Extreme Weather and the Energy Metabolism of the City[1]

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ABSTRACT

This study uses a critical realist perspective to investigate relations between social constructions and the dynamics of nature. The material metabolism of the modern city is based on the redeployment of the processes of nature. This redeployment provides energy for anabolic processes in which complex social and physical hybrids (heating, lighting, transportation, communication, water-supply systems and climate-controlled micro-environments) are built from simpler structures. Massive energy flows of nature can, however, confront the city, unleashing catabolic reactions in which complex social and physical hybrids are broken down to simpler ones. This case-study of the 1998 ice storm in north-eastern North America documents the learning that occurs as a result of nature's overwhelming energy flows destroying the essential infrastructures of modern urban life. This extreme weather event knocked out for an unusually long period the electrical transmission system that provides the energy for a metropolitan area situated in a dark, frigid environment, and thereby produced the most costly disaster in Canada's history.

KEYWORDS

Critical realism, disaster, technology, learning

Pristine nature untouched by humans is ending on the surface of our planet. Human action has affected all of its parts and nature's dynamics are being manipulated as never before. Humans remain nevertheless sensory beings observing and experiencing a material world that cannot be reduced to their social constructions. Dynamics autonomous of human construction, which are referred to in discourse as ' nature', still affect social constructions whether these

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are material constructions, conceptions, or perceptions. The goal of this paper is to examine relations between the independent dynamics of nature and social constructions. This will be done through a case-study of an extreme weather event in the second-largest Canadian city, which proved to be the most costly disaster in the history of that country.

FROM SOCIAL CONSTRUCTIONISM TO CRITICAL REALISM

Many investigations of environmental issues are limited to the study of social practices and do not examine the relations between these and the dynamics of nature. Social constructionism is a prominent example of an approach that restricts its investigations to the social even when studying science, the environment, nature, and risk. Constructionism has different variants.[2] Extreme constructionism[3] adopts the idealist doctrine that reality is a mental construct.[4] Hence it limits reality to conceptions and only investigates how these are socially constructed. Nature and risk are reduced to conceptions of nature and of risk. This extreme constructionism based on social reductionism is naive because it ignores and obscures what is not socially constructed but instead created by the dynamics of nature.

Mild constructionists do not deny material risks and dynamics of nature independent of conceptions.[5] They just refuse to study them and their relations with social constructions. For methodological and strategic reasons they only investigate socially constructed claims of risk and conceptions of nature. The net result is that mild in principle becomes extreme in practice: the analysis is purified of the influence of the dynamics of nature and of the issue of whether risk is real. Relations between social practices and the dynamics of nature remain unexamined. Conceptions of nature and of risk are investigated in the name of analysing nature and risk. Such loose talk replaces more precise studies that distinguish between nature and conceptions of nature, risk and perceptions of risk. Bracketing nature's dynamics out of the analysis results in an oversimplification of social practices, treating humans as if they were only pure spirits socially constructing reality as they please in a material vacuum. Schmidt shows that constructionists thereby 'deny the possibility of any serious learning' and 'the possibility of bringing one's evaluative criteria under some degree of reflective control'.[6] Social constructionists fail to appreciate humans as sensory beings living and learning in a world of nature's autonomous dynamics.

A different variant of constructionism incorporates the issue of the validity of claims into the analysis, even if it does so implicitly or unadmittedly. Grundmann's analysis of the negotiations leading to the Montreal Protocol controlling CFCs and the depletion of the ozone layer gives great importance to clever measurements of depletion.[7] What is the status of these measurements? Are they arbitrary, baseless, make-believe fabrications of scientists, not much different from lies? The most plausible answer is that the properties of the ozone layer affected what was perceived by the scientists and through their clever observations affected the resulting negotiations, much like the incapacity of water to support humans influences perceptions and conceptions about the possibility of walking on water. The unperceived risk of ozone layer depletion was transformed by these scientific measurements into perceived risk in this learning process, which strongly affected the negotiation of the Montreal Protocol. Underlying scientific struggles there is a material reality that leads certain hypotheses and purported evidence to be more persuasive than others. Unfortunately Grundmann's analysis stops short of explicitly integrating the changing properties of the ozone layer into the analysis, but at least they are there implicitly. Hannigan's constructionist analysis goes further toward realism: 'social constructionism as it is conceptualised here does not deny the independent causal powers of nature but rather asserts that the rank ordering of these problems by social actors does not always directly correspond to actual need'.[8] The implication is that an optimal analysis needs to incorporate rather than evade 'the independent causal powers of nature' as well as the issue of the correspondence or noncorrespondence between actual need and ranking of problems. Ungar showed how Americans learned through direct experience: the experience of the heat wave of 1988 increased the awareness of global warming in the United States.[9] Nye's constructionist study shows how values and norms are embedded in material human constructions, such as electrical systems, which then affect future preferences and material constructions.[10] The real material world is seen as having a significant effect on perceptions, conceptions, and social constructions, and that effect is incorporated into the investigation. Their heavy dose of realism entitles these studies to be called realist constructionism or constructionist realism.

From a realistic perspective it is important not to confuse 'social constructs or interpretations with their material products or referents'[11] nor to bracket the autonomous causal powers of nature out of the analysis because they have significant effects on social constructions. Realism examines 'the way in which social order is embedded and conditioned by the natural order from which it is emergent and on which it in turn acts back'.[12] As sensory beings, humans learn about the material world of which they form a part through observation, experience, and science. Two types of realism need to be distinguished. The first conceives of the real world as transparent, and knowledge as a reflection of it. For example, science is viewed as pure, disinterested, impartial knowledge. This version of realism is naive because it leaves little or no room for the roles culture, power, and inequality play in the social construction of knowledge. Critical realism, on the contrary, sees knowledge as socially constructed on the basis of culture, power, and inequality. Precisely because of this, such knowledge – including scientific knowledge – is seen as partial both in the sense of being incomplete and of favouring those groups that control its development.[13]

