Supply Mix
Written Submission

This text is based on three years of activity at the University of Toronto by Stan Pejovic, Bryan Karney, Andrew Colombo and 15 years of prior work by Stan Pejovic.

Table of Contents

1 Add 1 (Analytical tools, modeling tools and data, assessment of risks, environmental attributes, cost characteristics. Detailed models to future demand and supply resource mix. Financial, market, environmental and other quantifiable and qualitative risks.) 3
1.1 Optimisation of the Electrical System 3
1.2 Supply Mix 4
1.3 Stability and Spinning No-Load: Two Free Benefits from Optimizing an Electrical System 5
1.4 Electricity Production at Best Efficiency Incorporates Free Spinning Reserve and Offers Stability 5
1.5 The Electricity Market 6
2 Add 2 (CDM ("Conservation and Demand Management") options and associated risks. Based on credible recent publications and sources from industry organizations, research and public agencies and developers, included in the long-term supply mix plans, achievable potential, costs, implementation barriers, sector specific characteristics, experience.) 8
2.1 Demand Side Management 8
2.2 Renewables – Solar, Biomass and Wind 8
2.3 Small Power Plats 9
2.4 Deep Lake Water Cooling Project Cools Toronto 9
2.5 Geothermal 10
3 Add 3 (Supply technologies and resources and associated risks. Capital and operating costs, performance characteristics, technology life-cycle, environmental impacts and any other relevant characteristics. New natural gas generation, coal gasification (with and without CO_2 sequestration), nuclear (new and refurbished) and, based on Ministry of Natural Resources (Ontario) data and inventory, wind, biomass and hydro-electric resources.) 11
3.1 Introduction 11
3.2 Profit On-Line Management and Control 11
3.3 Coal Fired Generation 12
3.4 Gas Fired Generation 12
3.5 Hydro Electric 13
3.6 Reversible Pump-Turbine Storage - a Solution to Peak Power Generation 14
3.7 Pump-Storage Plants to Replace 50 % of Thermal Plants 15
3.8 Ancillary Pumped Storage Benefits 15
3.8.1 Power Factor 15
3.8.2 Spinning No-Load Reserve 15
3.8.3 Stand-by Reserve 15
3.8.4 A Complement to Wind and other Renewable Energy Sources 16
3.9 Pump-Storage Plants Are All Over the World but not in Ontario 16

4 Add 4 (Methods to assess the impacts on the natural environment of generation options. Long-term planning, able to capture the cumulative impacts and provide indications of the sustainability of options and supply mix plans. Identification and quantification of relevant environmental factors for assessment.) 17
4.1 New Developments 17
4.2 Stability and Spinning No-Load 17
4.3 Nuclear Generation 18
4.4 The Transmission Grid 18
4.5 Education and transfer of knowledge 19
4.5.1 Multidisciplinary Transfer of Experience and Knowledge 19
4.5.2 Requirements for New Graduates 19
4.5.3 Technical Perspective - Two Decades of Inaction 19
5 Add 5 (Proposals to develop and manage an effective inclusive stakeholder consultation process which demonstrably meets contemporary regulatory and public expectations. The process will provide baseline measurements as well as reusable interactive models for sustained application.) 21
5.1 Closing Thoughts 21
5.2 International Thermonuclear Experimental Reactor 22
5.3 Hydrogen 22
5.4 Nuclear, hydrogen, hydro future 22
5.5 Gas producing microbes 23

1 Add 1[1] (Analytical tools, modeling tools and data, assessment of risks, environmental attributes, cost characteristics. Detailed models to future demand and supply resource mix. Financial, market, environmental and other quantifiable and qualitative risks.)

1.1 Optimisation of the Electrical System

The economy of power plant design implies that units' maximum efficiency corresponds to a lower output then the so-called rated capacity, or maximum output. If the system is optimized to produce electricity at the lowest price, the difference between the generating power and maximum (rated) power (with some generators 10% overloaded) of all units in operation will be an essentially free spinning reserve that stabilizes the system (market), not only reducing the level and variability of production costs, but also protecting the system as a whole from possible blackouts. The two most important goals achieved are: (i) free spinning reserve, and (ii) the best price of electricity (cheapest electricity production \$/kWh)[2]. Such an environment would help the entire economy to flourish and, as of today, investments should be directed to this achievable goal. Accordingly, the Ontario Power Authority, the Ontario Energy Board, Ontario Power Generation, universities, investors, manufacturers and designers must act together to develop the proper generating mix, upgrade the transmission and distribution system and reaffirm Ontario's (Canada's) Kyoto commitment. The crippling effect of an undefined market and investment uncertainty must be averted by clarifying the financial

[1] (Copy from RFP) 1. Provide analytical tools, including modeling tools and data, to be used in implementing a planning approach that focuses on assessment of risks, environmental attributes and cost characteristics of various portfolios. Develop detailed models applicable to Ontario's future demand and supply resource mix, and utilize these models to assess representative scenarios and portfolios that are developed and judged to meet criteria. Provide assessments of Ontario's future supply mix for the period to 2025 (per instructions from the Minister, noted above) using these tools and data. Provide assessments also of resource scenarios and portfolios developed in components 2, 3 and 4 (below) of this RFP.

This stage of planning requires speed and flexibility in assessments rather than detailed models. The OPA will value a focus on assessment of risks that could affect portfolio performance, including financial, market, environmental and other quantifiable and qualitative risks. A framework to assess the exposure to these risks and mitigation measures to reduce such exposure is required.

The chosen consultant (the "Consultant") will work closely with OPA personnel during the execution of this work and recognize the OPA's additional objective of transferring technical capability and knowledge to such personnel.

