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Ontario–U.S. Power Outage—Impacts on Critical Infrastructure

PURPOSE

The purpose of this paper is to describe the Northeastern Interconnection power outage of August 14, 2003 and to identify how critical infrastructure was directly and interdependently impacted in Canada.

AUDIENCE

This paper is intended to assist critical infrastructure protection and emergency management professionals in assessing the potential impacts of large-scale critical infrastructure disruptions and to encourage the private and public sectors to review their critical infrastructure protection and emergency management plans.

SOURCES

This paper is based primarily on Canadian and American media reports and cross-sectoral information sharing with the federal and provincial governments as well as the private sector.

EXECUTIVE SUMMARY

- On August 14, 2003, at 16:11 EDT, a massive power outage caused blackouts throughout most of Ontario, along with New York State, Ohio, Pennsylvania, New Jersey, Vermont, Michigan, Connecticut and Massachusetts. This power failure was the largest in North American history, spanning 24,086 square kilometres and affecting approximately 50 million people.
- The Canada–U.S. Power Outage Task Force convened on August 15 to begin an investigation into the causes of the blackout.
- Ontario Premier Ernie Eves called on residents and commercial entities to conserve energy until the electrical grid could return to full operability.
- The power failure impacted, to varying degrees, a wide range of critical infrastructure and emergency management sectors in both Canada and the U.S.

Electricity

- The August 14 power outage significantly impacted most of the sources and means of generating, transmitting and distributing power within the Eastern Interconnect portion of the North American electrical grid.
- Hydroelectric, fossil-fuel and nuclear generating plants took varying amounts of time to resume electricity production.

- The availability of backup generators and fuel supplies became critical in maintaining essential services.
- The pleas for reduced consumption were largely successful; major industrial and commercial users were credited with having made a significant contribution to power conservation.
- The lack of electricity, in addition to impacting virtually all [10 critical infrastructure sectors](#), also hindered the ability of the oil and gas sector to manufacture or transport its products either via traditional transportation means or by pipeline.

Communications

- Landline and cellular companies experienced various operational difficulties as a result of the blackout; however, the Canadian telecommunication industry as a whole succeeded in maintaining the operation of its telephone networks.
- Telecommunications companies across Ontario activated their Emergency Operations Centres to ensure continuous operations of their respective networks.
- Most wireless services including cellular and Personal Communication Services (PCS) were overloaded during the power outage due to high volume usage.
- The blackout, much like the September 11, 2001 terrorist attacks, has led to calls for priority access to telephone lines (wire line and wireless) for emergency responders.
- Newspapers and the electronic media struggled to release information to the public, and in most cases, employed backup generators to power their production processes.
- The occurrence of the blackout coincided with the emergence of two critical cyber threats, the Blaster and SoBig worms. Corporate networks that were unpatched or only partially patched were significantly impacted.

Services

Banking and Finance

- The Banking and Finance industry, which is heavily reliant on computer networks, telecommunications and wireless technology, experienced an immediate degradation of services following the collapse of the electrical grid.
- Business continuity plans, including the use of backup generators and secure network servers, allowed most financial institutions to remain open and provide at least nominal services on August 15.
- The power failure had minimal impact on North American market activity because it occurred approximately 15 minutes after trading closed.

Food Distribution

- The power outage caused shipping and storage difficulties for commercial retailers and dairy producers. Many commercial retailers were forced to discard large quantities of stock due to spoilage while many dairy producers were required to ship milk to Manitoba for processing.
- Production operations have become increasingly reliant on just-in-time delivery of supply, making production schedules extremely vulnerable to any interruptions of supply delivery.

Water Treatment, Supply and Distribution

- The Province of Ontario had adequate supplies of treated, potable water throughout the blackout.
- Due to the prevalence of business resumption and continuity plans, water treatment facilities generally functioned normally and without incident; however, a number of

incidents were reported of waste treatment plants releasing only partially treated waste water into neighbouring waterways.

- A protracted blackout might have caused more serious difficulties in procuring the chemicals necessary to treat and purify water.

Manufacturing

- In a province-wide effort to scale back power consumption while the grid underwent restoration, commercial and industrial businesses chose to either shut down completely or reduce production.

Transportation

- The timing of the blackout, coinciding with the closure of workplaces across affected areas, compounded the negative effects on transportation networks. The afternoon rush hour was complicated by the loss of power to traffic lights, electronic highway signs, traffic monitoring stations and their equipment, and by delays at bus, rail and airport terminals.
- The blackout affected fuel distribution because many gas station pumps were inoperable.

Safety

Emergency Services

- Across the affected areas of the province, police, fire departments and ambulance services experienced a dramatic increase in the volume of calls received.
- Virtually all branches of the emergency services sector encountered transportation delays, backlogged hospitals and intermittent difficulties with communications equipment.

Environmental Safety

- Some environmental safety concerns were reported to be directly related to the power failure. Boil water advisories were issued in several communities after waste treatment facilities released partially treated waste into waterways.
- Several chemical plants reported the release of hydrocarbons into the atmosphere.

Nuclear Safety

- Out of Ontario's 11 nuclear reactors, four were able to remain in standby mode and eight had to shut down. This situation required some reactors to start "cold," slowing the availability of sufficient electricity to meet consumer demand. However, this did not slow down the restoration of the grid.

Government Services

- Only essential Government of Canada employees in Ontario were to report to work on August 15. This directive was reissued on August 17. Ultimately, an estimated 150,000 Government of Canada employees did not report to work for most of the, if not the entire, work week of August 18–22.
- Numerous government departments invoked Emergency Operations Centres to monitor situations and offer aid to various critical infrastructure sectors.
- During the power outage, a Government of Canada telephone line service was maintained in order to provide Ontario residents with current information about available provincial services.
- The priority of the Government of Canada was to maintain fundamental public services such as public health, safety and security, and social and economic welfare.

Economic Impacts

- The impact of the blackout and “ensuing power restrictions are estimated to have reduced Ontario’s gross domestic product (GDP) by 1.4%, which in turn reduced the National GDP by 0.7%—the biggest monthly GDP decline in a decade.”¹ An estimated 2.4 million workers in Ontario and Gatineau, Quebec, lost 26.4 million hours of work time in the second half of August because of the blackout and subsequent conservation period. At the same time, an estimated 713,000 people, or 11.0% of workers, put in a total of 7.5 million overtime hours. The net effect was a loss of 18.9 million hours.²
- Estimates indicate that the power outage cost Ontario’s economy between \$1 billion and \$2 billion.
- On average, most retailers experienced a 40-percent decline in sales during and up to four days after the outage, while the service sector including health, financial, insurance and utilities experienced a similar decline with transactions decreasing by 41 percent the day after the blackout.
- Gas stations and convenience stores were among the exceptions, with many experiencing a 30-percent increase in sales following the outage.
- According to a survey conducted by the Canadian Federation of Independent Business, the outage negatively impacted 82 percent of small businesses in Ontario.

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INTRODUCTION

On August 14, 2003, at 16:11 EDT, a massive power outage occurred resulting in blackouts across most of Ontario, along with New York State, Ohio, Pennsylvania, New Jersey, Vermont, Michigan, Connecticut and Massachusetts.³ The power failure was the largest in North American history, spanning 24,086 square kilometres and affecting approximately 50 million people.⁴ States of emergency were declared in Ontario, Ohio, Michigan, New York, Pennsylvania and other New England-area states.

During the estimated nine seconds it took for the electrical grid to collapse, thousands of events occurred over the vast network of power plants, transmission lines, switching stations and control centres, which may have contributed to the blackout. Numerous theories have been put forward regarding the cause of the outage, but investigations by the North American Electricity Reliability Council (NERC) and the Canada–U.S. Power Outage Task Force indicate that numerous related causes, including a shortage of reactive power⁵, voltage problems⁶ and flow patterns⁷ across several states, triggered the event.⁸

The Task Force was jointly convened on August 15, 2003, by Prime Minister Jean Chrétien and U.S. President George Bush. The Minister of Natural Resources Canada, Herb Dhaliwal, and U.S. Energy Secretary Spencer Abraham jointly chaired the Task Force, which included as Canadian members: the Chairman of the National Energy Board and the President and CEO of the Canadian Nuclear Safety Commission. John Efford later replaced Herb Dhaliwal as Minister of Natural Resources Canada and as co-chair of the Task Force on December 12, 2003. The U.S. members included the Secretary of Homeland Security, the Chairman of the Federal Energy Regulatory Commission and the Chairman of the Nuclear Regulatory Commission. The Task Force also had three Working Groups to examine the electrical grid: nuclear safety, physical security and cyber security. The Working Groups included all relevant federal departments and agencies as well as representatives from the affected states and provinces. In addition, NERC and the affected Independent System Operators (ISO) and utilities agreed that their investigations would supplement and contribute to the work of the Task Force.⁹

From airlines to blood supply levels to energy and water supplies, the power failure impacted a wide range of critical infrastructure and emergency management sectors in both Canada and the U.S. In Ontario, residents were thrust into an energy crisis as officials worked to reconnect power to the electrical grid. The shortage of available energy prompted Ontario Premier Ernie Eves to call on both residents and commercial entities to dramatically curtail their energy consumption until the threat of rotational blackouts could be lifted and the entire electrical grid could be brought back on-line at normal capacity.

The power outage had a definitive impact on the economic and social welfare of Canada and Canadians, and provides an opportunity to learn about the importance of effective critical infrastructure protection and emergency management strategies. This paper provides a broad overview of the Canadian critical infrastructure sectors affected by the blackout and examines the interdependencies between sectors—which the sudden and immediate loss of electrical power demonstrated.

BACKGROUND

ELECTRICAL POWER GRIDS

Figure 1.0 – North American power grids¹⁰



Electrical power grids are geographical sections of transmission lines. North America's energy system is a highly integrated, complex network of transmission lines. It efficiently interconnects major generating facilities and consumers on both sides of the Canada–U.S. border.

Since electricity cannot be stored in large quantities, it must be constantly generated, transported and delivered to the customer.¹¹ In this regard, an energy system using an interconnected electric grid is an effective and reliable way of delivering power to consumers since it creates a market for surplus power and a source for backup power. For example, if a utility experiences power demands that it cannot immediately supply, other utilities can supply these demands until the affected utility can get its reserve generation back on-line.¹²

The reliability of the interconnected grid is overseen by NERC, which “develops standards for the planning and operation of the grid, investigates power disturbances and monitors compliance with reliability standards.”¹³ All major Canadian utilities that are interconnected within the North American grid participate in NERC.

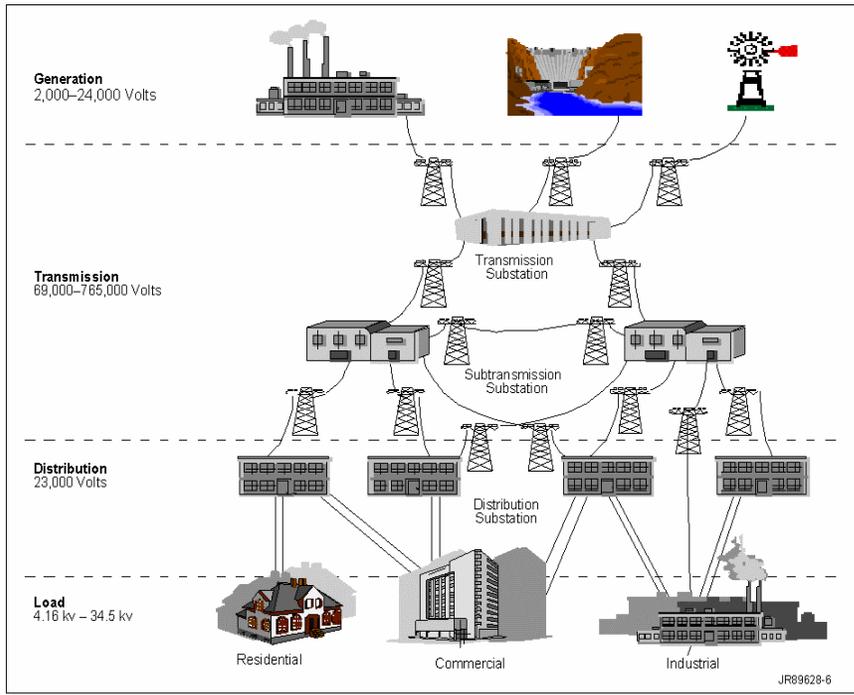
Canadian provinces are part of an interconnected electrical grid, forming a network of power plants, substations and transmission lines crossing provincial and international borders between Canada and the U.S.¹⁴ The majority of the Canadian provinces, including Ontario, and most of the northeastern U.S., including New York and Michigan, are part of the grid known as the Eastern Interconnect or Interconnection (see Figure 1.0). It should be noted that Quebec is linked to the Eastern Interconnection; however, this link is through direct current lines rather than alternating current lines. This direct link limits Quebec's interconnectivity with the Eastern Interconnection.¹⁵ As evidenced by the power

outage, this division of the grid facilitates regional operations and can limit the spread of grid faults.