Relations between social constructions and the dynamics of nature are significant in critical realism, but knowledge of nature and perception of risk are problematic social constructions: 'risk perception that is at odds with the "real" risk underlies the process of risk transference, which encourages development that increases long-term vulnerability'.[14] Dickens gives the example of the transmission from cows to humans of *spongiform encephalopathy,* which attacked the human mind long before the risk was perceived as real and produced catastrophic social results in Britain.[15] Social, cultural, and economic factors led to the risk being unperceived and unacknowledged even after visible symptoms began to appear in cattle and then in people.[16] 'We have no alternative but to attempt to assess the relative practical adequacy or objectivity of different social constructions'.[17] Dickens argues convincingly that there 'is therefore an extremely strong case for developing the social sciences in ways which make them reflect on-going and rapidly developing interactions between society and the causal powers of nature'.[18]

Nature's dynamics form the context affecting socially constructed perceptions and conceptions because humans are physical sensory beings who experience and observe (either unaided or through science or both) those dynamics and learn about them. Surprises from nature's dynamics remind humans of their ignorance about it and the need to distinguish between nature and current conceptions of it. The natural environment is the testing ground where socially constructed meanings imposed on nature's dynamics prove to be wrong (BSE cannot be transmitted to humans, cod fish off Newfoundland are so abundant that they will not be over fished, CFCs cannot deplete the ozone layer, Thalidomide is safe for pregnant women) or right (the Colo volcano will erupt in 1983 so the island should be evacuated, earthquakes will occur in Japan so buildings should be reinforced, etc.). Nature's dynamics eventually reveal through experience which of the contested claims are right or wrong. This typically occurs after a time lag[19] where even previously unperceived risk becomes transformed into perceived risk. Hence it is crucial to arrive at an accurate assessment of risk as soon as possible to avoid damage. The significant question is whether serious learning appropriate to the dynamics of nature will or will not take place. Such learning is a problematic social construction. It can occur in a mundane, everyday way, as when sinking leads humans to learn that they cannot walk on water, painful symptoms teach them not to eat poisonous mushrooms, etc. Learning can also occur when confronted with dramatic forces of nature, such as the Chernobyl explosion, Thalidomide babies, earthquakes, the Concorde plane crash, etc. And learning can ensue through scientific observation and measurement, as happened in the case of the depletion of the ozone layer, where nature's autonomous dynamics affected perceptions, conceptions and the negotiation of the Montreal Protocol through the mediation of socially constructed science and its development of extraordinary means of measurement of those dynamics.

HYBRIDS CO-CONSTRUCTED BY HUMANS AND BY NATURE'S DYNAMICS

Latour documented how Pasteur's laboratories have transformed society and how the development of quasi-objects like electricity recompose the social, increase its scale, and redefine it.[20] But, in what some commentators[21] see as distancing himself from his earlier work, Latour does not now view this in terms only of active humans making social constructions using passive objects of nature. Instead both the social and the natural are active and are co-constructed in this process: they 'mutually exchange and enhance their properties'.[22] Social practices are no more independent from nature's dynamics than the latter are from the former in the modern world. Recently Latour has replaced the theory of the social construction of reality with that of the co-construction of hybrids by society and nature together. Far from bracketing the dynamics of nature out of the analysis, their relations with social constructions become the focus of the analysis. Other investigators agree that the social sciences 'must abandon the security of the "social" in order to engage with those hybrid "nature-cultures" that determine the shape of the modern world'.[23]

The promise and strength of this approach can be disentangled from Latour's confusion of concepts and their referents – for example, his implausible argument that the anthrax bacillus did not pre-exist the experiment. To take another illustration: it need not be assumed that *evolution* began with Darwin's theory, which would contradict that theory, rather that the *theory* of evolution originated at that point. It is necessary to distinguish between constructing nature in a material sense, which humans do partially in the sense of manipulating its dynamics to create hybrids such as technology, and constructing various conceptions of nature.

The essential infrastructures of modern society – such as the power transmission lines to be dealt with here – are hybrids: constructions of humans and of nature's dynamics that transform nature and change society. In this co-construction nature's dynamics do not lose their potential autonomy. Despite human efforts, hybrids explode, corrode, etc. Furthermore, these hybrids exist in a broader field of nature's forces that humans had little if any part in constructing, such as sun storms, ice storms, lightning, earthquakes, and floods. New technological hybrids may even expose society to disturbances of nature in a way that was not the case for older technologies.[24] Socially constructed beliefs about safety and risk are embedded in the technical norms according to which essential hybrids, such as the power grid, are constructed. These beliefs then confront their referents – the autonomous dynamics of nature – in the testing grounds of nature's broader dynamics.

THE INTERNALISATION OF NATURE INTO SOCIETY

A severe storm in Antarctica is not a natural disaster because there are few if any humans in that pristine wilderness to be affected by it. On the other hand, cities such as Lisbon in Portugal and Messina in Sicily, which took centuries to be socially constructed, were destroyed in minutes and their inhabitants killed by the forces of nature.[25] As humans invade areas of nature previously untouched by humans and build their social constructions, nature retains its autonomous dynamics, which invade society in new ways. The transformation of a territory that was pristine nature into a socially constructed artefact, far from replacing nature, incorporates the autonomous dynamics of nature, which were previously external to society, into it. This intensifies the need to monitor and protect society from dangerous dynamics of nature to ensure the safety of humans and their constructions.

As humans assailed wilderness and intensified their manipulation of nature near the end of the 1980s, the United Nations designated the 1990s as the 'International Decade for Natural Disaster Reduction'. When dealing with the dynamics of nature, however, designations in discourse are one thing but results are quite another. The number of incidents of great disasters worldwide remained in 1991–95 at the high level of more than 25 which it had attained in the early 1980s, whereas it was less than 10 for similar time periods prior to the 1980s. And the economic losses worldwide from great disasters have continued to rise exponentially: reaching 120 billion US$ for the period 1991–95 compared to 40 billion US$ for 1986–90 and less than 5 billion US$ prior to 1971.[26]

Risk concerning nature is most dangerous when it is unperceived and/or unacknowledged,[27] precisely because expensive, complex monitoring and protection are not done. Tides in the Bay of Fundy are as high as a tsunami and they roll in quickly, but do not cause a disaster because their coming and going are predictable, risks are clearly perceived in advance, and social constructions make appropriate adaptations. Disasters, on the contrary, result from the surprises of nature; they are only perceived and/or acknowledged when it is too late to take defensive or evasive action.

