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ONTARIO CENTRE FOR ENGINEERING AND PUBLIC POLICY

THERMAL ENERGY GENERATION FROM UNDERGROUND POWER TRANSMISSION CABLES

By Silbert Barrett

LAND-USE CONVERSION of power transmission corridors, such as the ones criss-crossing the Greater Toronto Area (GTA), offers a unique and strategic opportunity to realize the potential of underground high-voltage transmission cables. These can be used for the development of innovative thermal energy generation technology, as well as creating the potential for the planning and development of sustainable urban and rural communities. Current practices in urban development and, subsequently, the pattern of urban growth have given rise to increased concerns over sprawl, traffic congestion, loss of bio-diversity and farmlands, and the quality of air across major urban centres in North America and around the world. Urban planners and others are calling for a sustainable approach to urban development–in which opportunities for incorporating sustainable development features and practices, such as increasing affordable housing and access to public transportation, and creating more compact and energy-independent communities–are the key considerations.

Ontario's Long-Term Energy Plan states that, by 2030, Ontario's population is expected to rise approximately 28 per cent, a gain of almost 3.7 million people. Ontario's population will become more urbanized, with population growth taking place in primarily urban centres. The GTA population will increase by almost 38 per cent over the same period. These challenges will require new and innovative partnerships and approaches, especially in dealing with the issues of providing the necessary infrastructure to promote growth and economic development on one hand, while protecting our social fabric and the environment on the other.

A triple-bottom-line approach to urban investment strategies can be achieved by releasing the potential for energy and sustainable urban development within the GTA power transmission corridors. This approach is sometimes referred to as full cost accounting (FCA), a process to ensure sustainability in infrastructure delivery by evaluating projects according to three sets of criteria or benchmarks: financial viability, social equity and environmental responsibility.

OVERVIEW

The GTA power corridor's total network, starting from the substation in Pickering, is made up of three main branches. A north corridor (500kV) runs west for most parts along Highway 407 to the border of Milton. Also from the east a central corridor (230kV) runs west along Highway 401 to Highway 407 at Highway 403 and then continues along Highway 407 to the substation at Queen Elizabeth Way (QEW) and Highway 403 at Highway 407 in Burlington. There is a south corridor connected to the central branch at Route 27 and Highway 401, running just east of Highway 427 to QEW. The third corridor (115kV) runs south from the Pickering substation diagonally and through the centre of Toronto's central business district. It merges with the south arm of the central corridor at Highway 427 and the QEW and continues west along the QEW to Oakville.

The corridor comprises some 4000 hectares stretching more than 200 kilometres across the GTA, traversing diverse urban communities and other land-use patterns. The corridor offers ease of access to all major modes of transportation, as well as institutional, commercial, industrial and community facilities. The proposed development would include a built-out population of between 220,000 to 400,000 people over a 20-year planning cycle, and an innovative renewable energy technology, which is expected to generate in excess of 2500 megawatts of electricity to supply approximately 1.6 million homes and produce some 220 million short tons of steam for space heating and cooling as well as hot water for industrial processing.

The project would involve replacing the entire network with a more efficiently laid-out system of underground cable tunnels with smaller branches where necessary by combining both the north and central corridors in one tunnel with a 500 kV double-circuit cable system integrated with an underground state-of-the-art smart grid system. The new grid system should be designed to withstand extreme climatic incidents of hazardous floods, snow storms and earthquakes. The smart grid concept would envision the full modernization and automation of electric power networks to be responsive to supply-and-demand pressures in an efficient and sustainable manner.

This would involve the province transferring development rights to a consortium that, in turn, would assume all responsibility for the planning, financing and development of a number of mixed-use and urban communities on these lands to include district energy for heating and cooling.

SOCIAL, ECONOMIC AND ENVIRONMENTAL BENEFITS

The project's estimated cost is approximately $13.4 billion, of which $3 billion could be financed with public-private equity investments and the remaining long-term debt of approximately $10 billion secured in part against annual certified emission credits of roughly $328 million over the life cycle of the project.

The environmental benefits would create the largest sustainable urban development in North America, as the renewable energy component, based on the United States Environmental Protection Agency's estimates, results in offsetting approximately 12.4 million metric tons of carbon dioxide annually. Annual greenhouse gas emission reductions would be equivalent to 2.3 million passenger vehicles, 64,804 railcar loads of coal and 5.3 billion litres of gasoline. The social and economic benefits in terms of job creation and providing a secure and sustainable source of funding for affordable housing development as well as the province's infrastructure and strategic transportation plans are significant and supported by the project's financial analysis.

POLICY IMPLICATIONS

In 2004, the Ontario government introduced a comprehensive policy framework to make it easier for the province, municipalities and other public-sector partners to plan for, finance and procure public infrastructure assets to support sustainable urban development as well as to enhance the efficient delivery of public services.