The continuous balancing of supply and demand within a grid is managed by control areas and reliability coordinators across North America, who forecast demand, monitor system conditions, and direct the operation of generation and transmission facilities. Without this coordination, individual equipment failures could affect other equipment and cause cascading interruptions if left unchecked.

Almost all critical infrastructure (CI) elements are directly dependent on electricity and a loss of power will instantly affect a wide range of key infrastructure operations on which a modern, post-industrial society relies. A serious degradation of electrical power can produce an interdependent failure across a number of CI sectors, a phenomenon generally referred to as a “ripple effect.” This ripple effect could become widespread and affect the CI systems and networks that underpin the electrical industry.¹⁶ While the temporary loss of electricity can be problematic, a longer-term fault in the electrical sector is likely to be devastating. Moreover, it can act as a “force multiplier,” in that many CI sectors inherently dependent on the timely and reliable delivery of electricity can suffer irreparable damage as a result of a lengthy power loss.

Figure 2.0 - Overview of the generation and transmission elements of the electrical industry.¹⁷



The quality of a facility’s backup architecture and contingency plans, as well as the extent and duration of the incident, will determine a power failure’s impact on a facility’s operations. In most circumstances, impacts to infrastructure operations will occur within hours, and at the most days, rather than weeks or months later.¹⁸

EVENT DESCRIPTION / TASK FORCE TIMELINE

During the Task Force probe, investigators sought to answer critical questions regarding the reason the outage cascaded so rapidly and whether utilities and grid operators followed emergency guidelines.¹⁹

On September 12, 2003, the Task Force released its initial blackout chronology pieced together from thousands of logged events across the grid. The timeline indicated that there were nearly 40 transmission line failures and power plant shutdowns in the U.S. approximately four hours before the grid collapsed. The Task Force timeline revealed that most of the events that appeared to have contributed to the blackout occurred between 12:00 EDT and 16:13 EDT. The blackout timeline was meant to provide an early overview of what transpired and not explain the cause of the blackout. Conclusions and recommendations were released later in the Final Report.

The joint Canada–U.S. Task Force *Initial Blackout Timeline* is available in its entirety at http://www.nrcan.gc.ca/media/documents/Blackout_Summary.doc

According to the Task Force timeline, after several transmission lines tripped on the U.S. side of Lake Erie at 16:10 EDT on August 14, power flowing westward in the U.S. reversed

direction and began flowing in a giant loop back from Pennsylvania to New York and then to Ontario into Michigan. The resulting energy surge caused the disconnection of numerous transmission lines and tripped generators. Ten seconds after the massive power reversal, a main transmission system in New York State split along an east-west line. Within the next 20 seconds, at 16:11 EDT, Ontario separated from New York west of Niagara Falls and west of St. Lawrence. By 16:13 EDT, the cascading sequence was complete.

The Interim Report of the Task Force examining the specific causes of the blackout was released in November 2003 and was followed by the Final Report in April 2004. The Interim Report summarized the facts that the bi-national investigation found regarding the causes of the blackout. It assessed the conditions of the electric transmission grid, outlining the physical causes of the outage and discussed events and conditions that enabled the blackout to spread. The Interim Report cited three main causes: "inadequate situational awareness" at FirstEnergy Corporation (in Ohio), FirstEnergy's failure to trim trees around power lines, and a failure of the grid's reliability coordinators to identify and deal with the problems before they were out of control.

After November 19, the Task Force's expert Working Groups continued their analysis, focusing on drafting recommendations for the consideration of the Task Force. The recommendations, which addressed the prevention of future blackouts and the reduction of the impact of any blackout that occurs, were released in the Task Force's Final Report. The Task Force made a list of 46 recommendations. The most important recommendation was to make reliability standards mandatory and enforceable, with penalties. While this report added some new information on the origin and the cascade stage of the blackout, the updated analysis did not change "the validity of the conclusions published in the Interim Report."²⁰

The Canada–U.S. Task Force Final Report on the blackout is available in its entirety at http://www.nrcan-rncan.gc.ca/media/docs/final/finalrep_e.htm .

In the period since the release of the report, government agencies, NERC and the electricity industry have pursued a wide array of initiatives to reduce the risk of future blackouts.²¹

IMPACT TIMELINE

The following timeline indicates the impact of the power outage on various CI sectors and the general public.

Thursday, August 14 (EDT)

- 13:06 Power lines near Cleveland, Ohio, and across other northeastern states reportedly shut down over the course of three hours, forcing other grids already working near capacity to search for power elsewhere. The ensuing disparity between the available supply and the requested demand on the grid precipitates even greater power surges in connected grids in Canada and eastern U.S.²²
- 16:11 Minutes before the grid fails, it experiences a dramatic loss of voltage, which in turn, triggers automatic switches to shut off major consumers. Overloaded

- transmission systems start to shut down and within nine seconds, a cascading power failure causes the eastern power grid to collapse. As a result, 100 power plants²³ and 22 nuclear power plants are shut down.²⁴
- 16:15 The flow of electricity across Ontario and the Eastern Seaboard comes to a halt. The blackout affects 24,086 square kilometres and 50 million people in the province of Ontario (10 million) and the states of New York, New Jersey, Vermont, Michigan, Ohio, Pennsylvania, Connecticut and Massachusetts.²⁵
- 16:45 U.S. Department of Homeland Security officials assure the public that their initial assessments of the situation indicate that the power outage is not the result of a terrorist act. U.S. power regulators say that a New York plant outage had a cascading effect on the Niagara Mohawk power grid; a New York state official says the grid is overloaded.²⁶
- 16:54 The New York City mayor's office and the U.S. Federal Energy Regulatory Commission (FERC) reiterate that the blackout was not caused by a terrorist attack.
- 17:30 New York Governor George Pataki declares a state of emergency.
- 18:15 The Prime Minister's Office initially attributes the power outage to a suspected lightning strike at a power plant on the U.S. side of the Niagara region,²⁷ while U.S. officials look at a power transmission problem from Canada.²⁸
- 19:13 All Air Canada flights to and from Toronto and Ottawa are cancelled for the day. Flights to and from all destinations in the northeastern U.S. are also cancelled.²⁹
- 19:15 The Prime Minister's Office points to a fire at a Con Edison power plant in Niagara Falls, New York, as a possible cause.³⁰
- 20:00 Toronto Mayor Mel Lastman announces that power will resume again at midnight, and that it will be restored to most areas of the city by morning.
- Independent Electricity Market Operator (IMO) issues a statement that it could be a couple of days before power is restored in Ontario. Residents are told to expect rolling blackouts after power is restored to prevent the overloading of power generators.³¹
- 20:30 U.S. President George Bush holds a news conference and offers to aid U.S. cities affected by the blackout.³²
- 22:30 Power resumes in some areas of Ontario.
- 23:00 Ontario Premier Ernie Eves declares a state of emergency and directs only essential Province of Ontario employees to report to work.

Friday, August 15

- 08:00 Half of Ontario's power is restored, but rolling blackouts (controlled temporary loss of power to some geographic areas) remain a strong possibility.

16:00 Air Canada resumes partial operations.

President Bush calls the blackout a “wake up call” and says the power grid needs to be modernized.³³

All connected load is restored, although insufficient generation is available to meet demand. Rolling blackouts remain a possibility if consumers do not heed advice to conserve.

Saturday, August 16

03:00 Toronto Hydro announces that power is restored to 95 percent of the city; two areas of the city remain without power.

09:30 New York State power is fully restored; New York City subway returns to regular service.

12:00 Mayor Lastman calls on Premier Eves to spare Toronto from rolling blackouts, stating that Toronto is the “economic engine of Canada.” Mayor Lastman says he wants to ensure that subways, which carry an estimated one million people daily, are operating by Monday morning.³⁴

15:00 The U.S.-based NERC states that transmission lines in northern Ohio likely caused the blackout.³⁵

Sunday, August 17

- All Government of Canada departments continue to operate at reduced levels.³⁶

11:00 Premier Eves implores the province to curb its electricity use by 50 percent.³⁷ Premier Eves also states that Toronto has more than enough power to function properly.

17:00 NERC reports that most transmission lines are now operational. Transmission lines between Michigan and Ontario remain out of service for operational security reasons. While Ontario calls for power conservation, no public appeals are issued in the U.S.³⁸

18:00 Premier Eves reissues the call for Ontario business and industry to halve normal power consumption.

Ottawa Mayor Bob Chiarelli recommends that only essential municipal employees in Ottawa report to work on Monday, August 18.

Monday, August 18

06:00 Toronto subways and street cars return to full service.

- FirstEnergy Corporation, the Ohio-based utility company at the centre of controversy for its alleged role in the cause of the blackout, issues a news release stating that the company is analyzing the data from its system operations. The

company states that based on its own preliminary data, the transmission grid in the Eastern Interconnection, not just in its own system, was experiencing unusual electrical conditions prior to the event.³⁹ Four events were reported to have occurred on the FirstEnergy grid, including: unexplained voltage swings, which the company stated brought down a coal-fired generator; two power line outages, one of which was caused by a tree; and the failure of an automated warning system.⁴⁰

Wednesday, August 20

- FirstEnergy asks customers to reduce power consumption and warns that it could be forced to institute rolling blackouts beginning in Cleveland, Ohio, if customer load is not lowered voluntarily.⁴¹

Friday, August 22

- FirstEnergy announces that it will no longer ask customers to implement power conservation measures and that rolling blackouts will not be required.⁴²

20:00 Premier Eves announces an end to the state of emergency in Ontario.⁴³

Saturday, August 23

- The IMO returns the grid to regular market operations, signalling the viability of the grid.⁴⁴

AFFECTED SECTORS

ENERGY AND UTILITIES

Electricity

The August 14 power outage significantly impacted most of the sources and means of generating, transmitting and distributing power within the Eastern Interconnection. The impact of the incident on the electricity sector in Ontario was considerable and pervasive. Moreover, the interdependencies between the electricity sector and other CI sectors in Canada, compounded by the length of time required for restoration of regular power service, caused extensive problems throughout numerous CI sectors.

The following details how the outage impacted the electricity sector in Canada, as well as the efforts that were made to mitigate the impact and assist with power restoration.

Generation

There are many types of power generation facilities operating throughout North America with the most common types being fossil-fuelled (oil, natural gas and coal-fired), hydro-electric (run-of-river or pumped storage) and nuclear. At the time of the incident, Ontario's electrical generation system was comprised of 28,900 kilometres of transmission lines and 94 generating stations producing 30,548 megawatts. The generating stations included: four nuclear generator locations (10,836 megawatts); 59 hydroelectric stations (7,615 megawatts); five coal-fired generators (7,546 megawatts); 24 oil/natural gas stations (4,485 megawatts); and two miscellaneous—wind, biomass, geothermal and solar power

(66 megawatts).⁴⁵ Depending on demand, Ontario could import approximately 4,000 megawatts from Manitoba, Quebec, New York, Michigan and Minnesota.

The power outage impacted virtually all of Ontario's main sources of power to varying degrees, with Ontario's heavy reliance on nuclear power contributing to the delay in restoring full power to the province. Once shut down, nuclear plants take considerably longer than coal-fired plants and hydro-generating facilities to restart and return to full production. Ontario relies on nuclear power for nearly 50 percent of its total electricity supply.⁴⁶

When a major event such as a power failure occurs, a plant is brought back on-line by generating power in small increments. Load is added simultaneously in manageable increments.⁴⁷ By August 18, Ontario Power Generation (OPG) reported that its constituent members had approximately 85 percent of their power generation reconnected, including all of their hydroelectric capacity, most of their fossil-fuel generation and all four nuclear units at Darlington station.⁴⁸ A map of the power production system in Ontario is available at <http://www.opg.com/ops/map.asp>. Figure 3.0 lists Ontario's nuclear plants and their level of activity as of August 14, 2003.