Society can protect itself from the disturbances of nature to some extent if it perceives the risk and has the wealth and technical knowledge to deal with it. 'Low-income nations had over 3,000 deaths per disaster, high-income ones under 500. Japan lost an average of sixty-three people in forty-three disasters, Peru an average of 2,900 in thirty-one'.[28] Holland is a wealthy, low-lying country which has perceived the risk from the sea and protected itself with an elaborate, expensive array of dikes and sea gates; Bangladesh is a poor low-lying country with a rapidly increasing population that has no protection and regularly suffers a disastrous flood (300,000 deaths in 1970, 131,000 in 1991). 'Rich countries lose fewer lives because they have built up systems, from the local fire department to the U.S. Army Corps of Engineer, that identify danger and that warn, reinforce, shield, and evacuate'.[29]

In general it is only modern, industrial societies that have the knowledge and money to accomplish such monitoring and/or protection. The result is that the number of deaths from the explosive dynamics of nature is usually much less in those countries. On the other hand, it is precisely those societies that have the capital to put valuable constructions in the path of danger. Hence they are the ones to suffer most of the property damage. 'Since 1900, deaths from tropical cyclones in the United States have declined from six thousand per year to only a few dozen; yet property damage has soared to over $1.5 billion in recent decades because of the amount of new construction in hurricane-prone areas'.[30] Hurricane Andrew of 1992 in Florida killed only 43 but resulted in property damage of $30 billion and bankrupted six insurance companies.[31] In 1994 a Richter 6.6 earthquake damaged 40,000 buildings in the Los Angeles area, resulting in a loss of $35 billion, but only killed 55.[32] 'During the twentieth century, China has suffered an earthquake death for every $1,000 in property damage, whereas the United States has experienced only one death for more than $1 million in property damage'.[33]

Modern society has modified the character of its relationship with nature, and with it the character of risk. 'We have exchanged risk to human life for greater exposure to property damage, and then distributed the cost of that damage over space and over time. We have assumed an increasing burden of vigilance along with our protection. Technology is again taking its revenge by converting catastrophic events into chronic conditions – even as natural catastrophes persist'.[34] Not only developing but also developed societies are afflicted with painful cost/benefit decisions concerning expensive monitoring and protection, in a domain of uncertainty and ignorance of the dynamics of nature where even the calculated probabilities are problematic.

There is a growing consensus among scientists that this ignorance is not just a temporary state in humanity's construction of knowledge about nature but instead is based on a fundamental characteristic of nature. Society exists in a vortex of autonomous dynamics and flux of energy transformations which we call nature. Unusual, rapid disturbances are to be expected: 'it is these last sorts of disturbances, caused by the restlessness of climate, that the new generation of ecologists has emphasized'.[35] Previously ecology had been so dominated by the equilibrium perspective that it neglected disturbances, but no longer. Many sciences are developing chaos theory because it has been found that nature 'is *fundamentally* erratic, discontinuous, and unpredictable. It is full of seemingly random events that elude our models of how things are supposed to work. As a result, the unexpected keeps hitting us in the face'.[36] Nature is much more complex than scientists imagined. 'Our powers of prediction, say ecologists, are far more limited than we imagined. Our understanding of what is normal in nature now seems to many to be arbitrary and partial'.[37] But if nature is unpredictable, and prediction is necessary for protection, how does society deal with the disturbances of nature?

A popular distinction in the literature is that between natural disasters (earthquakes, hurricanes, floods, etc,) and technological disasters (explosion of nuclear reactors, chemical plants, etc.),[38] with the former evoking a solidarity-enhancing response and the latter a corrosive, blame-attribution reaction. Since the use of a technology can result in a disaster that is not sudden, Gramling and Krogman[39] have introduced the concept of 'chronic technological disasters'. In addition, the impact of natural disasters in today's society depends so much on technology and social organisation (earthquakes on resistant buildings, floods on dams, hurricanes on meteorological warnings and evacuation procedures, all of the above on the efficacy of emergency measures organisations, etc.) that there is ample potential for the attribution of blame. The sharp distinction between natural and technological disasters should be replaced by a different way of relating technology to nature's disturbances.

The dynamics of nature have been internalised into society in two ways. First, the material metabolism of society is based on the redeployment of the energy of nature through the construction of hybrids. This is true for all societies to some extent but it has become predominant in modern society. The redeployment of nature's forces provides energy for anabolic processes in which complex physical hybrids (automotive, telecommunications, heating, lighting, sanitation, and water supply systems and climate-controlled micro environments) and social structures (governments, transnational corporations, universities, concert halls, etc.) are built from simpler ones. The material metabolism upon which modern urban living conditions depend has been transformed since the industrial revolution as a result of fossil fuels and mega projects to produce energy.

Second, massive energy flows of nature can confront these hybrids unleashing, to carry the analogy further, catabolic reactions in which complex social and physical hybrids are broken down to simpler ones. The catabolic reactions can occur as a result of the dynamics of nature without being initiated by humans. Or the forces of nature and resulting catabolic consequences for society could be unleashed by human action. For example, if the worldwide use of fossil fuels leads to global climate change, more frequent and intense weather events could provoke destructive effects and social crises.

This study will use a critical realist perspective to investigate relations between social practices and the processes of nature. The focus will be especially on the catabolic dimension of energy exchanges between society and nature. A case-study of the January 1998 ice storm in north-eastern North America will be made. That extreme weather event knocked out for an unusually long period the electrical transmission system that provides the energy for complex physical and social hybrids situated in a dark, frigid winter climate, thereby breaking down those structures into simpler ones. Freezing rain struck a vast territory in north-eastern North America, including south-western Quebec and eastern Ontario in Canada and the northern part of New York State and the New England states in the United States.[40] It had much less effect on the United States than on Canada because the erratic disturbance hit a region of Canada that was densely populated (Montreal and Ottawa) whereas in the United States it struck an area that was closer to being wilderness. The incorporation of a territory into society and its social reconstruction internalises dynamics of nature, such as freezing rain, which had previously been external to society when the territory was wilderness. The focus of this paper will be on the metropolitan area of Montreal, Quebec because that was where the most disastrous consequences occurred.

