Bottled Water and Energy

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The consumption of "bottled water"—fresh water sold in individual, consumer-sized containers—is growing rapidly. More than 200 billion liters of bottled water were sold in 2008 (the last year for which reliable, public data are available), mostly in North America and Europe, but with rapidly expanding sales in many developing countries as well.[1]

During that same year, the Beverage Marketing Corporation, which tracks beverage sales, estimated that consumers in the United States purchased around 33 billion liters of bottled water, or an average of more than 110 liters (nearly 30 gallons) per person. Bottled water sales have increased by 70 percent since 2001 in the United States, though they declined slightly in 2008 from the previous year. They now far surpass the sales of milk and beer (Table WB 1.1). The only beverage category with larger sales is carbonated soft drinks.

Bottled water is purchased by consumers for a wide variety of reasons, ranging from convenience to worry over the availability and quality of potable water from municipal systems. But new efforts are under way to cut the use of bottled water and to address its major environmental and social consequences. Among the issues of growing public concern are the impacts of water extractions on local watersheds, equity issues associated with commercializing a public resource, the environmental consequences of producing and disposing of plastic bottles, and the energy (and resulting greenhouse gas emissions) required to bottle water (Gleick 2010). We address the issue of energy here (and in detail in Gleick and Cooley 2009).

Energy to Produce Bottled Water

Energy is required in all segments of the bottled water supply chain, from production to packaging, transportation, chilling, use, and recycling. The total amount of energy needed is complicated by many factors, including the location and type of the water source, the distance from the bottler to the consumer, the types of material and packaging used, the method of transportation, and much more. Gleick and Cooley (2009) compute the energy required to bring the water to the consumer, including specifically the energy to make the plastic materials used in bottles, fabricate that plastic into the actual bottles, process the water prior to bottling, fill and seal the bottle, transport the

1. This Water Brief is modified and updated from Gleick and Cooley (2009).

Table WB 1.1 Sales of Major Beverages in the United States, 2006

Beverage	Million Liters
Carbonated Soft Drinks (regular and diet)	57,169
Bottled Water (95% still and 5% sparkling)	31,238
Beer	24,489
Milk	21,476

Sales of bottled water in 2008 increased from 2006 to approximately 33 million liters.
Source: ERS 2007.

product to the end user, and chill it for use. Rather than compute a single energy factor for bottled water, we offer three examples to explore the range of bottled water energy requirements from production to point of sale.

Energy Required to Manufacture Plastic Bottles

Bottled water is sold in containers ranging from small eight-ounce or half-liter containers popular in school lunches to the multi-gallon bottles used in home and office water coolers. Most single-use plastic water bottles are made out of polyethylene terephthalate (PET). PET is a thermoplastic polymer resin used for a wide variety of purposes, ranging from the production of polyester fibers and clothing to food and beverage containers. In the United States, PET is easily recognized by the recycling code "1" (Figure WB 1.1), which is imprinted on the bottle to help consumers identify and recycle different forms of plastics. Some larger containers, such as those used in office coolers, are made from polycarbonate, which has greater rigidity at large sizes and requires approximately 40 percent more energy to produce than bottle-grade PET (Bousted 2005).

Energy is embodied in PET material itself, and additional energy is required to turn PET into bottles. This energy is typically supplied by natural gas and petroleum, along with electricity from the local electricity grid. Two comprehensive life-cycle assessments for producing PET and PET bottles have been completed; these indicate that the energy required to produce PET resin is approximately 70 to 83 megajoules (MJ) (thermal) per kilogram of PET resin (Bousted 2005, Franklin Associates 2007).[2] Producing preforms and turning them into bottles requires an additional 20 MJ per kilogram of finished bottle. The total energy used in producing PET bottles, including some transportation energy to move the resin to the point where bottles are produced and then filled, is thus about 100 MJ per kilogram, or 100,000 MJ per ton of PET.