Figure 3.0 – Ontario's nuclear electricity generation plants at the time of the blackout⁴⁹

Site	Reactors	Operator	Location	Status
Bruce-A	4	Bruce Power Inc.	Kincardine	Shut down / Refuelled (3+4)
Bruce-B	4	Bruce Power Inc.	Kincardine	Operational
Pickering-A	4	Ontario Power Generation	Ajax-Pickering	Shut down
Pickering-B	4	Ontario Power Generation	Ajax-Pickering	Operational
Darlington	4	Ontario Power Generation	Bowmanville	Operational

Fossil-fuelled

Fossil-fuelled generating plants in Ontario consist of coal-fired stations as well as those fuelled by other means such as oil and natural gas. All coal-fired plants in Ontario were shut down by the blackout. As of August 19, operating fossil-fuelled units were: six of eight at Nanticoke, all four each at Lambton and Lennox, and three of four at Lakeview.⁵⁰

Hydroelectric

Hydroelectric plants are considered to be the simplest and quickest type of generating facilities to restart following an outage. They require some measure of generated power to open valves; however, this task may also be accomplished manually. Typically, restarting these facilities takes a few hours. Subsequent plants restart sequentially following the first plant, and typically match its speed and voltage while continuing to add load in small increments until they return to full output.⁵¹

During restoration efforts, extraordinary measures were taken in the hydroelectric sector to bolster the quantity of electricity available to the electrical grid. The International Joint Commission (IJC) and its international St. Lawrence River Board of Control authorized the increase of outflows from Lake Ontario through to the St. Lawrence.⁵² The increased outflows permitted OPG and the New York Power Authority to operate their hydro facilities in Cornwall, Ontario, and Massena, New York, at full capacity, thereby adding power to the grid.⁵³

In addition, the U.S. State Department and the Department of Foreign Affairs and International Trade (DFAIT) reached an agreement permitting the Niagara River Diversion Treaty of 1950 to be temporarily and voluntarily suspended in order to maximize the diversion of water from the Niagara River and generate more power for emergency purposes.⁵⁴

Nuclear

At the time of the blackout, there were 11 CANDU (Canada Deuterium Uranium) nuclear power reactors operating at high power in Ontario—four at Bruce-B, four at Darlington and three at Pickering-B.

When the blackout occurred, all nuclear generating stations were automatically disconnected from the grid to avoid damage to the generating equipment.⁵⁵ All eight Bruce-B and Darlington reactors decreased power automatically upon the loss of the grid, and four (Bruce-B units 5, 7 and 8, and Darlington's unit 3) were successfully able to maintain standby mode. Two others were shut down due to system problems, and two were shut down manually because the required system reviews could not be completed and checked in time.⁵⁶ Standby mode is an operational state where the reactor is able to function at 60 percent capacity; otherwise, it has to be shut down. The four reactors that were able to maintain standby mode were supplying power to the electrical grid within a few hours of the event. Bruce Power reported that all of its standby systems worked as designed when the blackout occurred, with the exception of unit 6, which tripped and was shut down completely.

Pickering-B reactors were unable to maintain standby mode, and required more time than the Darlington or Bruce units to be brought back on-line due to substantial design differences and the need for equipment adjustments caused by the outage.⁵⁷ By August 18, the remaining three Darlington units were reconnected, and by August 23, two Pickering-B units were connected while the remaining two remained shut down.

Reconnection of the CANDU reactors, that were on-line at the time of the blackout, occurred at:

August 14 (19:13 to 21:13) - Bruce 5, 7 and 8,
August 14 (21:18) - Darlington 3
August 17 (20:36) - Darlington 2
August 18 (03:15) - Darlington 1
August 18 (11:12) - Darlington 4
August 22 - Pickering 5
August 23 (01:03) - Bruce 6
August 23 - Pickering 8
August 25 - Pickering 6

Also, Pickering 4 was reconnected to the grid on August 22, 2003, for the first time since being closed for upgrades and refurbishment on 2 April 1996.⁵⁸

The power outage had a significant and lengthy impact on the nuclear power generation sector, which, at the time of the blackout, accounted for nearly 50 percent of Ontario's power generation.⁵⁹ On average, it takes an estimated 36 hours to restart a nuclear

plant.⁶⁰ With 8 of 12 nuclear reactors requiring re-start after the power outage, including 7 of 8 OPG reactors⁶¹ and 1 of 4 Bruce Power reactors, their absence prolonged the crisis.

In New York State, the U.S. Nuclear Regulatory Commission reported on August 18 that 5 of the state's 6 nuclear power stations had resumed electricity output at 10 percent capacity or better.⁶² A total of 9 nuclear facilities were shut down in the U.S. during the blackout: Fitzpatrick, Ginna, Indian Point 2, Indian Point 3, Oyster Creek, Fermi 2 and Perry. Most units were reported back in service supplying power to the grid by August 18; those that remained shut down included Indian Point 3, Fermi 2 and Perry.⁶³

Generators

Ontario provincial energy officials attempted to restore some generation capacity through the use of emergency generators. Twenty-four hours after the blackout, the Government of Ontario made a request to the Government of Quebec for 30 generators with a capacity of 30–60 kilowatts per hour. Hydro-Quebec subsequently delivered 40 generators and sent six generator technicians to Ontario on August 15, 2003.⁶⁴

With the threat of rolling blackouts looming over the province, Ontario provincial officials also established reserve generator sites as power was being restored to the grid. Each reserve generator site (Toronto, Kingston and Orangeville⁶⁵) consisted of a variety of generators with a maximum capacity, which could have conceivably met the needs of a major hospital.⁶⁶

Transmission

With the exception of a fire beneath a transmission line in the U.S., an incident which was investigated as a potential contributor to the power failure, the blackout does not appear to have impacted the electricity transmission sector.

Distribution

During the outage, Hydro-Quebec supplied 1,000 megawatts of power to an estimated 3.4 million homes throughout the U.S. and Ontario.⁶⁷

Hydro Ottawa restored power to 80 percent of its customers by 16:00 EDT on August 15, but warned that some customers may have their power interrupted for approximately one hour every five hours. Municipal officials in Ottawa opted for a rolling blackout schedule, meaning that one hour of power would be followed by three hours without power to assist with restoration efforts during the weekend of August 16–17.⁶⁸

On August 16 at 23:00 EDT, Hydro One Networks reported that electricity had been restored across the province, but that rolling blackouts could not be ruled out because of inadequate generation.

Interdependencies

From August 14–16, 2003, electricity generation, transmission and distribution were the most tangibly affected sectors of the blackout.

The blackout demonstrated the central role that the electrical sector plays in any modernized, post-industrial society that relies on critical

infrastructure elements and networks to underpin its social, cultural and economic fabric.

When residents and consumers lost power on August 14, 2003, at 16:11 EDT, their ability to access banking and financial information in real time became compromised. Residents no longer had access to media devices (including television, radio and Internet). Telecommunications companies experienced difficulty receiving the requisite amount of fuel to power its backup generators, which had been brought in to provide electricity to the local area network cellular facilities. Without the emergency power, the coverage area of subscribers would have been severely compromised. Hospitals and emergency services struggled to maintain full operational capacity. Power to oil pipelines was cut, reducing the flow to refineries and limiting the amount of available refined oil available for purchase at the limited number gas station pumps that were still operating. Commuters discovered that traffic lights, railroad crossings and bridge toll booths were no longer functional. Similarly, commuters travelling by train or aircraft were confronted with significant delays or, in many cases, cancelled transportation.

Conservation

With the sudden loss of power on August 14, and the fragility of the electrical grid foretelling the possibility of rolling blackouts, Premier Eves made numerous requests to private citizens, industry and the government to curb energy consumption. The news media consistently reported that the grid system could experience another widespread blackout, rolling blackouts or brownouts if consumer demand exceeded generation capacity.

The pleas for reduced consumption were largely successful. Major industrial and commercial users were credited with having made significant contributions to the power conservation efforts.⁶⁹ Data from the Independent Market Operator (IMO), which oversees Ontario's electricity market, indicated that during the recovery, power consumption in Ontario was 4,000 to 4,500 megawatts lower than usual.⁷⁰ According to estimates from Toronto Hydro Corporation and the Association of Major Power Consumers in Ontario (AMPCO), reductions in power usage by major commercial buildings in Toronto, combined with a 50-percent decrease in consumption by the 60 giant industrial members of AMPCO, accounted for savings of 2,900 megawatts alone.⁷¹ AMPCO stated that its members, including Ford, Inco, Dofasco, and Abitibi Consolidated, normally account for 15 percent of the power consumption in the province. Companies widely agreed that adhering to Premier Eves' request to reduce power consumption by 50 percent was essential to the recovery of Ontario's electricity system and thereby cut usage by 2,000 megawatts.⁷²

Crude Oil

An adequate supply of crude oil is highly dependent on a sufficient and reliable supply of electricity. All facilities requiring the delivery of crude oil for the mission-critical aspects of their operations, including refineries and service station pumps, require electric power to operate. Moreover, the supply of crude oil to plants and facilities is also contingent on the reliability of the existing road, rail and marine transportation infrastructure, which are also exceedingly dependent on electricity. In addition, oil pipelines, the most efficient and cost-

effective means of transporting massive quantities of crude oil, are inherently dependent on electricity to move the product to its intended destination.

The outage impacted several aspects of the crude oil sector, including the shut down of refineries, the depletion of storage facilities for generator usage, the disruption of transmission crude oil pipeline operations and the distribution of refined products to consumers.

Refining

The power outage forced seven oil refineries in North America to temporarily shut down their operations, reducing refining capacity by 800,000 barrels per day, which represents nearly five percent of industry's refining capacity.⁷³ In Ontario alone, six refineries producing an average of 545 thousand barrels of oil per day were temporarily shut down. Preliminary assessments on the recovery efforts concluded that the restoration of Canadian refining capacity was slow by industry standards. According to energy experts, oil refineries can be restarted in as few as two days if there is no damage to facilities;⁷⁴ however, by August 21, only three of six refineries in Ontario were operational, accounting for 60 percent of regular production.⁷⁵

Storage

Refined oil storage facilities provided a buffer between demand for refined petroleum products, including the necessity for generator fuel, and the reduced supply that occurred after the outage forced some refineries to shut down. Bulk supply terminals in Ontario were sufficient to contend with consumer demand up to and including August 24. Industry representatives reported that oil supplies would have been limited, but manageable, had refineries not come back on-line by the week of August 25. Once refineries became operational, storage facilities in Ontario were able to resume regular shipping and holding schedules at their bulk terminals.⁷⁶

Transmission

Oil pipelines are highly reliant on electric power to operate. Consequently, the blackout impacted several of Ontario's oil pipelines, forcing them to shut down or limit through-flows. Enbridge Incorporated reported that its crude oil pipelines resumed operations on August 18, and that refineries at the receiving end of the pipelines enabled them to begin returning their operations to full capacity.⁷⁷ Enbridge noted, however, that full flow rates may have been unavailable on certain lines due to the power limitations imposed by a limited supply in the electrical grid and the request made by the province to reduce consumption rates.⁷⁸ On August 21, with the grid restored to full capacity, Enbridge pipelines were able to resume regular operations.

Distribution

The distribution of oil and petroleum is heavily reliant on an adequate supply of electricity for all points of shipment. The pipeline, land and sea transportation network, refineries, and holding stations have proved to be inherently dependent on each other in order to provide just-in-time service. They were also dependent on electricity to stimulate the supply and demand schedule. As such, within the oil and gas sector, it was the distribution of oil and petroleum that was most affected by the mass outage of electrical power. Industry officials stated that the diminished supply caused by the blackout and the unrelated breach of an Arizona pipeline contributed to severe spikes in the cost of fuel for the average consumer.⁷⁹ Canadian gasoline prices jumped between 10 and 15 cents per litre.⁸⁰ Industry analysts stated that the problem was compounded by a low inventory

caused by last year's long and cold winter.⁸¹ Officials from the Canadian Petroleum Products Institute (CPPI) stated that refineries were unable to replenish their inventories last spring due to heating oil demands from consumers, meaning that when supply is lowered and demand remains the same, the price inevitably increases.⁸²

The CPPI reported that petroleum companies across Ontario were working closely with one another and Emergency Management Ontario (EMO) to constantly assess the supply of fuel.⁸³ Shell and Esso coordinated the delivery of fuel to emergency response organizations, such as hospitals, to ensure that the necessary fuel supplies were being distributed.⁸⁴ On August 21, officials decreed that some service stations would be closed temporarily in order to more efficiently distribute the limited supply of commercial fuel.⁸⁵

Interdependencies

The diminished capacity to produce and deliver oil and gas supplies to the province impacted a number of related and dependent CI sectors. The most glaring example was the availability of fuel for emergency service backup generators across the province. A priority list was established to ensure that adequate supplies of fuel were distributed to appointed industries and sectors. Hospitals and emergency services, telecommunications providers and transportation hubs such as airports and public transportation services in large urban centres were, by necessity, included as priority points for fuel supplies; however, in a shortage situation, this meant that many other sectors received either reduced supplies or none at all. Some remote communities, including First Nations reserves, which in some cases rely on the airborne delivery of community fuel supplies, experienced shortages. Manufacturing industries, which in many cases are heavily reliant on oil for heating, drying and other thermal operations, experienced shortfalls in their ability to operate. Combined with the provincial Premier's request to limit commercial activity, this contributed to many companies ceasing their regular operations.