The Consultant shall commence work on the planning framework and risk assessment immediately upon signing of the contract and provide ongoing analysis and iterative portfolio assessment prior to and following receipt of the deliverables under component 2, 3 and 4. Final portfolio analysis is to be completed by the Consultant by October 31, 2005.

[2] Available upon request (e-mail: pejovics@asme.org):
1 Electric Generators Profit/Costs On-Line Management and Control, Short Description.
2 Electric Generators Profit/Costs On-Line Management and Control.

landscape surrounding power generation in the province or erratic prices will continue and effective control of the whole system could be forfeited.

1.2 Supply Mix

Wind can supply only a small fraction of the requisite electricity supply. There is often no wind during summer hot spells and winter cold snaps, and yet these are times of high electricity demand. Consequently, even when wind-generating equipment is installed, it must be buttressed by other sources at those times when consumption is the greatest and the wind supply is insufficient. Solar power is also a popular concept, but it is expensive and available less than a third of the time. Therefore, it is also only capable of supplying a small part of future requirements. Overall, solar and wind energy as well as conservation, cannot solve the electricity generation shortfall; they cannot replace aging coal-fired and nuclear base-load generation over the coming years. Given justified concern over air pollution, there are two realistic alternatives, namely more gas-fuelled generation or increased nuclear power production, but the best solution is to combine them with pumped storage plants in order to relieve about 50% of their pollution burden and to proportionally curtail the risk and amount of nuclear waste. (Please see Chapter *Pump-Storage Plants to Replace 50 % of Thermal Plants*)

Natural gas pollutes the atmosphere less than coal, but still cannot be considered a clean energy source. Current policies and proposals lean more heavily on gas, a diminishing resource whose cost and reliability is questionable. Storage plants are again part of the best solution.

Nuclear power production combined with pumped-storage plants is relatively non-polluting, has controllable optimal operating costs, and has almost "unlimited fuel sources." Environmentalists should consider supporting nuclear and storage power plants as a possible realistic alternative to greenhouse gas problems caused by burning fossil fuels.

Hydrogen currently appears to be the leading candidate for replacing gasoline. Various institutions are studying technologies for generating hydrogen in large quantities. High natural gas prices are pushing industries to steak alternative sources of hydrogen.

Ontario needs a variety of approaches, ranging from wind and solar power, to conservation initiatives that are economically achievable. Moreover, there may be a need for some new gas-fuelled generation for peak load purposes. But unless nuclear and pump storage form the central part of the generating capacity for base and peak loads, the deficit in energy generation linked to cleaner energy is unlikely to be solved. Something similar has already been stated publicly, but pumped-storage power plants should be highlighted as the most economically viable scheme for generating peak and storage energy.

1.3 Stability and Spinning No-Load: Two Free Benefits from Optimizing an Electrical System

There is one economic and physical challenge that deserves particular attention: For an electrical system to be stable, and thus to avoid blackouts if there is a sudden shift in load conditions, it is essential that there are plants operating in the system that are “spinning” but with no-load, or some plants running at partial loads. Such plants are not actually producing electricity but their rotating generators are still electrically connected to the grid. This would allow the system to quickly respond to changing conditions, and thus to match power production to energy demands. (Great Britain has two pumped-storage plants operating at partial loads and speed no load mode and they have successfully averted blackouts and frequency variation; they are: Dinorwig, 6x330 MW ≈ 2000 MW and Ffestiniog – 4x90 MW ≈ 360 MW. Please see our PowerPoint presentation)

The economy of designing power plants implies that unit maximal efficiency occurs at a lower output level then the so-called design or rated level. This situation creates an excellent opportunity for achieving both higher efficiency and providing a free spinning reserve. Specifically, if the system is optimized to generate power at the lowest price, the difference between the generating power and maximal, or rated, power of all units in operation serves essentially as a free spinning reserve. This capacity can be used to stabilize the system (and market), with the benefits of a more uniform electricity price and an infrastructure that is less prone to blackouts. Thus, an overall approach for optimizing the system should assure the realization of two important goals: (i) “free” spinning reserve, and (ii) the best price of electricity (leading to the cheapest price per kW or to maximal profit).

1.4 Electricity Production at Best Efficiency Incorporates Free Spinning Reserve and Offers Stability

A key issue in providing a reliable and affordable electricity system is that of price, and its variation. Yet, without explicit consideration of production and spinning reserves in power generation, we contend that stability cannot be achieved and the resulting instability would inevitably create significant adverse economic and social consequences. Although the 2003 blackout was imported from the US through the south transmission line, the provincial blackout occurred because Ontario had insufficient running power and weak connections with other provinces; essentially, the province had insufficient reserve capacity to stabilize the system after a sudden and unexpected loss of the power from South.

The demand for power is not uniform in time, and its variability ought to be specifically built into the system if stable and affordable power is to be ensured. The minimal available spinning and stand-by reserves must be equal to the production deficit associated with the uncontrolled removal of the biggest generator (largest power plant) or the unanticipated interruption of a major transmission line, whichever is greater. One rule for operating a system, often called the "n-1" criterion (the US criterion), is based on the premise that no single event (such as the loss of a line, generator or an electric plant) should lead to the uncontrolled cascading failure of a large portion of the system.