ANABOLIC PROCESSES IN MODERN QUEBEC

The public utility of Hydro-Quebec was created in 1944 to supply cities and towns, industries and residences, with electrical energy. At first it purchased electricity from private companies that had been created to redeploy the gravitational attraction on water in rivers as electrical power. Then it began constructing power plants of its own. During this early period, hydroelectric power was generated close to the cities and towns. In a bold move of economic nationalism and public sector domination in1963, the Quebec provincial government nationalised the power companies and consolidated them into Hydro-Quebec, whose sole shareholder is still the Quebec government. Since then the Quebec state has financed and promoted the extensive development of hydroelectric power under the monopoly of Hydro-Quebec. Because this is entirely within Quebec and under the control of Quebecers, it has been seen as a secure, renewable source of energy for the construction of a modern society. The OPEC cartel's reduction of oil production in the 1970s and resulting increase in energy prices created a mighty incentive to develop alternative sources of energy around the world. Quebec seized the opportunity. Huge hydroelectric power plants were constructed in northern Quebec, which was previously pristine wilderness, as well as interminable electrical transportation lines to the south where the population and businesses are located. Enormous amounts of electricity are also sold to the United States.

Quebec, a province of about eight million people, has become the third largest producer of hydroelectricity in the world, behind the United States and Brazil but ahead of huge countries like Russia and China. In 1996 production totalled 199 billion kWh with an installed power of 40,405MW.[41] In that same year 96.8% of electrical power in Quebec resulted from the redeployment of the force of gravity on water, a uniquely high proportion.[42] Mega production of electrical power more than one thousand kilometres from the points of consumption has resulted in some of the longest transmission lines in the world at the highest voltage: Hydro-Quebec has more than 10,000 km of 735kV lines.[43] A

450 kV direct current line was completed in 1992 to take power from the turbines of northern Quebec to Boston in the United States.[44]

Quebec has made physical and social constructions that are more dependent on electricity than most societies. In 1996, 40.9% of its energy was electric, compared to 23.9% for Canada as a whole, 19.8% for the U.S.A., 21.8% for France, and 24.2% for Japan. Electricity is the form of energy that powers many modern constructions in all societies, but the higher use in Quebec reflects its growing importance as a means of heating in a frigid winter climate: 72.5% of residences were heated electrically in 1996 compared to 12.2% in 1974. Since electrical plinths are used, the heating system cannot be changed without a significant investment by the homeowner. So Hydro-Quebec has a captive clientele.[45] None the less electricity rates have remained relatively low, which has made it the means of economic development in other parts of the economy. Quebec has become the third largest producer of aluminium and newsprint in the world, contributing 10% and 12% respectively of world production.[46] For Quebecers, Hydro-Quebec is the most powerful symbol of Quebec's success in the modern technological and business world, and it is seen as more environmentally friendly than other energy corporations to boot.[47]

As in most countries, the long, high-voltage transmission lines are above ground because the special tunnels needed for underground high-voltage lines would be much too costly. Unlike Europe, however, North America has a high proportion of low-voltage distribution lines constructed above ground as well. This is because there was already a high population density in Europe but only a low one in North America when knowledge was constructed of how to redeploy nature's energy in the form of electricity and build hybrids to produce power. Underground lines were therefore less economical in North America, and the systems have been built up following the initial patterns.[48] About 90% of distribution lines in Quebec run in the open air from wooden pole to pole. Only in rare parts of metropolitan areas, usually wealthy ones, are more expensive underground distribution lines constructed for aesthetic reasons.[49]

CATABOLIC PROCESSES, UNPERCEIVED RISK AND LEARNING FROM EXPERIENCE

The initial perception by the population, the state, and Hydro-Quebec of security of energy supply led to few safety measures to protect the long transmission and distribution lines. Until the mid-1960s, lines were built without considering exceptional events: if a weather event had a low probability of occurring, it was ignored in the design of the network.[50]

These perceptions and procedures were challenged by the dynamics of nature. For example in 1969 thirty 735 kV pylons collapsed in a domino-like fashion as a result of an extreme weather disturbance in a major transmission corridor, causing a general blackout throughout Quebec. A similar occurrence happened in 1973 in a different transmission corridor. In the winter of 1972 freezing rain that deposited 30 mm of ice in a small area led to a blackout of the complete Hydro-Quebec electrical network. Wind, lightning, freezing rain, and even magnetic storms caused eight general blackouts of the whole network between 1969 and 1979.[51] It was becoming apparent that over longer periods of time, and over an immense space, improbable events do occur and affect the entire network. Climatic disturbances were causing major electrical problems in local areas, and the tight technological coupling was propagating these problems throughout the complete network, shutting it down. Fearing that certain areas were prone to climatic disturbances, Hydro-Quebec adopted the policy of avoiding areas at high risk of weather disturbances in the construction of new transmission lines and of constructing no more than two high-voltage transmission circuits (4,000MW) in the same corridor, which increased costs.[52] This principle was not, however, applied to lower voltage lines. The 1969 and 1973 damage persuaded Hydro-Quebec to develop instruments and methodologies to measure the thickness and type of ice on lines. Norms were changed as a result of adverse experiences, and pylons and lines that were more resistant were constructed. Retrofitting was not done, however, because of the cost. The consequence even today is that different parts of the electrical network in Quebec meet different standards reflecting the date of their construction.[53] A collapse of important lines in April 1973 led to the realisation that it was impossible to guarantee zero risk, and to the elaboration of an emergency plan by Hydro-Quebec.[54]

Despite these measures, in April 1988 wet snow in north-eastern Quebec resulted in a series of short circuits, the loss of one of the two major centres of production of electricity (Churchill Falls), and an electrical blackout throughout Quebec. In the spring of 1989 a sun storm disrupted the Earth's magnetic field and sent a powerful surge of current through Hydro-Quebec's long transmission lines, which tripped safety devices that shut down the whole system for eight hours. Three blackouts of the entire electrical system lasting several hours occurred between 1979 and 1989. Other blackouts affected significant parts of the network. These autonomous forces of nature stimulated a change of perception: the vulnerability of long transmission lines was now seen. The repeated downing of the entire system or significant parts of it provoked the government in the 1980s to demand that Hydro-Quebec work and invest to improve the performance of its system. Shortly after the sun storm caused the general blackout, Hydro-Quebec made a second round of investments ($498 million) between 1989 and 1995 to improve reliability of service. New criteria were implemented at the beginning of the 1990s to protect the system against exceptional events (most involve the autonomous forces of nature, but not all, for example, sabotage). Robustness and reliability increased such that the index of hours lost per customer per year was reduced from 12.0 in 1989 to 3.5 in 1996.[55]