The mass of PET required per bottle depends on the style, thickness, and size of the bottle. Research from the Pacific Institute indicates that an average 1-liter bottle weighs approximately 38 grams, excluding the cap, which typically weighs an additional 2 grams (Gleick and Cooley 2009). Some manufacturers have launched new efforts to reduce the amount of PET required to make a water bottle. In 2007, Logoplaste Group in Portugal announced a new line of lightweight preforms with a 0.33-liter bottle weighing 11.5 grams (35 g/l) (Pittman 2006). Nestlé produces a lightweight half-liter bottle weighing 12.2 grams (or around 24.4 g/l) and is experimenting with the production of a 1.5-liter PET bottle weighing between 28 and 33 g (or between 18 and 22 g/l). The Coca-Cola

2. All energy units here are thermal, unless otherwise specified as electrical—e.g., $kWh_{(e)}$. All conversions of thermal to electrical assume an efficiency of 0.33—i.e., three kWhr (thermal) equal one kWhr (electrical).

Figure WB 1.1 Recycling Code for Polyethylene Terephthalate (PET). These codes, introduced in 1988 by the plastics trade association (the Society of the Plastics Industry, Inc.), help consumers identify and recycle different forms of plastics.

Company recently introduced a new 20-ounce bottle weighing 18.6 grams (or around 31.5 g/l).

Combining the estimate of the energy required to make PET and form it into bottles with the average weight-to-volume data results in a manufacturing energy cost of around 4.0 MJ per a typical one-liter PET bottle weighing 38 grams. This estimate includes the energy required to convert raw materials into PET resin, the energy required to turn resin into bottles ready for filling, and the energy to transport PET or bottles to the filling plant.

If all bottled water required an average of 38 grams of PET per liter, approximately 3.8 million tons of PET were required to produce the 100 billion liters of bottled water containers sold worldwide in 2008. If all bottled water producers shifted toward the lightest bottles, PET production could be reduced by around 30 percent. These estimates exclude any PET waste generated during bottle production or used for the packaging (such as the label, carton, or plastic wrapping) of the final retail product. Using these data, we estimate that approximately one million tons of PET were produced to make the plastic bottles consumed in the United States in 2008, and three million tons were produced globally. Producing the PET bottles to satisfy global bottled water demand thus required approximately 300 billion MJ of energy, or the energy equivalent of approximately 50 million barrels of oil per year.[3] The use of recycled materials could lead to additional energy savings, but almost all plastic bottles for water are currently made from virgin PET.

Energy to Process Bottled Water

Energy is also required to prepare water for bottling. Bottled water usually comes from two primary sources: municipal water systems (often called "processed" or "purified" or "municipal" water) and surface-water and groundwater systems (often called "spring" water). Both sources typically undergo some kinds of additional filtering or purification, even municipal waters that are already treated to meet drinking water purity standards (Figure WB 1.2).

Treatment processes can include micro- or ultrafiltration, ozonation, ultraviolet radiation, and reverse osmosis. As shown in Table WB 1.2, energy (typically electricity) requirements vary considerably among the various water-treatment techniques. Disinfecting water with ultraviolet radiation, for example, requires as little as 10 $\text{kWh}_{(e)}$ per million liters (SBW Consulting, Inc. 2006). Energy requirements for reverse osmosis, however, can be as high as 1,600 $\text{kWh}_{(e)}$ per million liters for source water with a total

3. Not all the energy used to make these bottles is oil, or even fossil fuels; thus, we use the common comparison of "energy equivalent."