Reversible Pump-Turbine Storage Plants are often the best solution for peak power generation, providing “spinning no load” reserve, stand-by reserve, and achieving a low price per unit produced (kWh) and installed (kW capacity). Droughts do not endanger supply as pumped-turbine storage electric plants typically reuse water that passes between their reservoirs, rendering them less vulnerable to diminished runoff and dry conditions. Despite the long-term promise of other technologies, pumped storage systems remain the only economical way to “store” large amounts of clean electricity. When combined with conventional thermal and nuclear power facilities, pumped storage plants can reduce contamination from power production by 50%, while simultaneously minimizing power production costs (dollars per kWh). New variable speed hydraulic machines operate continuously at best efficiency and with highly reduced vibration, decreasing operating and maintenance costs by even 50 % or more if appropriately managed. The overall efficacy of a plant can be as high as 85%; that is, as much as 85% of the electrical energy that is pumped into the storage at off peak hours is available again as generated energy from the plant, most or all of which as particularly valuable peak energy.

Finally, the only generators which could deliver electrical energy at a price below 5 cents per kWh are nuclear, hydro and coal fired power plants, but only if combined with pumped-storage plants and powerful transition lines connecting distance generators and the provinces into a strong network. Variable speed pump-turbines are the ideal units to deliver spinning and speed no load reserve, optimize energy generation and minimize the operating and maintenance costs of big nuclear and thermal generators. Designed and operated by qualified experts, generators can deliver electricity at a price below 4 cents per kWh.

1.5 The Electricity Market

The market’s challenge is to bear the costs for proposed storage and pumped storage plants which are required to operate only a few hundred hours per year, or perhaps never. Unfortunately, under the current power production regime, such standby or speed-no-load units are a necessity, but the critical question is how to make the system economical and profitable in a competitive market where each plant and unit is preoccupied with generating revenue. Privately owned companies will invest only if they perceive that their investment will be returned in a short time. Consequently, in the current free market paradigm, the cost of the previously described inefficiency is transferred to the consumer and is expressed in terms of high electricity prices. IESO (New name: Independent Electricity System Operator – IESO; old name Independent Electricity Market - IMO) pricing of energy production should properly finance generators. Standby, speed-no-load units and peak power plants must be paid for in a different manner than the continuously running units and other frequently operated generators. Peak power plants are stabilizing the electricity grid and safeguarding against blackouts which, when they take place, are extremely expensive. The chapter entitled *Optimisation of the Electrical System* demonstrates the possibility of achieving a free spinning reserve and, at the same time, the most economical power generation. This possibility offers a unique and remarkable source of “free” power and diminished pollution.

Most of the investments into big power plants are long-term, discouraging private investors from locking their money for the extended period (10 or 20 years) necessary in order to realize a profit. This problem has not yet been resolved, but if not addressed immediately, the energy crisis will worsen. Consequences of inaction have included blackouts with all their painful repercussions for industries dependant on a stable energy price.

2 Add 2[3] (CDM ("Conservation and Demand Management") options and associated risks. Based on credible recent publications and sources from industry organizations, research and public agencies and developers, included in the long-term supply mix plans, achievable potential, costs, implementation barriers, sector specific characteristics, experience.)

2.1 Demand Side Management

The Ontario Government pursues DSM (Demand Side Management) more than new generation opportunities. Implementation can be fairly straightforward and followed up at the commercial and residential levels. With time-of-use electric metering and substitution of electric resistance heating (e.g. baseboard heaters, water heaters, clothes dryers, etc.), energy savings, particularly during peak periods, can be achieved on the order of 5% of our total electrical demand. Achieving a 10% saving on peak power will be much harder and anything beyond that would require a complete transformation of the way we use electricity. One thing is certain, the more electricity costs, the more incentive there will be to save. Also DSM will clearly not help in alleviating the long-term rehabilitation exigency of our generation equipment in Ontario.

2.2 Renewables – Solar, Biomass and Wind

One of the great challenges in solar power difficulty in Southern Ontario was that we do not always have enough sunny days. In remote areas in Northern Ontario, solar power can only provide limited amounts of local energy production. Therefore, its impact has historically been negligible on the overall power generating capacity of Ontario. The potential is certainly greater, but its overall contribution to the needs of Ontario is uncertain and faces many technical and financial challenges.

Significant amounts of wood waste are available throughout Ontario, mostly from sawmills. A few of the larger sources have already been developed for power generation and are

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[3] (Copy from RFP) 2. Provide a comprehensive assessment of different CDM ("Conservation and Demand Management") options and associated risks. This requirement is to be based on credible recent publications and source information from industry organizations, research and public agencies and developers. Develop CDM portfolios to be included in the long-term supply mix plans. These portfolios must be applicable to Ontario over the period to 2025 (per instructions from the Minister, noted above), and be based on credible estimates of technical and achievable potential, costs, implementation barriers, sector specific characteristics, experience in implementation of CDM, and technology developments. Assumptions regarding current and prospective government policy support of CDM must be explicit, especially where there are assumptions with respect to additional measures required of government, the OPA or other industry actors and consumers in advancing CDM measures.

The Consultant shall present its draft analysis to OPA personnel who will subject this analysis to critical assessment. The Consultant shall finalize its analysis following this assessment.

The Consultant shall deliver the underlying draft analysis by August 26, 2005 and the final deliverable by September 16, 2005.

financially viable, provided the discarded wood is available at no cost. The biggest problem with wood waste facilities is that plant capital costs become excessive below an output capacity of around 10 MW (due to economics of scale) and transporting wood waste for more than 150 km is usually too costly and energy intensive to justify a broad network of such plants. Having said this, there are several wood waste projects under consideration and this energy source can provide several hundred MW of relatively "green power."

Another good source of energy is biogas from sewage treatment plants and landfill sites. Biogas can be used to fuel reciprocating engines down to several hundred kW in size and are relatively simple and "inexpensive" to build.