An ice storm east of Montreal, however, pushed the index back up to 5.9 in 1997. This extreme weather event triggered another wave of protective investments. A system was implemented in which an 'alert' warning would be sent to Hydro-Quebec staff when 12.7 mm of ice was detected on its lines.[56]

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The defences erected as a result of the experience of previous disturbances of nature did offer protection for the electrical system and for society when the 1998 ice storm hit. The system as a whole did not stop functioning this time.[57] The main centres of electrical production, which are located well beyond the area struck by the freezing rain, kept producing electricity. Transmission and distribution lines outside the area hit by the storm kept transmitting and distributing, and some lines within the storm area resisted. However, the consequence of this disturbance of nature was that the best prepared electrical system in Quebec's history suffered the longest blackout ever in its business and population centre.

Studies found that 3,500,000 people – half of Quebec's population – were deprived of electricity at the height of the ice storm and that a quarter of a million people had no power, heat, or lighting for three weeks.[58] And this blackout of a metropolitan area occurred in the darkest, most frigid days of winter. All bridges to the island city of Montreal from the south shore were closed because of icy conditions, collapsing overhead signs and structures, and fallen live electrical wires.[59] Underground rail transportation was not directly affected by the freezing rain, but lack of electricity idled it for more than fifty hours over ten days during and after the storm.[60] Other forms of energy were unavailable as well because they too were dependent on electricity: Montreal's two electrically operated oil refineries stopped functioning when deprived of electricity; petrol stations had to close because their pumps required electricity;[61] and oil and natural gas furnaces ceased to provide heat because they lacked the electrical spark to ignite.

This intense ice storm cut electricity to two major filtration plants, which stopped supplying water to 1.5 million people. Fire hydrants quickly lost pressure; the population was not informed for fear they would try to build up reserves of water, worsen the shortage, and leave fire-fighters even shorter of water. The crippling of the city's fire-fighting capacity at a time when there were numerous short circuits, fallen live wires, and houses being heated with rarely used fireplaces posed a grave danger. Water-cooled, gas-powered electrical generators began to overheat for lack of water. Water contamination became a threat with the filtration plants out of service. City authorities ordered that water be boiled for five minutes before consuming it, an order that only confirmed to residents without a source of heat how irrelevant the discourse of those authorities had become.[62] The filtration plants were down for about seven hours: completely for two hours and intermittently for five more hours as Hydro-Quebec desperately attempted to restore power. The commission of inquiry concluded it was sheer luck that no major fire or water contamination occurred in the interval.[63]

Telephone lines often shared the same wooden poles as electrical lines and were brought down by the weight of the ice and by falling trees. Telecommunications were seriously disrupted. Many people no longer carry cash because automatic banking machines, debit cards, and credit cards have become efficient means of doing business. These machines depend on electrical and/or telephone lines, and they too went dead.[64] People no longer had access to their own money to make urgent purchases in a time of emergency.

The very measures used to promote efficiency in normal weather aggravated the catabolic crippling of society by the weather disturbance. Electrical transmission and distribution lines were often located along roads and highways to serve a double function and be more cost effective, so the transportation system was paralysed not only by ice but also by the fallen live electrical wires.[65] 'Just-in-time' technologies that assume efficient transportation of goods thereby dispensing with costly warehousing of inventory left the disaster area without goods and propagated production problems well beyond that area because of dependency on it for the production of components. Hydro-Quebec assured cities of a continuous supply of electricity for their electrically powered water filtration plants, hence cities dispensed with the purchase of costly, emergency generators.[66] Elimination of redundancy, which is cost-effective under normal processes of nature, becomes particularly costly and life threatening when nature produces a disturbance.[67]

Despite the improved defences built into the electrical system, the essential infrastructures of modern society fell like dominoes. The intense, prolonged freezing rain *directly* caused some problems, but it *indirectly* provoked many more by depriving a modern society of the electrical energy upon which it had been constructed. This disturbance of nature introduced new elements of chaos, uncertainty, and complexity into social organisation.[68] Hydro-Quebec, the Quebec government, and the population had not perceived the danger of such an intense, persistent ice storm and were inadequately prepared.

Thirty people died in Quebec as a direct result of the 1998 ice storm: five from hypothermia, sixteen attempting to avoid hypothermia (burns or carbon monoxide asphyxiation from using generators, propane BBQs, fondue burners, candles, decorative fireplaces, etc.), one crushed by ice falling from a rooftop, and four falling from rooftops attempting to remove the heavy ice. Risk went unperceived and the consequences were suffered. In addition there is reason to believe deaths occurred indirectly as a result of the ice storm. The 1998 death rate in the region increased about 27% in January, 25% in February, and 4% in March compared to the same months the previous year.[69] On the other hand, no fatality occurred on the roads despite the awful driving conditions. This did not result only from reduced traffic. Canadians are well practised with icy roads: when risk is accurately perceived, precautions are taken.

The 1998 ice storm was the most costly disaster in Canada's history. In Quebec alone 611,947 claims were made to insurance companies for damage to residences, commercial properties, and vehicles for a total of $924 million.[70] The total cost of the ice storm paid by insurance companies, Hydro-Quebec, and the Quebec and Canadian governments has been estimated to exceed $4 billion dollars.[71] About 2,300,000 work-days were lost by 500,000 employees. Other employers had to pay 1.7 million hours of overtime to 55,000 employees.[72] Most significantly, interruptions of electricity decreased not when Hydro-Quebec, the Quebec and Canadian governments put in an enormous effort, but rather when the freezing rain ceased.

