated to take at least 7 years [49] Bulgaria started building its new nuclear plant in 1990 and is still in the process of doing so. In view that the nuclear industry is currently experiencing an increased construction demand compared to past years, it is likely that that by the time Lithuania places its first order, it may take ten or more years to complete its construction [50].

Best current estimate points to a completion date by around mid 2020-s. At that time Lithuania may have an obsolete reactor on its hands with many of the expensive attributes to go with it.

6. Effective alternative to a large nuclear reactor might be small or mini reactors in the power range of 25 to 125 MW [51]. Some scientists consider them the way of future in nuclear energy similar to the transition from very large computer complexes to desk top models. They provide the flexibility of rapid installation at different regions of the country to satisfy local power needs without reliance on extensive transmission networks from remote power plants. Also, if need be, small reactors provide the flexibility to cluster their outputs to power large turbines {52] [53] [54]

Small reactors have the advantage of being built as complete units at a factory and be delivered to power plant sites by rail or barge and in the case of the 25 MW reactor even by truck. This eliminates significant time bottlenecks and the associated high costs and complexities of constructing a large reactor on site from individual components. Another advantage of small reactors is the need for less frequent refueling such as once every 5 to 8 years instead of every 18 months to 2 years for large reactors, reaping a saving from less down time [55]. Also, small reactors do not pose a serious disruption problem to the entire electrical system due to their down time, since their individual effects are of much smaller significance than those of large reactors.

It appears that small reactors might offer significant advantages to Lithuania in terms of the country's financial capabilities. Small reactors are significantly lower in price, such as $3,000 to $5,000 per KW of capacity vs. up to $8,000 to $10,000 for large reactors, or millions of dollars instead of billions. Small reactors offer the flexibility to cluster them for gradually increasing power generating capabilities as the need for more power develops. More importantly, the manufacturer of the 25 MW reactor, by retrieving the whole reactor at the end of its operating life, also retrieves the spent radioactive fuel. In this case, the user does not have to be concerned with longtime storage of used fuel and the associated expenses [56].

7. **Electricity imports.** Ability to instantly interconnect to electricity imports are of crucial importance in stabilizing an electrical system in case of an abrupt disruption of generation at some domestic power plant. Accordingly, construction of a power bridge to import electricity from Sweden should be accelerated at maximum pace. Completion of the power bridge also will permit the creation of the Baltic power ring interconnecting all of the Baltic and Scandinavian countries [35].

8. **Liquefied Natural Gas (LNG).** LNG import could serve as another method of providing energy resources to fuel the power plants once the IAE shuts down. To import LNG, Lithuania would need to construct a sea terminal, pipe lines to on-shore storage, and extensive on-shore storage facilities. Fortunately, imported LNG, upon re-gasification, could be easily distributed to users within the existing gas distribution network [57] [58].

Inasmuch as the construction expenses for LNG facilities be could be substantial, they might be viewed as a competitive alternative to the construction of a larger nuclear power plant. Imported LNG could decouple Lithuania’ s dependence on Russia’s gas by providing consistent supply stream, price stability, and absence of politically motivated pressures. Current predictions are that LNG supplies are sufficient to take care of the world’s needs for the next 100+ years. Accordingly, it would appear that LNG imports would be a viable long term complement to support a good portion of Lithuania’s energy needs.

9. **Temporary gas supplies from Latvia**. A short term alternative might be natural gas imports from Latvia’s underground storage facilities. However, these imports may be of questionable availability were Russia to discontinue gas transmission to the Baltic countries. Although NES 2007 [59] notes of possible imports from Latvia to satisfy 50% of Lithuania’s needs for approx 2 months, there is no evidence of a formal agreement with the government of Latvia or of commercial contracts to assure that these supplies would be shared with Lithuania. Legally binding agreements should cover gas delivery on demand, quantities of delivery, rate and duration of delivery, price of gas, etc. Still, even with all that in place, Lithuania would have, at best, assurance of only short term relief rather than a solution of its long term energy problems.

10. **Controls of power distribution**. To assure energy independence, Lithuania should strive to break away from synchronization of its electrical system with Russia’s IPS/UPS system. To that end, some progress has been achieved by constructing a direct transmission line from Lithuania’s main generating facilities to the Klaipeda region through its own territory rather than by transmitting the power through the Kaliningrad region [35].

11. **Used tires as an energy resource.** Very large energy resources exist in used tire dumps. While it may be a difficult technical task, it might be extremely useful for Lithuania’s chemistry researchers to develop conversion methods of pliable tire materials into combustible fuels [60]. Once a conversion process is developed, large quantities of tires could be brought in from numerous other countries while also earning a disposal fee.