Natural Gas

Most natural gas consumed in Canada is produced by oil and gas companies located in Alberta. A large network of wells gathers natural gas, and once natural gas is moved to production areas, it is processed to remove water vapour and other impurities before it is delivered to customers. Processed natural gas is transported via pipelines to various consuming regions in Canada. The natural gas is delivered to industrial, residential and commercial customers by a range of natural gas utilities in consuming regions. Since consumers cannot store natural gas, it must be delivered as it is required.

The Canadian Association of Petroleum Producers (CAPP), which represents the production sector of the natural gas industry in its associations with regulators, pipelines or provincial and federal government, reported that the natural gas system in Canada was not affected by the outage. The demand for natural gas was reduced during the outage and most went into storage, which is standard procedure during periods of reduced demand.⁸⁶

Storage

Throughout the year the TransCanada pipeline operates at 100 percent capacity. During the summer months, the extra supply of natural gas is pumped into storage. During the

winter months, when demand increases, the natural gas in storage is utilized to supplement the natural gas supply from the pipeline. In November 1998, the stored volume of natural gas was 498 billion cubic feet, while the average demand for natural gas in November 1997 to March 1998 was an estimated nine billion cubic feet per day.⁸⁷ Despite the fact that estimates indicate there may be sufficient supply for approximately 55 days, on average, natural gas cannot be withdrawn quickly enough to meet the average daily demand in the winter months.⁸⁸

Transmission

The outage did not affect the 14,900-kilometre TransCanada pipeline system, with respect to its operations or its ability to deliver gas to consumers and customers.⁸⁹

Distribution

With a reduced demand for natural gas, adjustments had to be made to regular operations. The excess product was diverted to storage at EnCana's AECO-C Hub in Alberta and Duke Energy Union–Dawn Hub in southern Ontario.

Interdependencies

The maintenance of supply and the transportation of natural gas to customers are reliant on the functionality of operation centres, the electrical supply and telecommunications. A small number of natural gas compressors, mostly in production areas, rely on electricity, while most compressors operate on natural gas. In the event of a power failure, most natural gas pipeline operation centres and their telecommunications systems have backup systems in place.

A high percentage of the Canadian population and industry are dependent on natural gas as a main energy source. During the winter months, a disruption to the natural gas supply would seriously impact residents who are reliant on natural gas as their sole heat source. Alternative accommodation would need to be located for the affected population. Most schools, businesses, offices, public buildings and industries are also dependent on natural gas and would likely have to be closed if there was a disruption to service. In addition, the petro-chemical industry uses natural gas for feedstock. Moreover, a number of electrical generators and co-generators are fuelled by natural gas, which may not be able to convert to other forms of energy.⁹⁰

COMMUNICATIONS

Telecommunications

Landlines

In order to maintain the survivability of the networks, network management measures were invoked during the power outage.⁹¹ Telecommunications companies across Ontario activated their Emergency Operations Centres to ensure the continuous operations of their respective networks.⁹²

While telephone networks reported few operational difficulties, the need for generator fuel to maintain telecommunication switches, including the 911 system, continued to be an area of concern. Priority for fuel was requested to maintain operations.⁹³ Fuel deliveries were subsequently made to many sites across the province in order to sustain vital telecommunications links.⁹⁴ During the outage, people were asked to refrain from using their landline and wireless telephones except in emergency situations.⁹⁵

Although some switches were lost due to the fuel shortage, all landline services functioned properly because many switches operated on battery power and backup generators.⁹⁶

Telecommunications carriers sought information from utilities about when rotating outages would occur; however, this information was not always available, thereby making it difficult for telecommunications carriers to determine their priorities and to dispatch personnel.⁹⁷

Wireless

Several North American cellular phone companies reported experiencing clogged networks during the power failure. Most wireless services were overloaded due to high volume usage. Since cellular sites were being fed only by batteries, they required recharging from mobile generators.⁹⁸ Some cellular companies had increased their capabilities to recharge cellular sites using mobile generators from outside Ontario. By August 17, all cellular phone services were operating normally.

The U.S. Department of Transportation also reported that pagers were not functioning at all times.⁹⁹ Of particular concern during the outage was the failure of a paging system, which resulted in St. John's Ambulance emergency pagers ceasing to function.¹⁰⁰

Interdependencies

While most telephone and telecommunications firms had effective business continuity plans in place, the immediate need for fuel to power backup generators at local area network sites remained. This major reliance on emergency fuel supplies was likely revisited by many companies as they conducted post-blackout analyses.

With capacity limited due to an increased volume in traffic and an overall degradation of service, the prioritization of calls became paramount. In the immediate aftermath of the September 11, 2001 terrorist attacks, many officials began lobbying for a priority access to telephone lines for emergency responders. The blackout may lead to a renewal of such requests. The blackout reaffirmed this need. On November 23, 2004, the Government of Canada announced the introduction of wireless priority service (WPS) for emergency situations. WPS provides selected wireless telephone users, such as public safety officials and first responders, priority access to the network, even if it is heavily congested.¹⁰¹

Media

During the blackout, both the print and electronic media struggled to release information to the public, and in most cases, employed backup generators to power their production

processes. Some media outlets were forced to relocate their operations to different sites.¹⁰²

Print

The Toronto Star was able to publish a 16-page newspaper on August 15, while the Ottawa Citizen, using newly acquired backup generators, produced a newspaper that included extensive blackout coverage.¹⁰³

The Associated Press lost power at its New York City headquarters, thus shifting operations to Washington and Dallas.¹⁰⁴

The prevalence of backup systems among most of the major print media meant that residents in the affected areas had access to relatively timely information, despite the fact that television, radio and Internet service was limited at best.

Television

Major U.S. broadcast news stations such as ABC, CBS and NBC continued to report during the outage; however, due to the loss of electricity to viewers in affected areas, many viewers were unable to watch the broadcasts.¹⁰⁵

Many Canadian stations continued to broadcast during the outage, including the CBC and CTV 24-hour television news stations.

In Ottawa, CJOH was scheduled to broadcast live from the opening of the Central Canada Exhibition at 18:00 EDT on August 14, but instead provided updates on the situation in Ottawa to a national broadcast in Toronto for the first 15 minutes of the telecast.¹⁰⁶ CJOH produced the remainder of its program from the Exhibition, unsure of how many viewers could tune in, although the station did have an audience in western Quebec and some parts of eastern Ontario.¹⁰⁷ CJOH also aired its regularly scheduled 23:30 EDT newscast on August 14. Since the Ice Storm of 1998, the news organization has had a system in place to maintain newsroom operations with emergency power.¹⁰⁸

The NewRO in Ottawa provided updates throughout the evening and produced its 23:00 EDT newscast out of its Byward Market station. The station also had a standby crew at its master control located in Pembroke.¹⁰⁹ CBOT, Ottawa's CBC affiliate, provided Ottawa-area updates to a national broadcast covering the outage.¹¹⁰

Radio

For most residents throughout the province, the only source of news on August 14 and during the morning of August 15 came from battery-operated radios. CHUM Radio Ottawa, consisting of three FM stations and one AM station, consolidated all of its programming after the blackout hit, delivering the same broadcast from all four frequencies.¹¹¹ During the Ice Storm of 1998, one of the CHUM-operated stations, CFRA, provided around-the-clock coverage. As a direct result of that event, CHUM Radio Ottawa ensured that the station had an emergency plan in place.¹¹²

Information Technology

Network Infrastructure

Most Ontario enterprises appeared to be following contingency plans during the outage to ensure availability of critical applications and services;¹¹³ however, according to some IT

service providers, many Ontario-based enterprises were able to conduct business as usual, while other organizations were exposed as being ill-prepared to deal with major disruptions to their operations.¹¹⁴ Q9 Networks¹¹⁵, a Toronto-based hosting service provider, reported that its connectivity to major service providers across Canada ensured that many companies outside affected areas still had uninterrupted access.¹¹⁶ Q9 Networks utilized the company's two diesel generators in downtown Toronto and had 50,000 litres of diesel fuel stockpiled nearby to maintain customer websites during the blackout.¹¹⁷

Toronto-based CBL Data Recovery Labs reported that while many businesses were crippled during the Ice Storm of 1998 due to server failures and major data loss, the situation was different for many businesses during the power outage. CBL cited an apparently increased awareness in the corporate world of the importance of business continuity planning for this change.¹¹⁸ CBL further stated that while there was a 50-percent increase in the volume of calls it received, the calls were mostly from home computer users concerned about the potential for data loss.¹¹⁹

Info-Tech Research Group, a technology research firm based in London, Ontario, stated that a recent survey of U.S. companies revealed that although 76 percent of firms surveyed said the outage had an impact on their organization, most organizations admitted that they were not prepared.¹²⁰ Sixty-three percent of those surveyed said they were either planning to create a new disaster recovery plan or update an existing plan.¹²¹ Twenty percent of companies said they were planning to purchase a backup generator, while another 18 percent said they would review their agreements with their service providers; a further 13 percent reported that the blackout had cost their organizations more than US\$5 million dollars.¹²²

Problems Associated with Blaster/SoBig Viruses

On August 11, 2003, the Blaster worm, which exploited the Microsoft Windows Distributed Component Object Model (DCOM) RPC vulnerability, began spreading rapidly across the Internet. During the ensuing weeks, several variants to the original Blaster worm were released. On August 18, 2003, a new variant of the Blaster worm, dubbed W32/Nachi or W32.Welchia, which was supposed to be a "White Hat" variant¹²³, was released. This latest variant attempted to repair an infected computer by downloading and applying the Microsoft patch found in the [Security Bulletin](#). The patched computer was subsequently instructed to seek out other similarly infected computers by pinging a specific range of IP addresses. The extremely large number of W32/Nachi worm-infected computers attempting to locate other infected computers on their networks or across the Internet caused a denial-of-service (DoS) that crippled many networks. In some cases, networks had to be shut down in an attempt to contain the Internet Control Message Protocol (ICMP) flood. Complicating an already dangerous cyber environment, on August 18, 2003, the latest variant of the W32/Sobig virus, W32/Sobig.f, was released.

Two highly publicized incidents highlighted the interconnection between the mission-critical systems of major corporations and their IT infrastructure.

In the first instance, the Blaster worm and its "White Hat" variant were believed to be responsible for the failure of Air Canada's check-in system on August 19, 2003.¹²⁴ The failures stranded thousands of passengers at major airports across North America as the

company's communications network slowed down, forcing staff to check in passengers manually.¹²⁵

In the second incident, CSX Corporation, a multimodal freight transportation company serving customers worldwide, experienced a shutdown of operations that halted train operations in 23 U.S. states and two Canadian provinces for the better part of a day due to a variant of the Blaster worm.¹²⁶

The propagation of the Blaster (and its variants) and Sobig.f worms occurred almost concurrently with the major power outage in Ontario and northeastern U.S. This complicated the patching procedures that had been, or were being, implemented.

Officials were concerned that if all systems and workstations were simultaneously powered up and re-booted once the electrical grid was restored, one infected computer could carry the possibility of infecting all of the terminals within a particular network. While many corporate environments may have properly updated anti-virus software to counteract the worm, the Blaster code searched for unpatched machines to infect by sending an ICMP echo request, known as a "ping." In many networked settings, the traffic generated by these "pings" created an effective DoS attack.