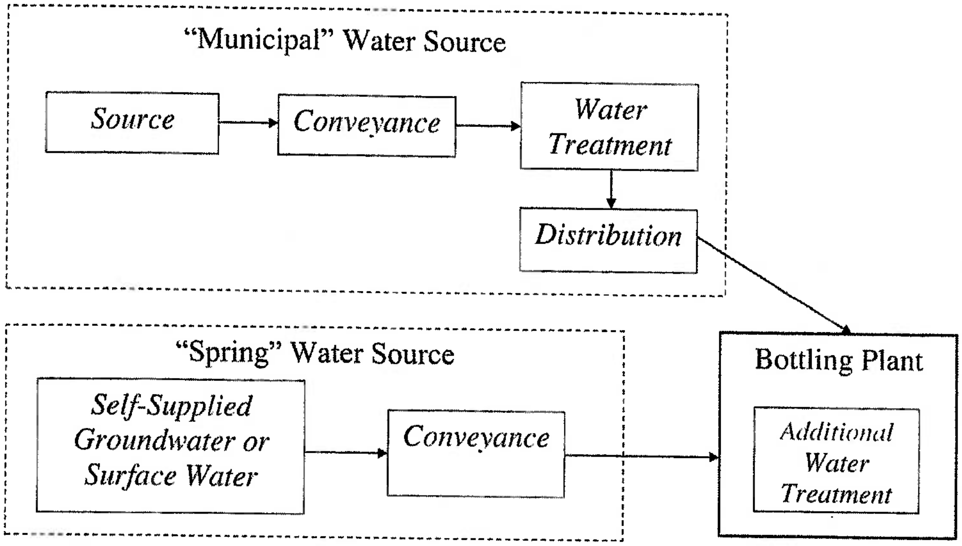

FIGURE WB 1.2 TYPICAL PROCESS DIAGRAM FOR BOTTLING WATER FROM A MUNICIPAL OR SPRING WATER SOURCE.
Source: Gleick and Cooley 2009

dissolved solids concentration of 4,000 parts per million (AWWA 1999) and even higher for desalinating seawater. Several companies worldwide are selling bottled water desalinated from seawater.

No public data are available on the number of bottling plants that employ the various treatment methods. Thus, the energy requirements for treating most municipal or spring waters at the bottling plant range from 10 $kWh_{(e)}$ per million liters for simple ultraviolet radiation alone to as high as 1,800 $kWh_{(e)}$ per million liters for treatment involving UV, filtration, ozone, and reverse osmosis. Even with this wide range, however, the typical energy requirements for processing water, even extensive processing, are small relative to the energy associated with the plastic bottle and its production. Extensive treatment requires only between 0.0001 and 0.02 $MJ_{(th)}$ per liter, a small fraction of the energy embedded in the PET bottle itself.

Energy to Clean, Fill, Seal, and Label Bottles

Following the production of the bottles and the treatment of the water, additional machines rinse, fill, cap, and label PET bottles. A review of energy specifications from nine major manufacturers shows that typical machines use between 0.002 and 0.01 MJ per bottle for machines that handle between 3,000 and 39,000 bottles per hour (Gleick and Cooley 2009). The average machine can clean, fill, and seal around 15,000 bottles per hour and requires 0.006 MJ per bottle.[4] High-volume labeling and packaging machines, such as those produced by Sacmi Industries, can label 36,000 to 42,000 bottles per hour using 27 $kWh_{(e)}$ per hour,[5] or around 0.008 MJ per bottle. Thus, the total energy required

4. We assume here an average ratio of 3 kW (thermal) per kW (electrical), and all energy use totals are presented as thermal equivalents.

5. Reported power requirements for a Sacmi beverage bottle labeler. Personal communication, Sacmi Industries, 2009.

TABLE WB 1.2 Energy Requirements for Water Treatment Methods

Treatment Technique	Energy Use ($kWh_{(e)}$/million liters)	Data Sources
Ozone		
Pre-oxidation (pre-treatment)	30	SBW Consulting 2006
Disinfection	100	SBW Consulting 2006
Ultraviolet Radiation (medium pressure)		
Bacteria	10	SBW Consulting 2006
Viruses	10–50	SBW Consulting 2006
Microfiltration/Ultrafiltration	70–100	SBW Consulting 2006
Nanofiltration (Source TDS = 500–1,000 ppm)	660	AWWA 1999
Reverse Osmosis		
Source TDS = 500 ppm	660	AWWA 1999
Source TDS = 1,000 ppm	790	AWWA 1999
Source TDS = 2,000 ppm	1,060	AWWA 1999
Source TDS = 4,000 ppm	1,590	AWWA 1999
Seawater Desalination (reverse osmosis)	2,500–7,000	NRC 2008

to clean, fill, seal, label, and package bottled water is around 0.014 MJ per bottle, or only about a third of a percent (0.34 percent) of the energy embodied in the bottle itself.