Before the 1998 ice storm, the only concern of Hydro-Quebec was to restore electricity as quickly as possible: in not more than six hours in winter and sixteen hours the rest of the year. Within those specifications the safety and health of the population would not be threatened, so priority was given to restoring current to industrial users over residential customers and the priority list made no mention of restoring current to shelters and other emergency centres. The experience of the 1998 ice storm revealed the risk of a prolonged power outage in winter, and perceptions modified by experience led during and after the ice storm to a rethinking of priorities in the restoration of power.[73]

The dynamics of nature constitute testing grounds for hypotheses, forecasts, standards, and norms. Theories of resistance of electrical lines and transmission towers were put to the test in a field situation. For example, on the third day of the storm 72 transmission towers fell like dominoes, even though the ice did not at that time exceed their theoretical working limit of 45 mm. Anti-domino towers placed at every tenth tower did not always prevent the domino effect. In one transmission line the anti-domino towers remained erect but all the others on either side of them fell like dominoes. The domino shock wave somehow passed through the anti-domino towers. The damage caused by the 1998 ice storm gave another impetus to testing and monitoring. It led Hydro-Quebec to propose increasing its norm to 65 mm of ice resistance so that its new lines would be stronger. It also led to the proposal to install more and better anti-domino towers to prevent a recurrence of the domino effect because that would limit damage not only in the case of freezing rain but also from other forces of nature such as earthquakes.

Small differences in temperature, precipitation, strength and direction of the wind, etc., resulted in large differences in impact in adjacent areas. Transmission towers consist of a multitude of parts, all of which must be resistant. The effect of the ice storm was a complex array of lines of destroyed towers next to unbroken ones. Some of the presumably more resistant, new towers collapsed whereas other older, supposedly less resistant ones remained in position undamaged.[74] This experience led to the proposal to take factors other than ice, such as wind, into consideration in the design of resistant lines and towers. Since many lines were downed by falling branches, the ice storm also led to a more extensive programme of trimming trees.

Aesthetic reasons had made some headway on the issue of burying distribution lines underground, but not much because of the cost. The ice storm of 1998 gave a powerful stimulus to burying lines for reasons of security of electrical supply. The Scientific and Technical Commission set up to examine the ice storm became a strong advocate of underground distribution lines and argued that the ice storm was the event that would unblock this issue.[75]

The Commission forcefully asserted that the principal lesson of the 1998 ice storm was that reliability of electrical supply should be one of the main objectives of the system, just as important as economic or environmental impacts.[76] To accomplish this, it affirmed the need for an independent risk analysis that would make a more comprehensive and realistic assessment of risks than had been done to date. The ice storm spurred Hydro-Quebec into action to reinforce its electrical network as well as its credibility. This disturbance of nature incited changes of perception, discourse, and practices by Hydro-Quebec, the Quebec government, and other public bodies.

The perceptions of risk provoked by the ice storm also stimulated new reactions on the individual level, for example, the purchase of petrol generators to give homes and businesses some independence from the long transmission lines of Hydro-Quebec. Previously this redundancy was seen as inefficiency: an unnecessary expense due to the reliability of electric supply. The lengthy blackout in winter as a result of the freezing rain transformed these supply perceptions, led to a sense of vulnerability, and to a rush on generators.

CONCLUSIONS

There are several conclusions that can be drawn from this case-study of the relations between social practices and the dynamics of nature.

Anabolic and Catabolic Dimensions of Social Metabolism

The socio-material metabolism upon which modern urban living conditions depend has been transformed since the industrial revolution as a result of the use fossil fuels and mega-projects to produce energy. This intensified redeployment of nature's dynamics is the anabolic side of the internalisation of nature into society. In this social construction, complex physical and social hybrids have been built from simpler structures. In the case studied here, wilderness areas were invaded to construct hybrids to redeploy the gravitational pull on water as a source of electrical energy to power modern society.

The internalisation of nature into society and the socio-physical metabolism of society cannot, however, be reduced to this anabolic dimension. This case-study has demonstrated that the dynamics of nature have been internalised into society in a second way. A disturbance of nature created massive energy flows which confronted society, unleashing catabolic reactions in which complex social and physical hybrids were broken down to simpler structures. The study has documented the material and social consequences of a sudden change from anabolic to catabolic processes as a result of nature's overwhelming energy flows, establishing the importance of investigating the catabolic side of socio-material metabolism.

Natural Disasters and Technological Disasters

The freezing rain itself had some impact on this populated area, but most of all it provoked a technological disaster consisting of a prolonged deprivation of the electricity so essential for all the infrastructures of modern life, which in turn caused most of the disruption and danger in a dark, frigid winter climate. The distinction between natural and technological disasters can no longer be treated as two mutually exclusive phenomena precisely because technological constructions and their consequences have invaded all corners of the surface of our planet. This does not imply, however, that disasters resulting from nature's disturbances have been replaced by technological disasters. Both natural and technological disasters are hybrids: nature's disturbances engender technological disasters in modern society. There is also the possibility – yet unproven – that creeping technological disasters, such as global climate change induced by fossil-fuel technology, are increasing the recurrence of natural disasters in the form of extreme weather disturbances.

Learning in a Material Context

Quebec's electrical network was constructed in stages. Until the mid-1960s, risks from nature's disturbances were unperceived or judged too improbable to be of significance, hence few if any preparations were made or defences constructed. Disturbances such as lightning, ice storms, sun storms, etc., subsequently disproved these taken-for-granted presumptions and demonstrated how disrupting and costly nature's disturbances can be for a modern society dependent on electrical energy. Failure to perceive risks and prepare for them enabled relatively minor disturbances of nature to become amplified into a general failure of the technological system because of its tight coupling.

Disturbances of nature incited the transformation of perceptions and the social construction of measures of preparation, defence, and prevention. Learning was done by extrapolation. Defences were constructed to deal with disturbances similar to those that had occurred. Preparation and protection were ratcheted up after the experience of each disturbance so that the system and society became better prepared for a similar disturbance in the future. If it has the knowledge and the means, society can learn from the experience of disaster and prepare itself for similar events in the future. Perceptions are not formed in a material vacuum. On the contrary they are formed in a material context that is experienced. The dynamics of nature are an important part of the context that influences perceptions and learning.

The social response to nature's disturbances was not, however, automatic. Social and cultural predispositions were crucial. Belief in the reliability of the essential infrastructures of modern life and in reassuring extrapolations about the improbability of extreme weather proved hard to shake. The taken-for-granted sense of invulnerability, in which the population believed that past disturbances of nature were isolated events that would not recur, was an important factor explaining the indifference and inadequate preparation for more powerful disturbances of nature.[77] The cost of protection also never ceased to enter into decisions whether or not to implement it. The presumed improbability of extreme events of nature, related to an unwillingness to pay the costs of implementing stronger defences for new disturbances, amounted to the absence of a culture of civil security in Quebec society. It is unlikely that Quebec is unique in this regard.