Wind power is probably the best-known renewable energy source under consideration. Although the technology to build windmills has evolved significantly, wind-generating plants are still relatively costly, but gradually becoming more competitive. Also, wind power is not deemed to be firm capacity since the wind is intermittent, a liability that can be greatly reduced if coupled with something like a pumped storage scheme. Overall, wind power needs to be backed up by conventional generation plants and can best be viewed as a fuel saving opportunity for fossil fuel plants. Nonetheless, wind power is capable of providing over 1000 MW of electrical power here in Ontario and it thus can play a role in achieving an overall solution. As mentioned, wind's effectiveness increases greatly when used in conjunction with a pumped storage scheme and hydrogen production; in this case, power can be produced whenever wind is available and the energy consumed whenever it is required, liberating such a scheme from the handicap of a sporadic energy source. All investments should be balanced, or at least carefully re-evaluated, and the money saved put into basic and peak generators.

2.3 Small Power Plats

The biggest problem with small generators is that plant capital costs become excessive below an output capacity of around 10 MW due to economics of scale. There is considerable opportunity to develop such new power plants, particularly of small to medium size, without significant environmental or economic problems being encountered. These are particularly attractive in sites where most of the other power production infrastructure is already in place. Unfortunately, small power plants cannot resolve the electricity crisis in Ontario, although they can be an important part of the overall solution.

2.4 Deep Lake Water Cooling Project Cools Toronto

Toronto has developed an alternative cooling system that uses cold water (typically near 4^0 C) to air condition high-rise buildings in the downtown core. This innovative system is beneficial for the environment as it reduces energy consumption and carbon dioxide emissions. Toronto now serves as a model for other urban centres looking to reduce their energy use, save money and make a positive impact on the environment.

2.5 Geothermal

Geothermal systems are offering relief to many homes and businesses and could reduce total energy demand. A geothermal heat pump is a mechanical appliance that transfers heat from one source to another, in this case pulling heat from the earth and transferring it to homes or businesses. Heat pumps can provide both heating and cooling using 30%-70% less electricity than conventional electric heating and cooling systems.

3 Add 3[4] (Supply technologies and resources and associated risks. Capital and operating costs, performance characteristics, technology life-cycle, environmental impacts and any other relevant characteristics. New natural gas generation, coal gasification (with and without CO_2 sequestration), nuclear (new and refurbished) and, based on Ministry of Natural Resources (Ontario) data and inventory, wind, biomass and hydro-electric resources.)

3.1 Introduction

The goal is to provide additional background and context for the specific suggestions. We strongly feel that what might appear to be relatively minor changes at this stage will entail a long-term and highly positive benefit for the production of an efficient, economical, renewable, reliable, sustainable, and stable power production system in the Province of Ontario. In fact, a full and comprehensive approach to the optimization of the electrical system offers the potential of realizing two significant goals: obtaining an essentially free spinning reserve and simultaneously achieving the most economical generation. By contrast, repeating the blackout experiences of the past may cost as much as 2 to 4 billion dollars per event.

3.2 Profit On-Line Management and Control

The method and software are designed to bolster profit, protect a unit from accidents and mishaps, and to instruct plant and system technical and management staff what to do when selecting the most profitable operating points of generators, plants and the system as a whole. Any trouble announces itself in time and thus effective real-time management and planning is absolutely crucial.

Vibrations constitute an important issue and they must be analysed and considered on-line all the time. When measured vibrations are close to established limits, operation should only be permitted under special monitoring and supervision. If the limit is exceeded, an incident should be expected and units must be repaired to prevent an accident.

[4] (Copy from RFP) 3. Provide a comprehensive assessment of different supply technologies, resources and associated risks. This requirement is to be based on credible recent publications and source information from industry organizations, research and public agencies and developers. The assessment will include identification of capital and operating costs, performance characteristics, technology life-cycle, environmental impacts and any other relevant characteristics. The assessment will present data suitable forplanning studies on a consistent basis for the following supply technologies and resources in the Ontario setting: new natural gas generation, coal gasification (with and without CO2 sequestration), nuclear (new and refurbished) and, based on Ministry of Natural Resources (Ontario) data and inventory, wind, biomass and hydro-electric resources.

<u>The Consultant shall present its draft analysis to OPA personnel who would subject this analysis to critical assessment. The analysis would be finalized following this assessment.</u>

<u>The Consultant shall deliver the underlying draft analysis by August 26, 2005 and final deliverable by September 16, 2005.</u>

Generators, Powerplants and System Profit On-Line Management and Control custom designed software can increase profit and select the most profitable operating points of individual powerplants and even the entire Ontario system. By determining the best exposure rate, the profitability and reliability of powerplants and related subsystems can be increased. On-Line Management and Control software is the monitoring and control system, which increases profit and the energy production level[5].

The selection of input data is based on standards, guidelines, model tests, site investigations and the technical literature. By means of the statistical analysis of measured and recorded data, the efficiency of the On-Line Management and Control software can be improved.

Energy production costs are dependent mostly on vibration intensity and the related exposure rate, which is increasing in time. The exposure rate, which is the correlation between the real and reference times of operation, is the most important characteristic of a unit. It is statistical data. Some standards, guidelines and technical papers consider vibration and correlate it to the exposure rate. The on-line measured data compared to the data recorded several hundred hours previously are both changing in time. They are highly influenced by real time operation and the exposure rate, as well as the system operating point. Vibrations (described by their amplitudes and frequencies) and other machine characteristics exert a strong influence on the numerical values of the exposure rate. Statistics are based on data reported in the technical literature and should (and could) be improved for any plant analyzing files of logged records, thus improving numerical on-line measured and calculated values[5].