Energy to Transport Bottled Water

After the production of bottled water, more energy is required to move the finished product to markets. Because water is heavy—weighing one metric ton per cubic meter—energy associated with transporting bottled water can be significant. The total transportation energy requirements depend on two major factors: the distance from the bottling plant to the market and the mode of transportation.

Numerous government energy and transportation ministries, including the U.S. Department of Energy, the U.S. Department of Transportation, the European Union, and Natural Resources Canada, have compiled and analyzed data on the energy costs of different modes of freight transportation. Table WB 1.3 summarizes typical transportation energy-intensity values for major modes of freight transportation in megajoules per metric ton of cargo per kilometer transported. Air cargo is by far the most energy-intensive mode of transportation; truck transportation is more energy intensive than transportation by rail or bulk ocean shipping.

The distance from the bottling plant to the final point of consumption varies significantly with the type of bottled water. From a practical point of view, "purified water" is usually produced by treating and packaging municipal water in major demand centers close to markets. These products are bottled at local bottling plants spread across the country near major urban areas, with deliveries to local markets. The Coca-Cola Company, PepsiCo, and other major bottlers produce treated municipal waters in many major cities for local distribution, often at the same plants producing soft drinks and other beverages.

In contrast, "spring" waters are usually packaged at specific, single sources and transported, sometimes significant distances, to points of demand. Nestlé, for example, bottles water under the Arrowhead label at plants in Southern California for distribution

Table WB 1.3 Transportation Energy Costs

Cargo Ship/Ocean (MJ/t-km)	Air Cargo (MJ/t-km)	Rail (MJ/t-km)	Heavy Truck (MJ/t-km)	Medium Truck (MJ/t-km)
0.37	15.9	0.23	3.5	6.8

All values in units of megajoules per ton cargo per kilometer (MJ/t-km) traveled. Heavy trucks are typically used for long-distance and inter-city freight transport. Medium trucks are typically used for intra-city freight delivery.

Source: US DOE (2007); Natural Resources Canada (2007).

throughout their western markets, and bottles water under the Poland Spring label in Maine for distribution in eastern markets. More extreme examples include Fiji Spring Water, which is packaged at the source in the South Pacific, or Evian water, which is packaged at the source in France and then shipped to markets around the world.

Energy requirements for transportation can be evaluated using data in Table WB 1.3 and assumptions about the distance traveled. Gleick and Cooley (2009) evaluated three different transportation scenarios for products shipped to the major Los Angeles, California, market: (1) processed municipal water that is distributed locally by truck; (2) spring water produced in the south Pacific (such as Fiji Spring Water), transported by ship to Los Angeles, and distributed locally by truck; and (3) spring water packaged in France (such as Evian), shipped to the eastern United States, transported by freight railcars to Los Angeles, and distributed locally by truck.

The transportation energy cost varies significantly among these scenarios (Table WB 1.4) and will vary with different assumptions about distance and transport mode. The scenarios summarized in Table WB 1.4, however, represent the approximate minimum and maximum energy costs, unless bottled water is shipped any distance by air. Locally packaged and marketed purified bottled water delivered within 200 kilometers of a bottling plant by truck has a total transportation energy cost of around 1.4 MJ per liter. Spring water transported across the Pacific from Fiji to Los Angeles and then delivered locally within 100 kilometers has a total transportation energy cost of 4.0 MJ/liter. French spring water shipped by truck from the source to French ports, by ship across the Atlantic, by train from the East Coast of the U.S. to Los Angeles, and then locally by truck has a transportation energy cost of around 5.8 MJ per liter.

Energy to Cool Bottled Water Prior to Use

Energy is also required to cool the bottled water prior to sale or consumption, including the energy to cool the water from room temperature to the temperature of the refrigerator or commercial display cooler, and the energy to maintain the cold water until it is sold. For the first component, Gleick and Cooley (2009) estimate that bottled water is cooled from a room temperature of around 20.0°C to a typical refrigerator or cooler temperature of around 3.3°C. Given that the specific energy of water is around 4.2 KJ per kilogram per degree K, we estimate that cooling one liter of water 17°C requires 220 KJ, or 0.2 MJ per liter.