Interdependencies

The simultaneous occurrence of the power outage and two significant cyber threats is notable because it reinforced the need for network security administrators to be vigilant regarding environment scanning in order to understand the current risk environment. The return to work of a large portion of Ontario's workforce represented a challenge for system administrators still trying to cope with the Blaster and SoBig worms, as well as their variants. Numerous corporate and government networks that were unpatched, or partially patched, were significantly impacted.

SERVICES

Banking and Financial Services

Banks

When the power failure occurred on August 14, one of the industries most immediately affected was the banking and financial services sector. Heavily reliant on computer networks, telecommunications and wireless technology, the industry as a whole experienced an immediate degradation of services following the collapse of the electrical grid. Branches and service centres with emergency backup generators were able to maintain some services at a nominal level; however, while the short-term impact was significant, the medium and long-range impact on the industry as a whole was negligible. For instance, while most branches were forced to close early on August 14, causing inconvenience to customers, there were no serious disruptions. Day-end settlement transactions were completed as usual and databank operations were maintained by backup systems. There were no reports of lost or forfeited transactions.

As Ontario struggled to return to normal generating capacity, the banking industry in the province returned to work with only sporadic interruptions. Many banks and financial institutions relied on backup systems run by diesel operated generators, which allowed most branches to regain partial to full functionality. Branches located in remote areas of the province had some difficulty acquiring sufficient fuel supplies to power their generators. Nevertheless, the Canadian Bankers Association reported that its constituent members indicated that most of its firm's branches were, indeed, equipped with backup generating capacity. In addition, all firms maintained the integrity of their customers' financial information on secure backup servers.

The Bank of Canada, which is also responsible for stabilizing markets and providing monetary liquidity during crises, continued its daily monitoring of the financial markets and settlement systems that banks use in order to make payments between them and their customers. The Bank of Canada closed its Ottawa headquarters on August 15 and moved employees to an emergency backup facility in order to maintain its monitoring of Canada's money and bond markets.

The Bank of Montreal (BMO) stated that the company was well-prepared for the power outage.¹²⁷ A spokesperson for BMO's information security department stated that the financial institution has backup power systems in place, which automatically start up when the power supply is cut. Moreover, BMO assured customers that personal data was not compromised as a result of the outage.¹²⁸ BMO officials also stated that the bank was able to follow contingency plans because of regular testing and updating of disaster recovery methods.¹²⁹ Aside from a minor scaling back of over-the-counter services, service at BMO branches and headquarters was largely unaffected by the power outage. On August 19, BMO announced that it had restored normal customer services in its Ontario branches and automated teller machine (ATM) network.¹³⁰

Royal Bank of Canada officials stated that the Toronto data centre and a backup centre at an undisclosed location were drawing only 10 percent of their power from the electrical grid.¹³¹ The remaining power came from backup diesel generators.¹³² According to bank officials, the bank did not experience any backup and data recovery issues.¹³³ The bank had disaster recovery strategies in place and continued to use diesel power until officials believed there would be no more blackouts. Officials from the Royal Bank stated that 80 percent of their 1,500 ATMs across Ontario were working by early afternoon on August 15, but only about 40–50 percent of Royal Bank's 460 Ontario branches were open.¹³⁴ Royal Bank and other major banks reported that automated transactions such as pay deposits and bill payments were completed despite the fact that the fifteenth day of the month is extremely busy for banks.

Major banks stated that their ATMs were working where backup power generation was available;¹³⁵ however, freestanding ATMs generally were not operational during the outage.

An official from the Interac Direct Network, which has 40,000 machines in banks and stores, stated that the Interac network was operational in some areas where machines had backup generators.¹³⁶

According to a Deloitte & Touche Global Financial Services Information and Security and Privacy Services official, the blackout tested the industry's willingness to be forthcoming

about the impact an incident such as a mass power outage might have on its operations.¹³⁷

Markets

The blackout had little impact on the trading markets on August 14 because the power failure occurred approximately 15 minutes after trading closed. The impact on the Toronto Stock Exchange (TSX) was further mitigated by the presence of backup generators, which were employed during the electrical grid restoration efforts.¹³⁸

The Toronto, New York and NASDAQ stock exchanges opened on schedule and were operational on August 15. Trading activity, however, was diminished as a result of persistent blackout conditions outside the trading facilities. The TSX closed at 7390.55, down 3.21 points on a volume of 34.9 million shares.¹³⁹

The New York Mercantile Exchange (NYMEX), which is the world's largest physical commodity futures exchange and trading forum for energy and precious metals, suspended its operations until August 18 and subsequently opened its markets on schedule.¹⁴⁰ A news release from NYMEX stated that the outage prevented many participants from accessing the NYMEX electronic trading and clearing systems.¹⁴¹ The electronic trading platform was operating normally after a few hours of being down.

The electricity trading market administered by the Independent Electricity Market Operator (IMO) was suspended until August 23.

Interdependencies

The banking and financial sectors rely on the stability and the dependability of the infrastructure which underlie it in order to operate effectively—namely, oil and gas, electricity, and telecommunications. The stability of the CI sectors enables investors to operate with a degree of confidence, which helps buoy the market economy. The power outage displayed the interconnectedness of these three distinct CI sectors. When the power in the Eastern Interconnection failed, and communication networks struggled to maintain full service, the regular operability of the banking and financial sectors was significantly impacted. When backup generators were used to maintain even minimal services, emergency fuel supplies were required in order to maintain operations.

Managing the linked vulnerabilities in the banking, telecommunications and electricity sectors is especially important when dealing with future emergencies.

Food Distribution

While no major disruptions to the food distribution system were reported, the storage and distribution of produce, dairy and meat products for some manufacturers and food retailers became problematic.

Working alongside the Ontario Ministry of Environment, the Canadian Food Inspection Agency (CFIA) extended hours of operation for storage and treatment plants to ensure the collection and disposal of spoiled food.¹⁴² An estimated 500 CFIA officers were dispatched

to monitor food safety, assist with the proper disposal of spoiled food and check animal welfare at the province's several thousand slaughterhouses, meat-packing plants, and food processing and storage facilities.¹⁴³ CFIA inspectors also ensured that any suspect products at abattoirs were placed under detention.¹⁴⁴ During the outage, the CFIA also released a food safety notice to provide the public with information about what types of food products should be discarded.

Virtually all milk-processing plants in Ontario were impacted by the power failure and, according to provincial manufacturers and processors, the impact would have escalated to a serious level had the power failure continued.¹⁴⁵ With six of the country's largest processing plants located in Ontario, the plants had to contend with a backlog of unprocessed milk. One million of the six million litres of milk processed daily in Ontario was rerouted to Quebec processors.¹⁴⁶ Several hundred thousand litres of unprocessed milk was sent to Manitoba processors.¹⁴⁷ Farmers had the capacity to store milk for at least two days using generators, but with limited storage and a backlog of unprocessed milk already evident at Ontario processing plants, farmers may have been forced to dump large quantities of milk if alternative sites had been unable to process the milk.¹⁴⁸

Major grocery stores throughout the province, such as Loblaws, were forced to throw out millions of dollars worth of food after it began thawing in refrigerators and freezers.¹⁴⁹ According to Loblaws officials, any product requiring refrigeration that went without it for more than 30 minutes was destroyed.¹⁵⁰ On Friday, August 15, the grocery retailer was also forced to close 100 of 300 Loblaws stores in Ontario; however, all were re-opened by August 16.¹⁵¹

Many restaurant owners and stores selling food products that required refrigeration gave away free food and then closed. Other businesses with access to generators or refrigerated trucks were able to remain open. In addition, shipments of fresh produce from the U.S. were delayed at the border due to tunnel and bridge closures and the resulting severe traffic congestion at border crossings.¹⁵²

Interdependencies

Production operations have become increasingly reliant on just-in-time delivery of supply, making production schedules extremely vulnerable to any interruption of supply delivery. Time-sensitive products such as food products are particularly vulnerable to any delays caused by clogged or delayed transportation networks. Shipments of food to storage facilities was hampered on August 14 by general delays caused by the failure of traffic lights and the closure of bridges, while maritime and airborne shipments were delayed at the points of import and export. Additionally, operators of cold storage facilities were forced to use backup generators to keep stocks from spoiling. Large quantities of food frequently had to be discarded due to a lack of space at facilities to accommodate new shipments.

Water Supplies

Water Treatment Facilities

A dependable supply of electricity and chemicals is required to maintain the flow of safe drinking water. The system is also reliant on the rail and trucking industries to maintain its supply of water to markets and users. Drinking water or tap water requires treatment in

order to reduce harmful micro-organisms and remove chemical contaminants that can cause serious illness. As such, all water treatment facilities normally maintain a two to four week supply of chemicals.¹⁵³ Following the water purification process, water is then pumped to reservoirs at treatment plants or directly into the municipal drinking water distribution system. Electricity is necessary to power the pumps that pressurize water systems. Insufficient water pressure in the distribution systems could lead to a variety of community problems. For instance, fire services would be compromised without water pressure for fire hydrants, and residents would be unable to flush sewage.¹⁵⁴ If a pump fails, it can be taken out of service and replaced with another on standby because most municipal water treatment plants in Canada are designed with multiple pump systems.¹⁵⁵ In addition, the majority of municipal water treatment plants also have diesel generators to provide backup power in the event of a power failure.

During the outage, due to the prevalence of business resumption and continuity plans, water treatment facilities generally functioned normally and without incident; however, a spill was reported in a cooling tower at Royal Polymers Chemical Plant in Sarnia, ultimately leading to the release of vinyl chloride into a water treatment plant system and the St. Clair River.¹⁵⁶ Measurements of vinyl chloride levels at the water treatment facility's inlet indicated that levels were at the maximum safe limit, and within provincial allowances at the plant outlet. Royal Polymers reported that two sets of follow-up tests conducted downstream indicated that there was no impact on water distribution systems. Emergency Management Ontario (EMO) reported on August 21 that the Royal Polymers spill was considered resolved.

Water Supply and Distribution

The province's water supplies were reportedly sufficient to cope if the power outage continued. There was cause for concern, however, when Toronto's reservoir system dropped to about 40 percent capacity early on August 15, although by late afternoon the reservoirs were reported to be about 70 percent full.¹⁵⁷ Reduced pumping capacity and damage to the main water feeder also seriously impacted Brampton's water supply.¹⁵⁸

In Kingston, reservoirs and water towers were not operational due to a failed backup generator, forcing the mayor to issue a boil-water alert.¹⁵⁹ The Mayor of Kingston requested that a 300-kilowatt generator with appropriate staff support, as well as water transportation and storage, be provided to ensure the safety of the municipal water supply and sewage facilities.¹⁶⁰ Canadian Forces Base Kingston was responsible for handling this request.¹⁶¹

Waste Treatment Facilities

Sewage treatment is vital to the entire population. Centralized sewage treatment facilities treat an estimated 13.9 million cubic metres of municipal wastewater daily.¹⁶² This figure does not include the 5.3 million Canadians who use septic systems.¹⁶³ The entire municipal sewage treatment system is dependent on utilities including gas, water, electricity, telecommunications and chemical/equipment suppliers. If equipment failures occur at a sewage treatment facility and replacement equipment cannot be supplied, affected plants have to be bypassed. While large sewage treatment facilities depend on computerized control systems, they also possess a degree of manual control, such as bypass and overflow systems, to compensate for any system failures. Smaller sewage treatment facilities are typically manually operated and would likely not be as significantly impacted by a power outage. Any community that becomes incapable of sewage removal

and treatment would be immediately impacted. Within 24 hours, the problem would escalate and within one week, a crisis would develop.

While most sewage treatment facilities operate on backup generators in the event of a power failure, approximately 39 sewage treatment facilities in Ontario reported bypass difficulties.¹⁶⁴ Consequently, some sewage treatment facilities were forced to spill raw sewage into local water flows during the weekend of August 15 to 17. As a result of this breach, 33 boil-water warnings were issued on August 15 affecting Oxford County, Alexandria, Kip Creek Mine and Brampton. By the following day, boil-water warnings for affected communities had increased to 59. In Ottawa, sewage treatment facilities reported that they were forced to dump thousands of litres of partially treated sewage into the Ottawa River, near Green's Creek. As a precautionary measure, city officials closed both Ottawa River beaches. Mooney's Bay beach on the Rideau River remained open to the public. R.O. Pickard Environmental Centre in Ottawa operated on gas generators to provide electricity and to preserve its supply; however, the company reported that it was forced to dump half-treated effluent into the river.¹⁶⁵

In Wayne County, Michigan, the Wyandotte Sewage Treatment Plant released approximately 60.6 million litres of untreated effluent into the Trenton Channel due to the power failure.¹⁶⁶ The Trenton Channel leads into the Detroit River, south of the Windsor area. While Environment Canada officials expected the discharge to remain on the U.S. side, Environment Canada continued to monitor the situation with the Ontario Ministry of Environment for any trans-border impacts on Canada.¹⁶⁷ The Ontario Ministry of Environment confirmed that all sewage treatment plants resumed operations by August 19.¹⁶⁸

Health Services

Ontario hospitals coped during the power outage by activating emergency plans, cancelling non-emergency services, turning off air conditioners, restricting visitors and employing backup generating systems. All hospitals shifted into emergency response mode, calling in extra staff or asking employees to stay past their regular shifts.