3.3 Coal Fired Generation

Although authorities would not imperil the electricity supply by shutting down coal-fired plants before replacement capacity is available, depletion of fossil fuels will do that soon enough. Until such time, a reasonable approach would be to upgrade the environmental emission controls of these plants by installing the appropriate air pollution control devices, and run these plants to the end of their life. At 36% thermal efficiency for these plants, conversion to natural gas would be completely uneconomical. The money would be better spent on hydrogen, hydroelectric, pumped storage, gas-fired peakers (i.e., plants specifically designed to meet peak load requirements) and transmission lines to connect the Ontario grid not only to the US but also to neighbouring provinces. At the same time, pumped storage plants lead to lower maintenance costs for thermal plants.

3.4 Gas Fired Generation

With natural gas prices tripling over the past five years, its use as a fuel for power generation has to be carefully scrutinized. The only foreseeable role for natural gas is to assist with

[5] Available upon request (e-mail: pejovics@asme.org):
1 Electric Generators Profit/Costs On-Line Management and Control, Short Description.
2 Electric Generators Profit/Costs On-Line Management and Control.

meeting peak power demand in the short term. Natural gas fired peaking plants may be attractive for dealing with daily load conditions, especially during the summer. They would only have to run for approximately 1000 to 2000 hours per year. Merchant class combined cycle plants with no steam host may be difficult to develop. It is unlikely developers would carry the fuel risk for such a project.

3.5 Hydro Electric

Surprising as it may seem, hydroelectric power has significant untapped potential in Ontario as the only cheap renewable energy that can also address concerns over peak generating capability. Yet if this potential is to be fully realized, one of the most pressing requirements is again to establish a reasonable and stable economic climate that will effectively reward and encourage suitable energy investments. This problem is itself challenging, but is a prerequisite to all other development. Bruno Trouille has recently published an excellent, reflective and well-written article on this topic ("The Need for a New Approach to Hydropower Financing," *HRW*, March 2004, 22-29)[6].

Once a suitable economic climate has been created, hydro investment can be pursued in three primary ways:

a. There is a significant opportunity in some cases to retrofit existing hydro facilities by replacing older or less efficient turbines with newer and more efficient units. Moreover, since hydro can play a decisive role as a peak provider, in some cases smaller plants can be expanded, and new larger units added (probably technically better solutions), with the goal of meeting short-term peak loads more effectively while at the same time not increasing the total amount of water passing through the plant on a longer duration basis (Grand Coulee hydroelectric plant in the US).
b. Probably most important, there is tremendous potential and need in Ontario to create pump storage plants. These can store energy, a capability that is uniquely and efficiently available in Ontario and Canada.
c. Lastly, there is a considerable opportunity to develop new storage and pump storage power plants, particularly of small to medium size, without significant environmental or economic problems being encountered. These are particularly attractive in sites where most of the other power production infrastructure is already in place (dams in particular).

Significant advantages could accrue from the development and use of pumped storage. One benefit that a pumped storage facility creates is the ability to run other energy production facilities far closer to their optimum points, thus saving power and reducing environmental burdens. The approach is simply to save energy in the form of elevated water during periods of low electrical demand (increasing the efficiency of the system), and to release this water to supplement peak production during periods of maximum demand. This single capability would have an enormously positive impact on energy reliability, the environmental burden of energy production, and on the economics of meeting energy demands. It should be noted that pumped storage plants play a critical role in the operation and stability of many countries

[6] Please see also our presentations on 17th November 2004 and 3rd March 2005.

(including Great Britain, Germany, France, Italy, Luxemburg, US, Japan, Russia, China, Taiwan). Ontario has fallen behind in the exploitation of this crucial resource for ensuring energy supply stability and reliability[7].

3.6 Reversible Pump-Turbine Storage - a Solution to Peak Power Generation

Peak electricity demand has been satisfied mostly with fossil fuel generation. Coal prices have increased 60 to 65% over the past couple of years while petroleum and derivative prices have surged by 60% or more in one year. Global news headlines have followed the dramatic rise of oil prices in recent years (US$13 in 1998 to US$65 in 2005 per barrel; with a record of $70.85 until September 2005). Natural gas-fired generation has long been considered as the method of choice to augment the electricity supply in this province, but prices for natural gas have tripled in less than five years and its long-term supply is by no means secure. The Alberta Reserves Report recently stated: "Conventional natural gas production in Alberta likely peaked three years ago, and a yearly decline of about 2.5% should be expected."

The substantial growth in input prices will work its way into consumer electricity prices as coal and oil reserves expire. While the core Consumer Price Index (CPI) is estimated at 2 to 2.5%, this figure excludes energy prices. Nonetheless, ratepayers do not have a similar opportunity to exclude them from their bills. Energy inflation is currently in the high single digits per year and climbing.

Clearly something must be done!

Hydropower plants, as well as reversible pumped-turbine storage electric plants, are a better solution than any other system to meet peak energy demand: they respond faster and are the only ones producing or taking advantage of clean energy. Furthermore, they typically enjoy a long service life (sometimes up to a hundred years or more) and they are very efficient. The heavy reliance on hydroelectric power in many countries of Central and South America has become a burden, primarily because drought interferes with the reliable supply of electricity; reversible pumped-turbine storage electric plants are far less vulnerable to protracted dry spells.

In Ontario and some countries which do not have plants with large reservoirs, reversible pump-turbine storage electric plants reduce production costs for the system. Ontario does not have reversible plants that could accumulate low-cost energy (deriving from wind and solar sources or when thermal plants operate below the technical *minimum*) by pumping water into storage reservoirs when there is a surplus of generating capacity and then releasing it when needed back through the pump-turbine assembly, which would operate in turbine mode.