Disturbances of nature are not always similar to past ones. At each step, more powerful disturbances or new types of disturbances were still unperceived, perceived to be improbable, and/or superior defences judged too costly. Hence protection and preparation afforded by the reinforced system proved insufficient for powerful new forces of nature. Time after time unexpected disturbances of nature overwhelmed the enhanced defences. In January 1998 the most robust electrical system in the history of Quebec was blacked out in its largest metropolitan and business core by an unexpected force of nature.

Pre-existing categories and pre-existing experience of nature's dynamics result in the burden of proof being placed on those who claim risk. This is the reason why experience and observation of nature's dynamics as well as scientific findings (a refined variant of observation and experience) are so important for modifying conceptions of risk. The intense, persistent ice storm demolished not only power transmission lines but also beliefs by meteorologists, engineers, disaster specialists, and lay people about security from dangerous perturbations of nature, which in turn led to calls for improved norms concerning risk to be being built into transmission lines. Risk that was unperceived came into the field of view when a surprising disturbance of nature struck. What was learned depended nevertheless on pre-existing cultural categories and assumptions as well as on what was observed, experienced, or measured. Whether risks are accurately perceived remains problematic.

The costly 1998 ice storm has been added to everyone's bank of experience from which extrapolations, decisions, and constructions are made by experts and the lay population. It has been a stimulus to develop proposals for the ratcheting up of defences against nature's disturbances to a still higher level, with not only the population but also the organisational losers (government, electrical power companies, insurance companies) examining possible protections against future occurrences. These nature-incited proposals once again run up against wishful beliefs of non-recurrence and the costs of protection.

Protection or Reaction?

It is difficult to predict nature's disturbances and it is costly to take preventive and protective measures in advance. But the ice storm showed that the absence of preventive and protective measures, resulting in the most costly disaster in Canadian history, could be more expensive. The unprepared reaction during the extreme weather event involved a great deal of disordered mobilisation that was only moderately effective. Relying on it proved to be costly in financial terms, in terms of organisational disruption, individual stress, and in some cases, death. If human-unleashed global climate change provokes even more intense and persistent extreme weather, then pinning all hopes on an *a posteriori* response may prove to be the most costly option. Far from promoting fatalism, the unpredictable part of nature's disturbances gives added weight to the precautionary principle of building in a solid margin of error when constructing socio-technical hybrids.

The Statistical Invulnerability of Modern Societies

When the effects of nature's disturbances are examined statistically, modern societies are found to suffer less loss of life now than they did in the past or than developing societies suffer. But when examined through a case-study of what happens during a powerful disturbance of nature, it becomes evident that the forces of nature are not under control and defences are close to the breaking point. The reestablishment of essential infrastructures is dependent on the circumscribed extent of the extreme weather (so that the unaffected rest of society can help) and on the ending of the extreme weather. If these conditions are not met, as they might not be if global climate change occurs, greater loss of life as well as more extensive disruption and material damage could result. The very dependence of developed countries on the smooth operation of technological hybrids renders them exposed to danger in a new manner: a way that often reduces fatalities if and only if preventive and protective measures are implemented, but that is particularly costly and still does not remove the threat to life if the disturbance proves too intense and persistent.

Critical Realism

At each step in its construction of a power network, Hydro-Quebec learned about new risks by experiencing the forces of nature. Hydro-Quebec ratcheted up its perception of risk and the defences it built into the system with each perturbation of nature. A social constructionist approach that brackets dynamics of nature and reduces claims to social strategies would miss this key element in the explanation of shifting claims. Leaving out of the analysis what humans as sensory beings observe and experience makes for a partial, inadequate explanation that fails to encompass human learning. Conceptions and even perceptions are socially constructed, but not in a material vacuum. They are socially constructed by sensory beings using observation, experience, and scientific measurements of the material world as building blocks. Critical realism, which examines the complex relations between social constructions and nature's constructions provides a more complete understanding than social constructionism, which brackets nature's dynamics out of the analysis.

NOTES

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[2] Birningham and Cooper 1999.
[3] Latour and Woolgar 1986, Woolgar 1988, Eder 1996.
[4] see Dickens 1992: 176–7.
[5] Capek 1993, Lidskog 1996, Macnaghten and Urry 1998.
[6] Schmidt 2001: 141–2.
[7] Grundmannn 2001.
[8] Hannigan 1995: 30.
[9] Ungar 1992
[10] Nye 1998.
[11] Sayer 1997: 482.
[12] Bhaskar 1989: 173–40.
[13] Murphy 1994: Chapter 9.

[14] Etkin 1999: 69.
[15] Dickens 2001: 93–4.
[16] Murphy 1997: 123–9.
[17] Sayer 1997: 468.
[18] Dickens 2001: 93–4.
[19] Adam 1995, 1998, 2000.
[20] Latour 1983; Latour 1991: 147.
[21] Schmidt 2001: 152.
[22] Latour 1999: 125.
[23] Murdoch 2001: 120.
[24] Murphy 2001.
[25] Zebrowski 1997.
[26] NRTEE 1998: Exhibit 1.4.
[27] see Murphy 1999.
[28] Tenner 1997: 92.
[29] Tenner 1997: 92.
[30] Tenner 1997: 94.
[31] Zebrowski 1997: 232.
[32] Zebrowski 1997: 233.
[33] Tenner 1997: 99.
[34] Tenner 1997: 91.
[35] Worster 1993: 164.
[36] Worster 1993: 167.
[37] Worster 1993: 153.
[38] Freudenburg 1997.
[39] Gramling and Krogman 1997.
[40] Phillips 1998, Sperandio 1998, Dotto 1999.
[41] Commission 1999: 372. This includes the power from Churchill Falls in adjacent Newfoundland, which was developed by Hydro-Quebec in a contract that still inspires bitter controversy in Canada's poorest province of Newfoundland. The OPEC driven energy-price increase in the 1970s transformed an equitable 100-year contract at fixed prices into a one-sided arrangement in Hydro-Quebec's favour.
[42] Commission 1999: 378.
[43] Commission 1999: 290.
[44] Commission 1999: 291, 347, 350.
[45] Commission: 1999: 372–3.
[46] Commission 1999: 374.
[47] Commission 1999: 374.
[48] Nye 1998.
[49] Commission 1999: 330–1.
[50] Commission 1999: 293.
[51] Commission 1999: 292.
[52] Commission 1999: 308, 346.
[53] Commission 1999: 345.
[54] Commission 1999: 299.
[55] Commission 1999: 297.
[56] Commission 1999: 300.