EMO was initially concerned that some hospitals in the province did not have extensive backup fuel or arrangements in place to obtain more fuel. Of particular concern was Toronto's Hospital for Sick Children, which had 10 hours of fuel remaining as of 20:30 EDT on August 14. The hospital had to resort to using the public address system to communicate because computers and paging systems were not functioning. On August 15, the hospital cancelled appointments at more than 100 outpatient clinics, as well as elective surgeries; however, the emergency ward remained open and operated at full capacity because additional fuel was eventually secured.

Several hospitals throughout the province cancelled elective surgeries, outpatient clinic appointments and diagnostic testing on August 15, including North York General Hospital (Toronto), Brockville General Hospital, Queensway-Carleton Hospital (Ottawa) and The Ottawa Hospital. The Children's Hospital of Eastern Ontario (Ottawa) cancelled appointments for nearly 800 families, including 10 surgeries and several clinic services.¹⁶⁹ In Ottawa, area hospitals carried on with essential work only, cancelling 150 elective surgeries, shutting down clinics and rescheduling diagnostic tests for dozens of patients.¹⁷⁰ At the Ottawa Hospital, emergency response teams manned phones and coordinated staff. The hospital, which has more than 1,000 beds, had adequate backup power supply

from its diesel-powered generators to run emergency equipment and keep the hospital minimally lit.

At the London Health Services Centre, generators kept emergency equipment including ventilators, anesthesia machines in operating rooms and cardiac monitors at the hospital's trauma centre functioning.¹⁷¹ The centre cancelled elective surgeries, but maintained inpatient operations and surgeries. The centre also cared for “medically fragile” individuals reliant on electrically powered medical equipment at home such as respirators and oxygen therapy.

While numerous hospitals were forced to cancel surgeries and scale back health services, some hospitals in Toronto, including Toronto General Hospital, Toronto Western Hospital and Princess Margaret Hospital, continued providing clinic appointments, physician appointments, emergency and elective surgeries on August 15.¹⁷²

Canadian Blood Services reported that, as a result of the outage, blood donations on August 14 and 15 were down by approximately 3,000 units from what would normally be collected over those two days.¹⁷³ With half of the nation's blood supply usually coming from Ontario, the blood supply reached dangerously low levels during and after the blackout.¹⁷⁴ The existing blood supply stocks were safely stored and protected by backup generators.

The Canadian Red Cross (CRC) placed all of its Ontario branches and approximately 500 disaster response volunteers, as well as a Red Cross Emergency Operations Centre, on standby.¹⁷⁵ Because temperatures were above 30 °C during the outage, about 100 CRC disaster response volunteers operated reception/cooling centres in Toronto, Ottawa, Windsor and Woodstock by providing water, first aid and medical assistance to individuals relying on electricity for a medical reason, such as patients using oxygen pumps. The CRC remained in regular contact with the municipal governments of communities affected by the blackout in order to determine the level of assistance their disaster response teams would need to provide. The CRC also issued a *Safety Tips* news release during the outage.

Interdependencies

The power outage highlighted the importance of properly deployed and informed contingency plans for the health sector. A sufficient supply of backup generators allowed most hospitals to maintain, at a minimum, emergency services. For the most part, patient records and files were available to staff via hard copy when the online networks were unavailable.

MANUFACTURING

In a province-wide effort to scale back power consumption while the grid underwent restoration, commercial and industrial businesses chose to either shut down completely or reduce production.

The automotive sector, which is part of the largest industrial manufacturing group in Canada¹⁷⁶, was especially affected by the blackout. Ford Motor Company reported 23 of its 44 North American plants were shut down in Ontario, southeast Michigan and Ohio.

General Motors said more than a dozen of its plants were off-line. Daimler Chrysler said nine of its 13 North American plants were closed, while Honda's plant in Aliston, Ontario, was down.¹⁷⁷

The Canadian chemical manufacturing industry (e.g. petrochemical, pesticide, fertilizer, pharmaceutical and medicine, resin, synthetic rubber and artificial and synthetic fibre manufacturing)¹⁷⁸, was also affected by the blackout. Over thirty chemical, petrochemical and oil refining facilities near Sarnia, Ontario suffered some form of outage resulting in the flaring of products at most of the facilities. Massive clouds of black smoke were visible throughout the area.¹⁷⁹ DuPont reported that sodium and lithium production at Niagara Falls and operations in Buffalo, New York, where Corian solid surfaces and Tedlar PVF film are manufactured, were shut down on Thursday, August 14, but were back to full power by Thursday night. Its automotive finishes facility in Mount Clemens, Michigan, suffered a complete outage but started to receive power a day later.¹⁸⁰ DuPont's major nylon intermediate facility at Kingston, Ontario, was down for more than a week.¹⁸¹ Dow Chemical's Sarnia site was shut down on April 14 and restarted on April 18.¹⁸² Nova Chemicals reported that the power outage affected its complexes at Corunna, Moore Township, Sarnia, and St. Clair River, Ontario, as well as at Painesville, Ohio. On August 20, Nova had not started up any of the sites due to intermittent power supply and a mandate by the electricity authority for businesses to reduce power consumption by 50 percent.¹⁸³

TRANSPORTATION

Surface

Road and Highway

Tunnel closures, severe traffic congestion and delays at border crossings were among some of the surface transportation issues that occurred during the power failure. With an estimated 27,000 vehicles crossing the Detroit–Windsor tunnel daily, closure of the tunnel on August 15 resulted in heavy traffic at eastern border crossings. Once the Detroit–Windsor tunnel reopened, delays of up to three hours were reported for truck traffic entering Canada as processing problems occurred at customs. There were no delays reported for truck traffic entering the U.S.

Cross-border traffic was also affected by the closures of the Ambassador Bridge, Walpole Island Bridge and Whirlpool Bridge.

Many motorists filling up at gas stations across the province experienced lengthy line-ups, limits imposed on the amount of gas they could purchase and the task of simply locating a gas station that was operational. Gas stations in Gatineau, Quebec observed an influx of Ontario motorists as a result of the outage.¹⁸⁴ Transport truck drivers also experienced slight inconveniences due to a lack of power at numerous fuel stops.

Responding to an estimated 1,662 service calls, the Canadian Automobile Association (CAA) eventually could not provide service to customers.¹⁸⁵ The incidence of traffic accidents, particularly those involving pedestrians, increased in some affected areas because traffic lights and street lights failed to operate. In Toronto alone, 1,773 traffic lights and 158,890 street lights went out during the outage; 67 personal injury accidents, mostly pedestrians hit by vehicles, were reported, compared with 21 the previous week.¹⁸⁶

Rail

Rail service was slightly impacted during the outage with schedule delays, detours and the cancellation of some passenger trains; however, most passenger and freight rail services did continue to operate because signal and detection systems were functioning with normal capacity or on backup power. To compensate for the loss of power, trains used manual systems instead of the standard electronic train control systems.

VIA Rail did experience minor disruptions to its service because nine trains were cancelled on August 15 in order to provide crew with a mandatory rest period. In two instances, passengers were forced to disembark VIA trains bound for Toronto from Ottawa and board buses that would transport them for the remainder of their journeys.¹⁸⁷ VIA Rail also reported schedule delays of between two and five hours for some other services. Crews reportedly relied on cellular telephones to notify operators when it was safe to depart stations because many freight and passenger trains were behind schedule.

Generally, CP and CN Rail did not experience major disruptions to service; however, CP Rail did report that it experienced rolling blackouts on August 15.¹⁸⁸

Public

Public transportation was significantly impacted during the outage, particularly in large urban areas such as Toronto where transit service to an estimated 503,795 regular transit users was intermittently interrupted. Although the Toronto Transit Commission (TTC) continued its operation of 1,468 buses following the outage, service was temporarily halted the next day. It was also reported that in Toronto alone, 196 cars stalled and 692 subway cars were shut down. The TTC and Toronto's subway system, which are used by approximately 1.5 million people per day, resumed service on August 18.¹⁸⁹ In Ottawa, the city's public transit buses continued running during the outage, although many customers experienced schedule delays and detours due to the closure of parts of the bus-only Transitway.

Light rail service in Toronto and Ottawa was significantly affected with 33 GO trains and Ottawa's O-Train halted. The O-Train operations were interrupted because signals were not functioning.¹⁹⁰

Air

By grounding much of Ontario and northeastern U.S. air traffic to and from major destinations in Canada and the U.S., the blackout seriously impacted the air industry in North America. In total, 12 U.S. and Canadian airports were partially or completely closed—Toronto, New York, Detroit, Newark, Cleveland, Montreal, Ottawa, Islip, Syracuse, Buffalo, Rochester and Erie.¹⁹¹ The closures left tens of thousands of passengers stranded and a number of airlines in chaos.

When the blackout occurred, runway lights and air traffic control systems were automatically switched to diesel-powered emergency generators, thereby enabling incoming flights to land safely at affected airports. All outgoing flights from Pearson International Airport in Toronto and Macdonald-Cartier International Airport in Ottawa were suspended. By evening, some Ontario-bound flights were diverted by NAV CANADA to Winnipeg and Montreal's Dorval Airport, affecting an estimated 1,000 passengers. Airports in London, Windsor, Sault Ste. Marie, North Bay, Sudbury, Hamilton and Timmins

operated on backup power, but would not permit departures or arrivals.¹⁹² Air Canada cancelled all flights to and from Ottawa and Toronto and suspended all flights to northeastern U.S. cities affected by the outage. In addition, British Airways cancelled nine of its flights from North America.¹⁹³

NAV CANADA, which controls most of Ontario's air traffic, switched its radar screens to backup power during the power failure. The agency decided to clear the sky over Ontario because antennas for the controllers' headset radios had to be switched to less-reliable battery power.¹⁹⁴ The decision to suspend departures from blacked out airports also stemmed in large part from security concerns. Without electricity, metal detectors and baggage screening equipment would not function. There were also concerns that powerless airports would not be equipped to respond to a take-off emergency.¹⁹⁵

Nearly 500 people were forced to spend the night at Toronto's Pearson International Airport following the suspension of all departures.¹⁹⁶ Canada's customs officials had to resort to manually inspecting the documentation of all incoming passengers on trans-border and international flights. By 22:00 EDT on August 14, four aircraft with a total of 800 passengers were awaiting processing by customs officials.¹⁹⁷ Some airports also reported difficulties accessing the Canada Customs and Revenue Agency's electronic database, which is used to track passports.¹⁹⁸

While both Pearson International Airport in Toronto and Macdonald-Cartier International Airport in Ottawa had resumed operations by August 16, airlines struggled to return to normalcy and did not resume full operations until August 20.¹⁹⁹ Air Canada and Tango had lost all flight plans when their Strategic Operations Centre failed on the morning of August 15. The loss of the main operating centre resulted in lengthy line-ups and a massive backlog of customers requiring rebooking. Air Canada was able to resume international flights by August 16, but had to ground most domestic flights until it was fully operational on August 20.²⁰⁰ WestJet resumed its regularly scheduled flights by 14:00 EDT on August 15 arranging new flights for all its 5,000–6,000 customers.²⁰¹

Interdependencies

The suspension of air travel affected both daily business operations and the worldwide supply chain. Production operations have become increasingly reliant on just-in-time delivery of supply, making production schedules extremely vulnerable to any interruption of supply delivery. Most, if not all, electronic equipment and chip manufacturers rely heavily on air transportation to ship their products around the world. Additionally, airports were forced to accommodate for the security, maintenance and operational requirements of grounded aircraft at airports throughout North America that were arriving at, departing from or connecting from airports affected by the blackout.