Hydrogen as a fuel cannot be a cheap and economical storage medium of electricity because the efficiency of the transformation cycle (electricity surplus – hydrogen – electricity peak energy) is around 40%. Moreover, the production of hydrogen depends on energy, something that energy accumulated in a pumped-storage scheme could provide.

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[7] Please see also our presentations on 3rd March 2005.

3.7 Pump-Storage Plants to Replace 50 % of Thermal Plants

Two thermal power plants (nuclear and/or fossil fuelled) could be exchanged with one thermal and one pump storage facility which transfers the energy surplus delivered by the thermal plant into its water storage reservoir. When consumers need more (peak) energy, both the thermal and pump-storage plants would furnish the required electricity. Therefore, the inconvenience of nuclear plant downtime and the burden of greenhouse plant emissions (GHG) from fossil power plants could have been reduced by 50%[8].

3.8 Ancillary Pumped Storage Benefits

Additional benefits of pumped storage (and hydroelectric) plants are as follows.

3.8.1 Power Factor

Various Canadian federal, provincial, and U.S. regulations provide financial incentives to electrical generators that can improve the power factor of the electrical grid. Hydroelectric plants, if designed for this purpose, can use turbine runners to spin in the air and thus increase the power factor; pumped storage plants can always play this beneficial role.

3.8.2 Spinning No-Load Reserve

The economic and physical challenges are described in paragraphs: 1.3 Stability and Spinning No-Load: Two Free Benefits from Optimizing an Electrical System; 1.4 Electricity Production at Best Efficiency Incorporate Free Spinning Reserve and Stability; 4.2 Stability and Spinning No-Load

3.8.3 Stand-by Reserve

Some electricity generating plants are held in a 'warm' state that allows them to increase electricity output immediately or on short notice. Since coal-fired power stations take several hours to warm up, some thermal power stations are kept in a condition known as 'spinning reserve'. Pumped storage plants are actually more efficient and do not discard energy while in standby or emit greenhouse gases such as carbon dioxide (CO_2), nitrous oxides (NO_x), sulphur oxides (SO_x), particulate matter, mercury, arsenic, volatile organic compounds (VOC), or other materials that are toxic for the environment and human health. Pumped Storage plants keep turbines “warm” as stand by reserve or rotating reserve with minimal water flow or even without flow (i.e., spinning in the air).

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[8] Please see also our presentations on 17th November 2004 and 3rd March 2005.

3.8.4 A Complement to Wind and other Renewable Energy Sources

All levels of government are encouraging the development of electricity generation from wind power. Yet wind blows intermittently and erratically. A large fraction of electricity generated from wind and other sporadic sources (such as photovoltaic, solar) cannot be relied upon at any given time. The unpredictable nature of these sources necessitates a greater amount of running and spinning reserve in order to cover situations when these sources may not be generating and/or when demand may surpass expected values. In the UK, a study by the former CEGB (Central Electricity Generating Board) estimated that "additional reserve might be required once intermittent sources supplied more than 20% of peak demand in England and Wales."

3.9 Pump-Storage Plants Are All Over the World but not in Ontario

Ontario (and Canada) are surprising exceptions when it comes to the effective utilization of pumped storage, with many countries enjoying its benefits for years already. Even small nations like Belgium and Luxembourg have more Pumped Storage capacity than we have. We respectfully submit that this does not make sense. Ontario (Canada) is not on the list of "1000 MW and Larger Pumped Hydro Installations Worldwide" but should have been long ago. (Viadnen, 1096 MW in Luxemburg was built in 1964; Lewiston, Niagara 2880 MW built in 1961 has a head of only 33 m – Ontario and Canada have thousands of sites around their lakes and seashores).

For example, there has been much discussion about the proposed Conawapa project in Manitoba. If, as an alternative to this project, or in addition to it, a pumped storage project of similar generating output were built in Ontario, not only would it create thousands of construction jobs and many well paying operational positions, but also it would save Ontario millions of dollars. The magnitude of savings in addition to employment and spin-off benefits would be substantial. Also, if such a project were located in Ontario it would have the additional benefit of helping to meet Ontario's Kyoto Protocol greenhouse gas emissions target, which would abate some of the pressures on Ontario industries during the transition.

4 Add 4[9] (Methods to assess the impacts on the natural environment of generation options. Long-term planning, able to capture the cumulative impacts and provide indications of the sustainability of options and supply mix plans. Identification and quantification of relevant environmental factors for assessment.)

4.1 New Developments

The most important task is to establish a multi-tiered pricing system for energy. Electricity from all existing and new generating facilities should be regulated with prices adjusted to reflect the true cost of generation. The Ontario electricity market has to be adopted as the Power Pool in order to assuage investor reluctance to support new power generation infrastructure from any available sources. If this goal cannot be achieved the market should be closed.

The era of fossil fuels is in its twilight with scarcity growing at an accelerated pace. In ten to fifty, or one hundred, years, first oil, than natural gas and finally coal will be exhausted. At that time, the only viable energy sources will be renewable and nuclear. We have to rely on known power generators and to invest in new technology while hoping for the discovery of new energy sources (hydrogen, ITER = International Thermonuclear Experimental Reactor), while even current exigencies necessitate the construction of new generating facilities. Twenty years of experience in Ontario has proven that failure to build new generation capacity is especially costly. Experts, knowledge and skill have been lost during these two decades of inaction and the continuity of know-how has been interrupted, ensuring a weak transfer of practical and theoretical experience. These trends must be reversed as soon as possible.