The Ontario Ministry of Infrastructure (MOI) was granted jurisdiction over the power corridor lands pursuant to an order-in-council (1487/2005), which took effect on September 21, 2005. This effectively transferred all powers relating to the ownership of Crown real estate, previously residing with the chair of the Management Board of Cabinet and the Management Board Secretariat, to MOI.

Planning for the GTA power transmission corridors underscores the need for integrated planning and would greatly influence the policy debate over rising population growth trends, infrastructure deficits, and the environmental impact of unabated urban sprawl. The "Growth Plan for the Greater Golden Horseshoe, 2006" is Ontario's growth management policy framework for the entire southwestern Ontario urban enclave around Lake Ontario, extending from the Niagara Region to Durham Region in the east. Including the GTA, the plan seeks to address questions of urban growth and, in particular, how to accommodate some 8.6 million people by 2031 and at the same time ensuring the best quality of life for those who will be making the GTA a place to live, work and play.

The power transmission corridor lands project provides the answer and, more importantly, helps to accomplish key policy goals of the Ontario government relating to growth and infrastructure management initiatives; starting with the *Capital Investment Plan Act* (1993) and the announcement in 2004 of a new infrastructure, financing and procurement policy framework, "Building a Better Tomorrow."

As governments around the globe actively debate measures and develop policies to combat climate change, this concept of using major power transmission corridors to facilitate sustainable urban developments could also serve as a model for the implementation of integrated planning policies for urban growth management.

An overall planning and development concept should seek to incorporate a land-use pattern or distribution having approximately 46 per cent residential uses, 27 per cent industrial, commercial and institutional, and 25 per cent infrastructure and open spaces. The goal is to preserve much of the existing active open space but more significantly to create greenhouse gas emission reduction equivalency in the form of carbon sequestration by some 2.8 million acres of pine and fir forest within the GTA.

INNOVATIVE THERMAL ENERGY TECHNOLOGY

This thermal energy technology uses the heat generated from underground power transmission cables to drive steam turbines or other similar technologies to produce electricity and steam. Water (or another working fluid) is pumped under pressure into an encasement around the cables or an external pipe running alongside the transmission cables. In assessing the feasibility of a 500 kV alternating current underground cable system for Alberta Electric System Operator (AESO), Cable Consulting International Limited (CCI) asserts in its February 2010 study that "forced cooling in which water pumped under pressure in circulating pipes alongside each cable (integral sheath cooling) can absorb up to 100 per cent of the power loss (dielectric) by an increase in the water temperature."

The encased power cable system would be in a loop, with a temperature differential between the exit point (heat exchange station) and the entry (recharge or injection) point. The temperature differential within the looped system is maintained in part by cool or cold makeup water mixed in with condensate from the turbine before travelling to a cooling tower where air cooling reduces the water temperature before it returns to the loop at the injection point. The process of heat recovery and cool recharge to the loop is repeated at intervals to be determined by load capacity and requirements. Sizing the thermal energy system will be a function more specifically of rate flow, pressure and cable surface temperature due to power loss.

The use of thermal energy generation from underground power transmission cables could also impact rural economic development by facilitating the creation of "winter farmlands and tropical farm belts" in which thousands of acres of farmlands along the outer rural fringes of the GTA are transformed into greenhouses for growing crops year-round. A network of small irrigation-like pipes could carry heat directly to the soil as well as nutrients to the plants and could also replenish our watersheds.

The groundwater replenishment system (GWRS) is an innovative sustainable technology that can be integrated with the heat recovery process from underground power cables. This would allow the use of "grey water" to provide heat and nutrients to winter greenhouses while recharging our watersheds. GWRS is being used in the United States, and according to Michael Markus, 2011, highly treated wastewater could be used to recharge the underground system: "The groundwater replenishment system (GWRS) takes highly treated wastewater that would have previously been discharged into the Pacific Ocean and purifies it using a three-step advanced treatment process consisting of microfiltration, reverse osmosis and ultraviolet light with hydrogen peroxide. The process produces high-quality water that exceeds all state and federal drinking water standards."

CONCLUSION

Increasingly, the public is demanding greater accountability in how major infrastructure is procured, planned and developed to ensure a safe, secure and healthy region in which to work, live and raise a family. This requires government to evaluate its capital investment decisions within the context of the triple-bottom-line approach, as attention to value capture as a source of public revenue has been increasing where some governments are experiencing declines in revenue from traditional sources and others face rapid urban population growth and require large investments in public infrastructure (Ingram et al., 2012).

The region's growing and diverse population could one day have access to cheaper, organically grown green produce and crops harvested from year-round greenhouses forming a "winter farm belt" along urban fringes, supported by underground power cable thermal energy. This would reduce the need for imported agricultural produce and lessen the environmental impact of freight transportation in terms of congestion and harmful emissions as well as developing a sustainable means of recharging our watersheds.

Supporting sustainable urban and rural development with investments in the thermal energy potential from power transmission corridors will have profound environmental benefits and at the same time allow for the creation of a secure source of revenue to fund the region's growing infrastructure needs in partnership with private consortiums. Σ

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