Marine

Surface marine traffic was virtually unaffected by the power outage; however, on August 15, containers were refused at the Fairview cargo terminal in the Port of Halifax because the computer system, which is linked with the northeastern part of the U.S., systematically failed.

The St. Lawrence Seaway remained operational because its facilities functioned on backup generators, while the Welland Canal reported that it was operating normally at 18:00 EDT on August 14.

Entry points such as Walpole Island Bridge and Whirlpool Bridge were closed, while Blue Water Bridge in Sarnia reported lengthy bridge crossing delays.

The Fisheries and Oceans Canada Canadian Coast Guard continued to provide services during the outage that were considered essential to public safety, including: search and rescue, marine communications, traffic services, and the operation of regional centres and Coast Guard ships.

SAFETY

Emergency Services

Across the province, police departments, fire departments and ambulance services experienced a dramatic increase in the volume of calls placed to emergency services. Additionally, the number of police, fire and ambulance personnel responding to emergencies in cities and towns in Ontario increased sharply during the power failure.

Major cities such as Toronto logged over 10,000 calls, more than double the regular amount, to police dispatch during the outage.²⁰² Toronto Police Service subsequently made 38 blackout-related arrests for robberies and assaults, and responded to 114 looting cases as well as 208 break-and-enters, compared with just 34 the previous week. Ambulance services in Toronto were also required to respond to 67 personal injury accidents, mainly involving pedestrians struck by vehicles, compared with 21 accidents the week before. Toronto Fire Services responded to 1,484 calls and 110 elevator rescues.²⁰³

Ottawa also experienced an increase in calls placed to emergency services during the power failure. Ottawa Police Service responded to 23 looting cases at various video and electronic stores located in the South Keys and Orleans areas. Three cars were also discovered set ablaze in Ottawa's south end. The Ottawa Fire Service responded to 370 calls during the outage, including a house fire caused by overturned candles, which claimed the life of a 15-year-old boy.²⁰⁴ The fire department typically responds to an average of 100 emergency calls a night. In the city of Sudbury, 170 miners at Falconbridge mines were trapped in an underground lunchroom for approximately eight hours. A two-storey building in Windsor also reportedly burned down after candles had been knocked over, causing an estimated \$1 million in damage.

While ambulance dispatch centres throughout the province operated on emergency generator power, of particular concern was the failure of St. John's Ambulance emergency pagers, which did not function as a result of the failure of the paging system. St. John's Ambulance services were able to remain operational because contingency communications plans were in place using e-mail, fax, cellular and landline telephones.²⁰⁵

Environmental Safety

Some environmental safety concerns were reported to have been directly related to the power failure. One such incident occurred in Sarnia, when eight chemical plants

simultaneously released hydrocarbons into the atmosphere following the failure of the plants' venting systems.²⁰⁶ Residents were instructed to remain inside and keep their windows and doors closed until the situation was resolved. Residents were informed on August 15 that they could safely resume activities outside their homes.²⁰⁷ In addition, the city's 20 chemical plants were shut down due to the possibility of prolonged brownouts in the area.

The Canadian Chemical Producers Association (CCPA) indicated that its member companies had activated their contingency and business resumption plans during the outage and that systems were functioning adequately. The CCPA reported that there was no indication of any concern within the chemical industry of a significant danger posed by the lack of electricity to the safety and security of chemical plants.²⁰⁸

Nuclear Safety

With nuclear generators in Ontario now supplying nearly 50 percent of the province's power, Ontario's heavy reliance on nuclear power posed some serious complications during the power outage. Many nuclear reactors were forced to shut down completely, thereby prolonging the period of time before adequate generation would be available to meet Ontario's needs.

The primary role of the nuclear power generating station is to convert energy into electric power, which can then be delivered to customers. There are strict safety rules in place, including those for situations where the quantity of energy produced exceeds the demand, requiring the generator to quickly shut down.

When the power grid collapsed on August 14, all 12 active nuclear reactors in Ontario had nowhere to send their power. While operators managed the incident safely, only four reactors were able to remain in standby mode throughout the blackout. With eight of 12 reactors shut down, plants were unable to produce electricity on demand resulting in a lengthy restart process.

Bruce Power managed the incident by shutting down one of its reactors, reducing three reactors to 60 percent capacity and releasing surplus heat into Lake Huron. To prevent overheating, the Pickering facility shut down all of its reactors and Darlington shut down its number three and number four reactors.

Restoration of the province to full capacity was slowed because the eight nuclear reactors could not immediately restart and begin delivering electricity once the grid was restored. On August 19, five of the eight reactors shut down remained out of service and unable to contribute to the recovery of regular power supply in Ontario.²⁰⁹ Reactor equipment problems also reportedly slowed down the restoration of generation capacity.²¹⁰

The blackout demonstrated that there is a need to review the capability of nuclear generators to withstand a grid disruption and more rapidly return to service. Nuclear facilities that can better cope with the large amounts of excess energy resulting from a sudden loss of the grid may not need to shut down their reactors in the event of an incident. Robust operational measures that enable reactors to be placed in a standby condition during large scale outages will decrease the amount of time it takes for the facility to resume normal operations.

GOVERNMENT

Services

In an effort to conserve energy while the electrical grid was undergoing restoration, Premier Eves issued a directive on August 15 indicating that only essential and emergency employees were to report to work.²¹¹ This directive was also issued by the Secretariat of the Treasury Board on August 15 and reissued on August 17 indicating that only essential Government of Canada employees in Ontario were to report to work²¹². Ultimately an estimated 150,000 Government of Canada employees did not report to work for most of the work week of August 18–22, if not the entire week. In Ottawa, this directive translated into 50,000 municipal, provincial and federal government employees remaining at home; however, two-thirds of municipal government employees, including police, fire and ambulance, were considered essential and worked extensive overtime hours.²¹³

Despite the outage, the Government of Canada worked to maintain the continuity of essential government services of public health, safety and security, and social and economic welfare in Ontario. Numerous government departments invoked emergency operations centres to monitor situations and offer aid to various CI sectors. Backup power for the Prime Minister's Office (PMO) did not function until the morning of August 15, and although the PMO communications staff had access to operational telephones, computers and fax lines did not function. A generator was utilized to print 30 copies of the government's official newspaper, the *Canada Gazette*, which records every appointment, regulation and law that governs Canadians. Typically, 2,500 copies are printed for subscribers in order to meet the government's obligation to make the newspaper publicly available. The OCIPEP website proved to be a valuable tool for the Government of Canada because several key websites, including the Prime Minister's Office and the Privy Council Office, were not functional due to server problems. The government's 1-800-O-Canada hotline, which handles thousands of calls daily for information regarding government services, remained available to users on August 14 and throughout the weekend; however, employees were sent home early and operations were shut down at 16:00 EST on August 15.²¹⁴ Normal service resumed on Monday, August 18.

During the power outage, a Government of Canada telephone line was maintained in order to provide Ontario residents with current information about available provincial services.²¹⁵ The reduction of government services was reviewed daily in conjunction with Ontario provincial authorities.

Benefits payments under Employment Insurance, the Canada Pension Plan, the Child Tax Benefit and veteran's benefits were among some of the services to continue during the outage.²¹⁶ Canada Post service to and from Ontario was slightly affected with delays being reported, but service returned to normal at all Ontario facilities by August 18.

Information about government services available during the power reductions is located in Appendix 1. A list of activated federal government emergency operations centres is located in Appendix 2.

Impact on Government of Canada Departments

Canada Customs and Revenue Agency (CCRA): The verification of documentation at border crossings had to be checked manually because IT systems did not function. This created occasionally lengthy delays. It took approximately 24 hours to restore the operability of the CCRA's Canada-wide networked database. CCRA estimated that up to 50 of its offices were impacted by the blackout.

Citizenship and Immigration Canada (CIC): Some services were disrupted or unavailable on August 15, such as the CIC Situation Centre, which was unavailable from 18:00 EDT on August 15 to 09:00 EDT on August 16.²¹⁷ The Citizenship and Immigration Canada computer systems located in Terminal 2 at Toronto Pearson International Airport were off-line and, as a result, CIC personnel had to perform immigration checks over the telephone to Terminal 1 and Terminal 3, where CIC computer terminals were still operational.²¹⁸ By August 16, all five National Headquarters buildings in the National Capital Region were back on-line. All ports of entry reported normal volume and activity throughout the blackout.²¹⁹

Department of Foreign Affairs and International Trade (DFAIT): DFAIT closed its Detroit, Michigan, mission on August 15, and all telephone inquiries were rerouted to Ottawa. DFAIT Headquarters in Ottawa was only partially operational, with one of two towers remaining functional with personnel deemed essential; however, reduced ventilation resulting from the government's conservation efforts limited the duration of employee occupancy of the tower. Contact with foreign posts was maintained.²²⁰

Fisheries and Oceans Canada (DFO): DFO e-mail capabilities were interrupted during the power failure and the department did not receive OCIPEP National Situation Reports.²²¹

Environment Canada (EC) / Meteorological Services Canada (MSC): During the evening of August 15, EC's critical meteorological forecast operations in Toronto (RCTO) and Ottawa were transferred to the Winnipeg office. The primary public forecast products for Ontario were then issued by Winnipeg. Meteorological observations for numerous sites in Ontario were unavailable. EC requested generators and fuel to operate the Canadian Weather Centre in Toronto, a request which was met by the Canadian Forces.²²² During the morning of August 17, MSC reported that power had been restored to its Toronto office. Some computer operations were also restored, including the dissemination of information from radar sites. Contingencies for the offices remained in effect because problems occurred with the uninterruptible power supply (UPS) systems.

Human Resources Development Canada (HRDC): All HRDC offices in Ontario were closed, although Employment Insurance cheques were still processed, and delivery was not affected. Some problems were experienced transferring the electronic information of direct deposit clients between HRDC, PWGSC and financial institutions.²²³ Operations relating to the 1-800-O-CANADA phone line, which offers information regarding Government of Canada programs and services, were shut down on August 15.²²⁴

Industry Canada (IC): Network management procedures were invoked to ensure the survivability of its communications networks.²²⁵

Department of Justice Canada (DJC): DJC operated on emergency backup generators, but lost the electronic access control system for the entrances to its Headquarters. DJC

was required to station guards at doors in order to verify the credentials of individuals wishing to enter the building.²²⁶

National Defence: The National Defence Command Centre reported that the impact of the power outage on its operations was minimal.²²⁷

Office of Critical Infrastructure and Emergency Preparedness Canada (OCIEP): At the onset of the blackout, OCIEP immediately implemented its “enhanced readiness mode,” concentrating its resources on fulfilling its roles in support of Ontario, federal partners, affected sectors and U.S. agencies. OCIEP remained at enhanced readiness for the duration of the provincial state of emergency. OCIEP’s backup power generators at its headquarters building ensured continuous availability of key tools for responding to an emergency (e.g.: computer networks and e-mail). The power outage came at the same time OCIEP was coordinating federal support to British Columbia’s response to serious forest fires, and was also active in the Canadian response to the Blaster and SoBig worms (two major worldwide threats to cyber networks).²²⁸

NAV Canada: The disruption of service at MSC had a number of operational impacts on NAV Canada. Data collection from the Flight Services Centre, dependent on NAV Canada’s Aeronautical Fixed Telecommunications Network (AFTN) and message switch, was intermittent. The NAV Canada aviation weather website was operational throughout the disruption, although some observations and all Notice to Airmen (NOTAM) operations were unavailable. American radar composites were substituted for Canadian composites. NAV Canada issued critical NOTAMs on weather distribution systems until the AFTN was functional and NOTAMs were available again.²²⁹

Natural Resources Canada (NRCan): NRCan initiated backup systems for mission critical systems. Internet and e-mail communications were unstable due to the Blaster worm and its variants.²³⁰

Public Works and Government Services Canada (PWGSC): PWGSC closed its Ontario regional office in Toronto with the exception of its National Call Centre, which remained operational while handling a significant increase in calls.²³¹ All Government of Canada buildings under PWGSC authority maintained only essential services and power consumption.²³²

Royal Canadian Mounted Police (RCMP): The RCMP National Operations Centre was fully operational during the outage.

Transport Canada (TC): TC operations continued despite the loss of power in one of the towers at its headquarters in Ottawa. Employees were advised to not report to work but, like all employees not deemed essential, were advised to check the employee information line on a regular basis.²³³ TC requested a 150-kilovolt generator for the failed Air Canada Strategic Operations Centre at Toronto Pearson International Airport in order to resume Air Canada flights.²³⁴

ECONOMIC IMPACTS

ECONOMY

Since Ontario represents approximately 42 percent of the total Canadian economy, it was no surprise that economic activity contracted sharply in August. Although it is not possible to isolate and quantify the exact impact of the blackout on gross domestic product (GDP), August's GDP fell 0.7 percent, the largest setback since September 2001, when GDP fell 0.6 percent.