4.2 Stability and Spinning No-Load

There is one economic and physical challenge that deserves specific mention. For the system to be stable, and thus to avoid blackouts if there is a sudden shift in load conditions, it is essential that there are plants that are "spinning" but with either no-load or running at partial loads. These facilities are not actually producing electricity but their rotating generators are still electrically connected to the grid. Such an operation allows the system to quickly respond to changing conditions, and thus to match power production to energy demands (Please see the

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[9] (Copy from RFP) 4. Provide methods to assess the impacts on the natural environment of generation options. The methods must be suited to long-term planning, be able to capture the cumulative impacts and provide indications of the sustainability of options and supply mix plans. The methods must provide for identification and quantification of relevant environmental factors for assessment.

The Consultant shall present their draft analysis to OPA personnel who will subject this analysis to critical assessment. The analysis shall be finalized following this assessment.

<u>The Consultant shall deliver the underlying draft analysis by August 26, 2005 and final deliverable by September 16, 2005.</u>

case when Dinorwig (6x300MW) and Ffestiniog (4x90MW) pumped storage plants prevented blackout in the UK on 22nd May 2002 at 17:42. Also, please see our presentation on March 3, 2005). The economic question that must be resolved, but has not been hitherto addressed in proposals, is who pays for this vital capability and who invests to build these generators?

Stated another way, the challenge is to bear the cost for those plants, which are required to operate only a few hundred hours per year, or possibly not at all. Unfortunately for power production systems, these standby or speed-no-load units must exist! However, how can the system as a whole be made economical and profitable in a competitive market in which each plant and unit is striving to make money? Privately owned companies will invest only if they perceive that their investment will be returned in short time. Consequently, in the current free market, the cost of previously described inefficiencies is transferred to the consumer (and taxpayers) and is expressed in terms of higher electricity prices. Current IESO pricing of energy production does not properly finance generators. Standby, speed-no-load running units, and peak power plants must be paid for in quite a different way than the units operating 24 hours 7 days a week, or indeed any other frequently operating generators. Peak power facilities play a decisive role in stabilising the electricity grid and protecting us from blackouts, which, if or when they take place, are extremely expensive. As mentioned earlier, a fully optimized system offers the potential of simultaneous free spinning reserve and the most economical generators.

4.3 Nuclear Generation

The capability to revitalize nuclear reactors and extend their lives simply must be put in place. With the careful overhaul of nuclear plants, we could buy time to plan a proper phase out with alternate energy supplies and decommissioning.

4.4 The Transmission Grid

In terms of energy transmission, there would be a great benefit (in parallel to any other improvements in energy production and storage) to building a high capacity transmission line that connects the various consumers and generators, as well as provincial grids. Such a system could exploit the time differences between provinces to spread peak energy demand across Canada, thus reducing the reliance of any one region on both peak energy imports and their high prices. Enforcing legislated standards would fall to the provinces collectively to make the problem both technically easier to solve and more economical. In this way, a Canadian energy system could be initiated. To date, Ottawa's action to curb GHG emissions can only be interpreted as a failure. Indeed, emissions are higher than ever. Ottawa could actually produce concrete results by helping pay for a transmission line. A secure national energy grid is certainly in Canada's best interest, both from an economic and a national security standpoint. Currently there are no east-west power lines of any important stature or sizable capacity. In fact, the big provincial power exporters — Manitoba, Quebec and British Columbia — send almost their entire excess power south of the border, not to their Canadian neighbours.

Canadian provincial systems are effectively small northern appendages to the large US transmission grids, but without high capacity Canadian transmission lines, provinces are technically dependent on the larger US system. This is the reason for the instability of the provincial grids. The 2003 blackout was imported from the US into Ontario through what proved to be an unreliable south transmission line and was exacerbated by insufficient running OPG generators and weak connections with the other provinces.

Canada once built railways and the St. Lawrence Seaway, understanding that ties of national importance needed to be established. The next step, no doubt expensive but also crucial and inevitable, is to create significant Canadian grid transmission lines, the sooner the better.

4.5 Education and transfer of knowledge

4.5.1 Multidisciplinary Transfer of Experience and Knowledge

Continuity has been lost. Canada has had more than 100 years of experience in the electricity sector but individual areas have lost valuable experience and knowledge that accrued during this period. Poorly coordinated transfer of practical and theoretical experience appears to be the root cause. The consequences are an unstable market and investment climate, accidents, inefficiency and the troubleshooting of these problems which have all shown up regularly in recent years and will continue into the future if appropriate steps are not taken. The organized multidisciplinary transfer of experience is a major task that needs to be undertaken by the universities and electricity sector in Ontario. It is urgent that decisions be made (or perhaps should have already been made). There is a clear need to plan, finance and implement some long-term initiatives.

The greatest task facing the electricity sector in Ontario is the design of new generators and the rehabilitation of nearly all existing units within a short time frame, yet there are too few experienced experts (engineers) and project managers who know how to cultivate the right skills from the market place.

4.5.2 Requirements for New Graduates

New graduates, particularly Masters or PhD recipients, should be able to manage or lead a team and should have 10 to 15 years of design and site experience as well as being able to select and read journals and textbooks. In addition, if there is no the expert to instruct, as it is now in Ontario for some specialities, learning time should be increased in order to ensure adequate competence and reduce the number of accidents and errors. Education costs millions of dollars but serious accidents can cost billions and possibly endangering lives.