12. **Reduction of power losses and waste.** Large reductions in power losses could be realized by implementing smart grid technologies at the network level and by adopting energy

saving programs at the user level [61]. Today's Lithuania's electric grids are generally old and inefficient. Higher than necessary energy losses occur throughout the delivery and at the site of use. Replacement of whole delivery systems is usually not economically justifiable, but significant improvements can be realized through integration of 'smart grid' technologies, distributed power generation, and end-user 'smart' energy consumption. Smart grids and intelligent transmission networks would assure coordinated and efficient power transmission and distribution, and avoid relatively large power losses [61] in transmission lines as well as possible costly damages to electronic infrastructures due to voltage fluctuations and system blackouts [62]. 'Smart grid' technologies also can provide customers with valuable data and information at any instance on how much power they use, associated costs and information that would allow them to lower their energy expenses. With proper information, the consumers would have the opportunity to select, for example, use of more efficient lighting systems, non-energy consuming TVs and computer systems while in dormant state, high thermal efficiency refrigerators, home insulation, and various energy-smart electrical appliances

Therefore, Lithuania, by combining advances in technical efficiencies of power transmission, distribution and appliance functions, could significantly reduce the demand for power generation and thus the need for resources to generate electricity. Active consumer incentives and promoted equipment improvement would greatly reduce the quantity of energy necessary to meet their respective needs. Such cost effective efforts could arise from the co-ordination of government, industrial and business collaboration to improve technical standards and through direct and indirect financial incentives for users of electricity not only to accept the changes, but also to embrace them.

Conclusions

Lithuania does not have sufficient in-ground energy resources to fully satisfy its long term electricity generating requirements. Accordingly, the closure of the IAE, necessitates the development of a thorough and far reaching comprehensive plan to address effectively and realistically Lithuania's future electricity needs. The plan should yield a sufficient power generation system to satisfy the country's needs at a price that its population can afford to pay. Therefore, it is important to recognize that the need for power be based on current and future economic realities. The plan should consider use of new energy technologies, availability and cost projections of various types of primary energy resources, implementation of EU mandates for energy self-sufficiency, power interconnection with EU, and broad and transparent public discussion and evaluation of potential alternatives. Long term objectives should strive to attain ever increasing energy independence by reducing as much as practical imports of energy resources. Ideally, such would reduce and perhaps over time eliminate Russia's controls over Lithuania's energy supplies and distribution and associated political leverage.

Currently Lithuania has sufficient generating capacity (even without IAE operating) to satisfy its present electrical needs. This can be achieved by powering existing generating plants with imported natural gas and/or fuel oil. However, such supplies, because of their continuous price escalation, might create prohibitively large expenditures which would severely strain Lithuania's financial resources and impede its economic development. Therefore, Lithuania may want to pursue the development of significant renewable energy resources to fuel its electrical power generators. These would include, but not be limited to large numbers of wind power plants, increased hydro generating capacities, and extensive use of locally grown combustible organic matter. Small nuclear power plants, featuring short construction times (2 to 3 years), long continuous operating time spans and minimal nuclear residues as well as LNG import should also be considered to supplement electrical energy deficits. For now, potential power shortages, which might last only a few hours during winter months, could be overcome by closely coordinated power generation by the existing Kruonis HAE and by electricity imports. However in time, Lithuania should consider construction of additional pumped storage hydro capacities to assure larger stored energy reserves either for generation of power for domestic use or for high priced energy exports at peak demand time. Furthermore, use of smart grids, reduction of energy losses in transmission lines and transformers, efficiencies of consumer appliances, electronic communication and entertainment equipment can significantly reduce the magnitude of additional power generating capacities.

To practically and economically achieve energy independence in the long term, Lithuania should strive to maximize the needed generation of electricity using its own resources. Total energy independence will be achieved when all its electrical, heating and transportation needs are satisfied by internally supplied resources. The opening of the power bridge to Sweden should be the time to initiate the march towards total energy independence.

Acronyms and units

IAE - Ignalina atomic energy power plant

EU - European Union

LEO.lt. - Lituanian Energy Organization (a quasi-government holding company)

HAE - pumped storage hydroelectric power plant

kW – kilowatts unit of power (one thousand watts)

MW - megawatt unit of pewer (one million watts)

tne - ton oil equivalent

Lietuvos elektrine – the largest gas or oil burning electric power plant in Lithuania (1800MW)

UCTE- Union for the Coordination of Transmission of Electricity

Baltic Power Ring – interconnected electrical networks of all Baltic and Scandinavian countries

kWh - kilowatthours (unit of electrical energy = 10^6 watthours)

TWh – terrawatthours (unit of electrical energy = 10^{12} watthours)

HE - hydro electric power plant

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