Reduced electricity affected almost every aspect of the economy, hampering manufacturing plants and service producing establishments: hindering production, transportation and distribution of goods and the sales and delivery of a wide range of business, personal and government services.

According to Statistics Canada, the power outage and the subsequent conservation period caused an estimated 2.4 million workers in Ontario and Gatineau, Quebec, to lose 26.4 million hours of work;²³⁵ however, an estimated 713,000 people (11 percent of employees) worked a total of 7.5 million overtime hours.²³⁶ It has been estimated that the time off given to federal government employees amounts to \$250 million alone.²³⁷ These figures represent a large portion of the total estimated economic impact of the power outage on the province of Ontario. The Canadian Federation of Independent Business (CFIB) announced on September 11, 2003, that the power outage had cost the provincial economy between \$1 billion and \$2 billion,²³⁸ a number with which Premier Eves concurred.²³⁹

The Toronto Dominion Bank estimated that the impact of the blackout would set the Ontario economy back by \$550 million. The bank added that had the rolling blackouts continued—concomitant with the conservation efforts, which prevented the return to work of a large portion of the province's workforce—the Canadian economy would have begun to feel recessionary pressures.

Canadian industrial capacity use edged down in the third quarter of 2003 in part because Ontario's industrial heartland was hit by the blackout. Industries operated at 81.2 percent of their capacity in the third quarter, the lowest rate since the fourth quarter of 2001.²⁴⁰

RETAIL AND SERVICE

The day following the cascading outage, retail sales decreased by 29 percent, or \$100 million.²⁴¹ Statistics Canada revealed on October 21, 2003, that Canadian wholesale sales tumbled 4.6 percent in August—a bigger decline than following the 1998 Ice Storm when wholesalers experienced a 4.3-percent drop. The decline left the total value of sales by wholesalers at \$34.2 billion. Over all, nine of 11 wholesale sectors lost ground during the month of August. The biggest wholesale declines were in sales of motor vehicles, as well as motor vehicle parts and accessories. Sales in the automotive sector as a whole were down 15.4 percent compared to August 2002.²⁴²

Most retailers experienced, on average, a 40-percent decline in sales during and up to four days after the outage while the service sector including health, financial, insurance and utilities experienced a similar decline with transactions decreasing by 41 percent the day after the blackout. Gas stations and convenience stores were among the exceptions with many experiencing a 30-percent increase in sales.²⁴³

The Moneris Solutions Corporation (Canada's largest processor of debit and credit card transactions) theorized that the decrease in consumer spending during and following the outage would be offset by "deferred" consumer spending, whereby customers would purchase goods at a later date that they did not purchase during the blackout.²⁴⁴ Moneris determined that consumer purchases increased by 15 percent once consumers returned to the consumer market four days after the outage occurred.

According to a survey conducted by the Canadian Federation of Independent Business (CFIB), the outage significantly impacted 82 percent of small businesses in Ontario.²⁴⁵ The CFIB survey, which polled 1,935 Ontario businesses, found that 47 percent shut down completely due to the outage while 35 percent shut down partially.²⁴⁶ More than one quarter of the businesses responding to the poll said they scaled back production while one sixth reported that they had asked some or all of their employees to remain at home.²⁴⁷ Seven percent of the businesses polled lost inventory due to lack of refrigeration or delayed transport, while two percent reported vandalism or heightened security expenses.²⁴⁸ The survey also indicated that 80 percent of small businesses cut down on air conditioning, 78 percent turned off lights and 65 percent reduced their use of office equipment to conserve power.²⁴⁹

OTHER

When the blackout occurred, the Insurance Information Institute, an industry trade group, stated that the power outage would have a limited impact on insurance companies because the loss of power is excluded from commercial insurance claims;²⁵⁰ however, insurance companies could lose money from secondary effects such as damage caused by fires or sprinklers, automobile accidents, health problems and food spoilage in restaurants.²⁵¹

Despite calling for energy conservation during the restoration of power in Ontario, Premier Eves maintained an electricity price cap that had kept the cost of electricity artificially low. Critics argued that the freeze cost taxpayers \$614 million in subsidies, and that lifting the price cap could prompt consumers to conserve more energy. The price freeze was subsequently lifted by Ontario's newly-elected Liberal government.

CONCLUSION

On August 14, 2003, at 16:11 EDT, the Northeastern Interconnection of the North American power grid went off-line, leaving approximately 50 million people suddenly without power throughout most of Ontario along with New York State, Ohio, Pennsylvania, New Jersey, Vermont, Michigan, Connecticut and Massachusetts.

In Canada's most populous province, every segment of society was affected in some appreciable manner. All critical infrastructure sectors—energy, communications, finance, health care, food, water, transportation, safety, government and manufacturing—as well as the economy, were directly affected by the blackout.

The provincial and federal government's response to the incident was both reactive and proactive. Ontario Premier Ernie Eves made a daily plea to users, primarily the commercial and large industrial users, to reduce energy consumption in the period following the blackout because there was insufficient generation to meet demand. The

Government of Canada acted in a variety of ways to ensure that efforts to help those people and industries affected by the loss of power were coordinated and efficient. Notably, the Government of Canada, together with the U.S. government, established the Canada–U.S. Task Force on the Blackout to examine both the causes and the effects of the power outage.

Ultimately, the magnitude of the blackout and the regional interconnectedness of the transmission grid demonstrated the importance of electrical power to the economy, safety and social welfare of society.

Notice to readers

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APPENDIX 1 – GOVERNMENT OF CANADA SERVICES DURING POWER REDUCTION¹

BACKGROUNDER **Government Services During Power Reductions**

OTTAWA - Here is an updated list of some of the federal services available in Ontario despite the power reductions:

PUBLIC HEALTH

1) **Health Canada** - opened its National Emergency Operations Centre last Thursday and offered assistance to Ontario government. It has continued:

- Screening for Severe Acute Respiratory Syndrome (SARS) at international airports;
- Operating laboratories in Ottawa, Scarborough and Guelph with emergency power;
- Research into food safety and nutrition;
- Operating nursing stations for First Nations in Northwest Ontario;
- Providing First Nations with Non-Insured Health Benefits Program maintained (drugs, dental care etc.);
- Monitoring of drinking water on First Nations reserves;
- Essential support to regions (intelligence, case management etc.).

2) **The Canadian Food Inspection Agency** - continued border inspection services at airports, inland border crossings and seaports. It has also maintained:

- Import Service Centres (pre-clearance for border inspections);
- Export certification services where withdrawal would impact food safety, animal health, or plant protection;
- Issuance of meat import permits;
- Inspection services for animal transport and animal welfare, upon receipt of complaint;
- Food inspection services (eg. meat plants);
- Critical laboratory analysis related to public safety, plant and animal health investigations;
- Emergency response, as required, and Emergency Operations Centre Services, with limited staff.

SAFETY AND SECURITY

3) **The Department of the Solicitor General, RCMP and other security services** have activated National Operations Centres that are connected to federal, provincial and municipal partners.

4) **Justice** - Continuing services include:

¹ Treasury Board of Canada Secretariat. *Backgrounder – Government Services During Power Reductions*. http://www.tbs-sct.gc.ca/media/nr-cp/2003/0820b_e.asp (20 August 2003)

- Extraditions and Mutual Assistance - responding to emergency requests from Interpol and United States;
- Family Orders, Agreements and Enforcement Assistance;
- Central Registry of Divorce Proceedings.

5) **National Defence** - Domestic and international operations are not affected as regular contact with forces overseas continues and support provided for federal and provincial governments. Other activities include:

- Office of Critical Infrastructure Protection and Emergency Preparedness is fulfilling 24 hour/7 days a week emergency response mandate;
- Activities at National Defence Headquarters and bases reduced to save power.

6) **Foreign Affairs and International Trade** - The following services continue:

- Import-export permits available, but some delays may be expected;
- Global communications system maintained in support of Canadian missions abroad;
- Passports - Nine of 11 Ontario regional offices were opened today.

7) **Coast Guard (Department of Fisheries and Oceans)** -- services essential to public safety continue, including search and rescue, marine communications and traffic services, regional operations centres and Coast Guard ships in Ontario.

8) **Citizenship and Immigration** - all ports of entry operating normally. The following services continue:

- Removals;
- Bond reporting centre;
- Refugee Assistance Program Cheques being processed.

9) **Transport** -- operations in support of safety with monitoring of all aspects of transport system and inspections continue.

SOCIAL

10) **Human Resources Development** is offering the following services:

- Human Resource Centres (Approximately 90 re-opened today in Ontario for processing of Employment Insurance and income security payments);
- Electronic Employment Insurance application;
- Employment Insurance (EI) claimant reporting;
- EI and Income Security Program cheque and direct deposit issuance;
- Issuance of cheques and direct deposit for the Canada Student Loan Program;
- Other program payments;
- HRDC websites;

- Call centres (re-routed to offices outside Ontario). While the call centre is open, there may be delays in speaking to a representative due to higher call volumes.

11) **Public Works** - continuing services include:

- Direct deposit of Government of Canada payments;
- Canada Child Tax Benefit will be deposited August 20, on schedule;
- Canada Post will treat cheques as priority;
- Data centres are processing payments under emergency power;
- Cheque production centres located outside Ontario (Winnipeg, Quebec City, Dartmouth);
- Suppliers' bid solicitations continuing, delayed deadlines in some cases;
- IT and Telecommunications - no disruptions to government systems.

12) **Indian Affairs and Northern Development** - services for First Nations will continue to be available, including emergency advice on water and sewer systems, and transfer payments to bands.

13) **Veterans Affairs** - all payments for claims made prior to August 15 will be processed and all normal monthly pension and allowance payments will be made. Also in operation:

- Ontario contact centre;
- Counselling for emergency services (staff working from home);
- Veterans' hospital facilities in London, Ottawa and Toronto.

14) **Canada Customs and Revenue Agency** - All customs and border operations, and customs information lines functioning. Other services in operation include:

- National Call Centre with some Ontario calls being transferred to other regions, which may affect accessibility;
- Issuance of National Child Benefit Cheques.

ECONOMIC

15) **Finance** - Foreign exchange, money exchange and stock exchanges are all running, ancillary banking and credit running. The collection and analysis of financial information and intelligence on suspected money laundering and terrorist financing continues.

16) **Agriculture** - Staff continue to work in fields and greenhouses, farm assistance programs available, work continues on files related to Bovine Spongiform Encephalopathy (BSE).

17) **Environment** - Weather services continue to be provided, Downsview (Toronto) is back online after service was provided temporarily from Manitoba and Quebec.

18) **Industry** - Emergency telecommunications services have been supported and maintained. Other continuing services include:

- Monitoring and analysis of industrial production;
- Processing of patents;

- Filing for Corporations.

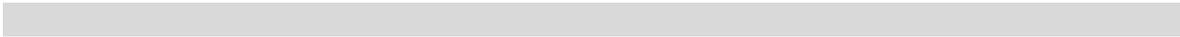
19) Natural Resources - Departmental energy sector is open and the following services continue:

- Atomic Energy of Canada, fully operational;
- Canadian Nuclear Safety Commission, emergency operations centre is open 24 hours a day, seven days a week. Staff are on site at nuclear power plants in Ontario and across Canada.

OTHER

20) **National Archives and National Library of Canada** - All valuable collections have been protected with climate control with most of the electricity supplied by generators.

21) **National Arts Centre** - Performances have continued since Monday.



APPENDIX 2 – GOVERNMENT OF CANADA EMERGENCY OPERATION CENTRES ACTIVATED

- Canadian Meteorological Centre, Environment Canada
- Canadian Nuclear Safety Commission
- Canadian Security Intelligence Service
- CANUTEC, Transport Canada
- Environment Canada (Montreal)
- Environment Canada (National Environmental Emergency Centre)
- Foreign Affairs and International Trade
- Industry Canada (Gatineau)
- Industry Canada (Coordination centre, Kitchener)
- National Defence
- Office of Critical Infrastructure Protection and Emergency Preparedness
- Public Works and Government Services Canada
- Royal Canadian Mounted Police
- Transport Canada

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