The second component depends on the length of time the bottled water is kept cool before consumption and the energy performance of the refrigerator. As of October 2008, more than 1,000 refrigerators met the U.S. Energy Star standards for efficiency. These refrigerators had an average volume of 17 cubic feet and used 450 $kWh_{(e)}$ per year, or

Table WB 1.4 Transportation Scenario Assumptions for Bottled Water Consumed in Los Angeles Metropolitan Region with Distances by Mode of Transport

Scenario	Medium Truck (km)	Heavy Truck (km)	Rail (km)	Cargo Ship (km)	Total Energy Cost (MJ/l)
Local production	200 (local delivery)	0	0	0	1.4
Spring water from Fiji	100 (local delivery)	0	0	8,900 (Fiji to Long Beach)	4.0
Spring water from France	100 (local delivery)	600 (Evian to Le Havre)	3,950 (New York to Los Angeles)	5,670 (Le Havre to New York)	5.8

Note: Distances in kilometers (km); Total energy in megajoules per liter (MJ/l).

around 8.65 $kWh_{(e)}$ per week. No data are available on the time the average consumer chills bottled water before consuming, but if we assume that a consumer keeps a liter of bottled water cold for a week before consuming it, then the energy required to maintain the cool bottle is another 0.2 MJ per liter.

Summary of Energy Uses

Table WB 1.5 summarizes the total energy requirements for capturing, conveying, and treating bottled water, producing the plastic bottles, and cooling the water prior to sale, given the assumptions described above. Based on these assumptions, the total energy required for bottled water will typically range from 5.8 MJ to 10.2 MJ per liter. In comparison, producing tap water typically requires about 0.005 MJ per liter for treatment and distribution (Burton 1996), making bottled water 1,000 to 2,000 times more energy intensive depending on the distance bottled water has to move from production to market.

Conclusions

This Water Brief summarizes research (done at the Pacific Institute and published in a peer-reviewed journal) on the energy footprint required for various phases of bottled water production, transportation, and use. For water transported short distances, the energy requirements of bottled water are dominated by the energy to produce the plastic bottles. Long-distance transport, however, can lead to energy costs comparable to or even larger than the energy to produce the bottle. Far less energy is needed for processing and treating the water, and for cooling bottles for retail sale. We did not evaluate waste disposal or recycling here. Transportation costs are highly variable, ranging from 1.4 MJ for water produced within 200 kilometers of the consumer market to 5.8 MJ for water produced in France and sold in Los Angeles. Combining all of the energy input totals, we estimate that producing bottled water requires between 5.6 and 10.2 MJ per liter—as much as 2,000 times the energy cost of producing tap water. Given an annual consumption of 33 billion liters of bottled water in the U.S., we estimate that the annual

Table WB 1.5 Total Energy Requirements for Producing Bottled Water

	Energy Intensity $(MJ_{(th)}/l)$
Manufacture Plastic Bottle	4.0
Treatment at Bottling Plant	0.0001 to 0.02
Fill, Label, and Seal Bottle	0.01
Transportation: range from three scenarios	1.4 to 5.8
Cooling	0.2 to 0.4
Total	**5.6 to 10.2**

We assume here an average ratio of 3.0 kWh(thermal) per kWh(electrical) and 3.6 MJ/kWh.

consumption of bottled water in the U.S. in 2007 required an energy input equivalent to between 32 and 54 million barrels of oil, or a third of a percent of total U.S. primary energy consumption—around 17 million barrels of oil equivalent to make the plastic bottles and the rest for other parts of the supply chain. Roughly three times this amount was required to satisfy global bottled water demand.