[57] Commission 1999: 35, 304.
[58] Commission 1999: 34.
[59] Commission 1999: 36.
[60] Commission 1999: 37.
[61] Commission 1999: 38.
[62] Commission 1999: 259–60.
[63] Commission 1999: 39.
[64] Commission 1999: 38.
[65] Commission 1999: 37.
[66] Commission 1999: 41.
[67] Commission 1999: 311.
[68] Commission 1999: 152.
[69] Commission 1999: 46–8.
[70] Commission 1999: 69.
[71] Commission 1999: 96.
[72] Commission 1999: 86–7.
[73] Commission 1999: 324.
[74] Commission 1999: 355–6.
[75] Commission 1999: 330, 341–2.
[76] Commission 1999: 380–1.
[77] Commission 1999: 140.

REFERENCES

Adam, B. 1995. *Timewatch*. Cambridge: Polity.

Adam, B. 1998. *Timescapes of Modernity*. London: Routledge.

Adam, B. 2000. 'The Media Timescapes of BSE News'. In *Environmental Risks and the Media*, eds. S. Allan, B. Adam, and C. Carter. London: Routledge.

Bhaskar, R. 1989. *The Possibility of Naturalism*. Harvester Wheatsheaf: Hemel Hempstead.

Birningham, K. and Cooper, G. 1999. 'Being Constructive: Social Constructionism and the Environment'. *Sociology* 33: 297-316.

Capek, S. 1993. 'The "Environmental Justice" Frame: A Conceptual Discussion and an Application'. *Social Problems* 40: 5-24.

Commission scientifique et technique chargée d'analyser les événements relatifs à la tempête de verglas survenue du 5 au 9 janvier 1998. 1999. *Pour affronter l'impévisible*. Québec: Les publications du Québec.

Dickens, P. 1992. *Society and Nature: Towards a Green Social Theory*. Philadelphia: Temple University Press.

Dickens, P. 2001. 'Linking the social and Natural Sciences'. *Sociology* 35: 93-110.

Dotto, L. 1999. *Storm Warning: Gambling with the Climate of Our Planet*. Toronto: Doubleday.

Eder, K. 1996. *The Social Construction of Nature*. London: Sage.

Etkin, D. 1999. 'Risk Transference and Related Trends'. *Environmental Hazards* 1: 69-75.

Freudenburg, W. 1997. ‘Contamination, Corrosion and the Social Order: An Overview’. *Current Sociology* 45: 19-39.

Freudenburg, W. and Gramling, R. 1994. *Oil in Troubled Waters*. Albany: SUNY Press.

Gramling, R. and Krogman, N. 1997. ‘Communities, Policy and Chronic Technological Disasters’. *Current Sociology* 45: 41-57.

Grundmann, R. 2001. *Transnational Environmental Policy: Reconstructing Ozone*. London: Routledge.

Hannigan, J. 1995. *Environmental Sociology: A Social Constructionist Perspective*. London: Routledge.

Latour, B. 1983. ‘Give me a Laboratory and I will Raise the World’. In *Science Observed*, eds. K. Knorr-Cetina and M. Mulkay. London: Sage.

Latour, B. 1991. *Nous n’avons jamais été modernes*. Paris: La Découverte.

Latour, B. 1999. *Pandora’s Hope*. London: Harvard University Press.

Latour, B. and Woolgar, S. 1986. *Laboratory Life: The Construction of Scientific Facts*. Princeton: Princeton University Press.

Lidskog, R. 1996. ‘In Science We Trust?’ *Acta Sociologica* 39: 31-53.

Macnaghten, P. and Urry, J. 1998. *Contested Natures*. London: Sage.

Murdoch, J. 2001. ‘Ecologising sociology’. *Sociology* 35: 111-33.

Murphy, R. 1988. *Social Closure*. Oxford: Oxford University Press (Clarendon).

Murphy, R. 1994. *Rationality and Nature.* Boulder: Westview.

Murphy, R. 1997. *Sociology and Nature: Social Action in Context.* Boulder: Westview.

Murphy, R. 1999. ‘Unperceived Risk: The Great 1998 Ice Storm in Northeastern North America’. *Advances in Human Ecology* 8: 99-123.

Murphy, R. 2001. ‘Nature’s Temporalities and the Manufacture of Vulnerability’. *Time and Society* 10: 329-48.

NRTEE National Round Table on the Environment and the Economy. 1998. *Greenhouse Gas Emissions from Urban Transportation*. Backgrounder. Ottawa: NRTEE.

Nye, D. 1998. *Consuming Power*. Cambridge, MA: MIT Press.

Phillips, D. 1998. *Blame it on the Weather*. Toronto: Key Porter.

Sayer, A. 1997. ‘Essentialism, Social Constructionism, and Beyond’. *Sociological Review* 45: 453-87.

Sperandio, E.P. 1998. *L’Enfer de glace*. Montreal: Trustar.

Schmidt, V. 2001. ‘Oversocialised Epistemology: A Critical Appraisal of constructionism’. *Sociology* 35: 135-157.

Tenner, E. 1997. *Why Things Bite Back: Technology and the Revenge of Unintended Consequences*. New York: Vintage.

Ungar, S. 1992. ‘The Rise and (Relative) Decline of Global Warming as a Social Problem’. *Sociological quarterly* 33: 483-501.

Woolgar, S. 1988. *Science: The Very Idea*. London: Routledge.

Worster, D. 1993. *The Wealth of Nature: Environmental History and the Ecological Imagination*. New York: Oxford University Press.

Zebrowski, E. 1997. *Perils of a Restless Planet: Scientific Perspectives on Natural Disasters*. Cambridge: Cambridge University Press.