4.5.3 Technical Perspective - Two Decades of Inaction

No substantial new generation capacity has been added to the province's supply over the past 20 years. Meanwhile, demand for electricity has continued to grow at 1-2% per annum (approximately 25% in total over that period). Ontario has continued to see its reserve margin shrink from 25-30% in the 1970s to 5% or less today. Also, there is a commitment to dismantle coal-fired generating stations (representing 7,500 MW or 30% of the theoretical total supply), and a number of nuclear reactors are off-line and in need of extremely expensive refurbishing or replacement. Never has there been such a pressing need for new generating capacity and particularly for “peakers” to handle the largest electrical loads.

New capacity is an ongoing necessity. Twenty years of experience in Ontario has illustrated that one of the most expensive strategies is to not build new power plants in a timely manner. New gas and oil fuelled generators are only a temporary solution which deliver expensive semi-clean energy, but long term solutions for low cost energy production can only be achieved by simultaneously combining pumped storage plants with nuclear and coal fired generators. Wind and solar units deliver relatively expensive energy that only slightly substitutes for dirty energy production that is ultimately backed by other power plants.

In summary, pumped storage is an opportunity that has been overlooked at a substantial cost to the environment and economy. Ontario can take advantage of this enticing prospect to achieve an efficient, reliable and stable power system and set the stage for exploiting the advantages offered by renewable fuels.

5 Add 5[10] (Proposals to develop and manage an effective inclusive stakeholder consultation process which demonstrably meets contemporary regulatory and public expectations. The process will provide baseline measurements as well as reusable interactive models for sustained application.)

5.1 Closing Thoughts

The blackout of Aug. 14, 2003 left vast stretches of Ontario without power. Toronto's subway came to a halt, food spoiled in refrigerators, Ontario residences over-heated in the dark, and stores and restaurants closed. The blackout cost the Canadian economy billions of dollars. Although official blame may fall elsewhere, insufficient spinning reserve and week trasmition lkines was the root cause of the blackout. It is clear that this blackout could have been prevented and that immediate actions must be taken to ensure our electric production and distribution system is more robust. In fact, failure to act will threaten the reliability of the electricity supply, a resource that is critical to the economy and national security. If the system had had spinning no load reserve, this price spike would not have happened. Even at the highest consumption, available power must be above demand. This means that all units must be ready: some are covering existing demand while the others are on stand-by, ready to cover unpredictable demand surges or compensate for equipment malfunctions. In the case where available resources cannot meet demand, power shortages leading to blackouts are the natural outcome. This has already happened. In many less severe cases, mismatches between generating capacity and demand have necessitated the importation of expensive power, sometimes increasing the price per kWh by a factor of 100 (0.02 to 2 $/kWh) and even more. In these situations, more severe instability could have induced blackouts

To bring about a new mix of power generation sources in Ontario and to replace our aging system will take time. Given the amount of nuclear and coal-fired capacity in question, it may take 15 to 20 years to replace about 2/3 of our existing capacity. An evolutionary approach using labour, technologies and capital available here in Ontario is preferred.

Developing professional staff in Ontario with competency in power generation will also take time (an important task for the universities, OEB, OPA and OPG). It requires a stable business environment where future projects are developed on a predictable basis. Without this in place, good people would move on to industry sectors in other regions, and our efforts here would be plagued by delays and cost overruns, as they are at present. Currently in Ontario, the average age for trades-people is 52. Since 1982 very few people have gone into engineering schools to study power generation. Even nuclear plant know-how is nowadays mostly accessible from

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specialist staff having served in the US Navy. Some of our best engineering and trades-people have already been drawn to the oil sands megaprojects, where pay scales rival that of OPG (and are based on merit). Ontario and Canada need the best experts.

To undertake a massive revamping of our electricity system will take more than 25 years. We must learn to maintain what we have, upgrade as required, and plan for what we will soon need. The revolutionary approach may work for software and microprocessor development, but it certainly does not work for power generation. The Ontario electricity system has to be reorganized to meet this task.

The planned multidisciplinary transfer of know-how is the task facing the electricity sector and universities in Ontario and Canada. Therefore, pivotal decisions should have already been made. Ontario and Canadian universities are not teaching students how to design, maintain, and operate electric plants and auxiliary systems of big thermal power plants

5.2 International Thermonuclear Experimental Reactor

Canada pulled out of this project because the costs seem to outweigh the benefits. It is going to be a long time before Nuclear Fusion generates thousands of megawatts. If this is true, it pays reconsideration of why other counties are in this project and Canada is not.

5.3 Hydrogen

Hydrogen is the prime candidate for replacing gasoline in motor vehicles. Various institutions are studying technologies for generating hydrogen in large amounts. High natural gas prices are pushing industries to steak alternative modes of hydrogen production. Hydrogen as a fuel cannot be a cheap and economical way to store electricity as the efficiency of transformation cycle (electricity surplus – hydrogen – electricity peak energy) is at the level of 40% or even less.

5.4 Nuclear, hydrogen, hydro future

Advanced nuclear reactors ought to be capable of producing electricity for about 4 cents per kWh. The best operational model could be mixed use, sending electricity to the grid during peak hours and making hydrogen and pumping water into storage the rest of time. The mix of hydrogen production, pumped storage and direct electricity production would depend on the market electricity price and capital costs. In a more sustainable energy paradigm, hydrogen might replace gasoline and hydroelectric and storage plants might offer greater spinning reserve to cover peaks and protect the system from blackouts. Moreover a robust nuclear-hydro-hydrogen generation structure can provide a framework for incorporating energy from wind, solar and other diffuse energy sources, which would become more important as those technologies improve.

5.5 Gas producing microbes

Some microscopic organisms have been discovered to produce methane as a metabolic by-product. These microbes could be deployed in coal seams to turn coal into gas. When such an approach may prove viable is a key consideration.