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WATER BRIEF 2

The Great Lakes Water Agreements

Peter Schulte

The Great Lakes comprise the largest surface freshwater system on Earth, containing roughly 84 percent of the freshwater in North America and about 21 percent of the world's total freshwater supply (see Figure WB 2.1). The Great Lakes Basin is home to more than 30 million people in the United States and Canada and accounts for 7 percent of American farm production and 25 percent of Canadian farm production (US EPA 2008). Freshwater is among the region's most valuable and important resources—economically, ecologically, and culturally. In the last century, however, these resources have been subjected to heavy pollution and increased withdrawals and diversions often leading to adverse ecological and community impacts. In response, many have called for more effective and coordinated management of the Basin's freshwater resources. The Great Lakes–St. Lawrence River Basin Water Resources Compact (not to be confused with the Great Lakes Basin Compact of 1968) is the most recent and comprehensive in a long series of legislative actions to strengthen and coordinate basin water management while protecting it from use by interests outside the region.

History of Shared Water Resource Management

Water management concerns in the Great Lakes Basin have for decades been largely centered on concerns about pollution and diversion of the water resources and how best to protect those resources from out-of-basin interests. Given the location of the basin at the border of the U.S. and Canada, many of these problems—and the policies designed to address them—are transboundary in nature.

Since the early 20th century, many compacts, treaties, and agreements have sought to coordinate management of the basin's water resources (Table WB 2.1). These agreements have evolved from an emphasis on data collection to more comprehensive water management policies and procedures. The latest round of adjustments was initiated in 1998, when the Province of Ontario approved a permit for a private interest to extract 160 million gallons of Lake Superior water per year to be sold in Asia.[1] This led to a public outcry both in Ontario and neighboring U.S. states that rely on Lake Superior water. In response, the Great Lakes governors and the premiers of Ontario and Quebec negotiated

1. As a Canadian province, Ontario was not subject to out-of-basin diversion restrictions established in the Water Resources Development Act of 1986.

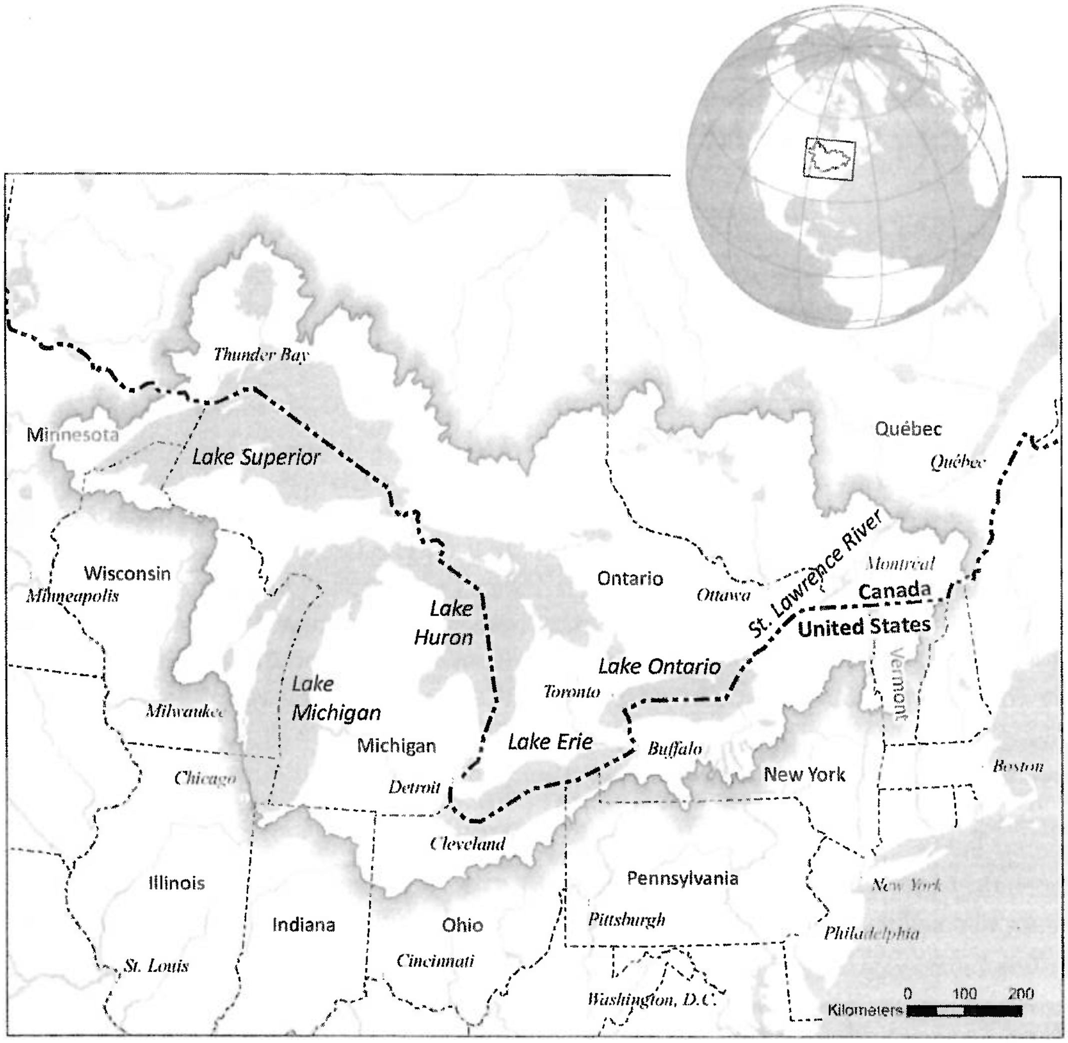

Figure WB 2.1 The Great Lakes Basin: History of Shared Water Resource Management.
Source: Pacific Institute 2011.

and then, in 2001, signed "Annex 1" to the 1985 Great Lakes Charter, which committed the parties to develop a collaborative water management system for the basin (CGLG 2010).

After significant further efforts, eight U.S. states and two Canadian provinces[2] signed the Great Lakes–St. Lawrence River Basin Sustainable Water Resources Agreement in 2005. This agreement provided a framework within which these states and provinces can collaboratively protect and manage their shared freshwater resources (CGLG 2005a). The United States then developed the Great Lakes–St. Lawrence River Basin Water Resources Compact to set forth the policies and practices by which the U.S. states adhere to their commitments under the Agreement. In 2008, it was ratified by all eight states, approved by the U.S. Congress, and signed by President George W. Bush (US EPA 2009; GLWI 2009). The Compact becomes fully binding in 2013 when states are required to formally establish their own water withdrawal regulation and management programs (SOP DEP 2011).

2. Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, Quebec, and Ontario are the 10 states and provinces that signed the Agreement.

TABLE WB 2.1 Compacts, Agreements, and Legislation Governing the Management of Great Lakes Basin Freshwater Resources

Name	Year	Stipulations / Function
Boundary Waters Treaty	1909	Established the International Joint Commission to examine and resolve disputes between the U.S. and Canada over use of the Great Lakes freshwater resources (GLWI 2009)
Great Lakes Basin Compact	1968	Established the Great Lakes Commission, whose authority was largely limited to collecting data, publishing reports, and making nonbinding technical and policy recommendations related to water management in the basin
The Great Lakes Water Quality Agreement	1972, 1978 (renewed)	Reaffirmed the rights and obligations of both countries under the Boundary Waters Treaty and outlined a series of commitments to ensure protection of basin ecosystems
The Great Lakes Charter	1985	Established a prior notice and consultation process for large water withdrawals, a cooperative resource-management program, and a Water Resource Management Committee to identify data needs, among other things (voluntary, not legally binding) (CGLG 2001)
The Water Resources Development Act	1986	Required approval from all eight states for any diversions taking water out of the basin (GLWI 2009)
Annex 1 to the Great Lakes Charter	2001	Committed basin states and provinces to develop a collaborative water-management system for the basin (Squillace 2007)
Great Lakes–St. Lawrence River Basin Sustainable Water Resources Agreement	2005	Outlines framework for management system committed to in 2001 Annex (CGLG 2005a)
Great Lakes–St. Lawrence River Basin Water Resources Compact	2008	Establishes procedures and policies that constitute American adherence to the 2005 Agreement (CGLG 2005b)

Function and Governance of the Agreement and Compact

The goals of the 2005 Agreement are to maintain and strengthen cooperative and sustainable management, ecosystem protection, and data collection established in previous agreements. It also seeks to move beyond the previous agreements by adapting management models to changing climate conditions (which is quite uncommon for transboundary water agreements [Cooley et al. 2009]), emphasizing public participation in Basin management, and incorporating elements of the precautionary principle into the decision-making processes (CGLG 2005a, Squillace 2007). The Agreement is notable in that it provides a framework for jointly managing both surface and ground waters within the basin (CGLG 2005a).

The 2008 Compact also has a number of important features. Unlike the Great Lakes Basin Compact of 1968, which was consultative in nature, the 2008 Compact is legally binding and calls for state-level management plans that define a process by which to manage new withdrawals and diversions (GLC 2003, CGLC 2005b). The major stipulations agreed to in the Compact include (1) a requirement that each state create a program to manage and regulate all new or increased withdrawals in their jurisdiction; (2) stringent restrictions on new or increased diversions outside the basin; and (3) an inventory, registration, and reporting requirement for all withdrawals in excess of 100,000 gallons per day, among other provisions (CGLC 2005b). The Compact exempts removal of water in small containers (i.e., commercial bottled water) or water included in other products (e.g., beverages, paint) from its out-of-basin diversion restrictions (CGLC 2005b). It does not specify a threshold volume for regulation of withdrawals or a process by which to do so but, rather, leaves this to the individual states (Squillace 2007).

The Compact explicitly calls for the creation of the Great Lakes–St. Lawrence River Basin Water Resources Council to act as its main governing body. The Council consists of the governors of the eight U.S. member states, who are tasked with conducting research, collecting data, and overseeing disputes related to the water management of the basin (CGLC 2005b, Squillace 2007). Each member of the Council is given one vote, and decisions brought before the Council are decided by simple majority (CGLC 2005b). Each governor has veto power over any out-of-basin diversions (even when water is diverted out of basin but within member states) in excess of five million gallons per day (Squillace 2007). The Council of Great Lakes Governors (CGLG)—established in 1983 to promote regional cooperation on a wide range of issues—acts as the secretariat to the Great Lakes–St. Lawrence River Basin Water Resources Council (CGLC 2011). While technically a separate entity from the CGLC, the 2008 Council consists of the same membership and could be seen as an expansion of the CGLG's authority.

Support for and Criticisms of the Compact

The Compact has been widely supported and lauded for pioneering the way for sustainable and collaborative whole-basin management schemes across state and national boundaries. Many contend that whole-basin management that cuts across political borders provides a better opportunity to address concerns of sustainability and ecosystem health, and to generally manage and regulate the natural resource more coherently and effectively (Ericson 2007, Forster and Marley 2008, PEC 2008, Office of Betty Sutton 2008).

However, the Compact has also faced numerous criticisms, typically regarding ideological views on the appropriate ownership of water resources. Some, such as Ohio state senator Tim Grendell, believe that the Compact puts all water resources in the public trust, threatening property owners' rights to groundwater (Henry 2007, Oosting 2008). Others, such as U.S. representative Bart Stupak, assert that bottled water's exemption from the Compact's diversion ban may allow private interests to bypass the Compact and take Great Lakes water out of the public trust (Egan 2008).

In addition to these debates, some have questioned the effectiveness of the Compact's stipulations in meeting its stated objective of ensuring sustainable use of freshwater resources and ecological integrity in the Basin. For instance, one critique laments the Compact's and Agreement's marginalization of the International Joint Commission, calling the Compact a move away from true bilateral dispute resolution (as enacted by the Boundary Waters Treaty of 1909) to a largely subnational approach (Parrish 2006). Another contends that the Compact is inconsistent with respect to definitions for "diversions" and "products," potentially opening the door for weaker state control over water exports. This same critique argues that, despite apparent commitments to public participation and addressing climate change, the Compact in fact has few provisions that implement these commitments in meaningful ways (Olson 2006).

Professor Mark Squillace of the University of Colorado Law School has provided one of the most pointed critiques (see Squillace 2007). He contends that the Compact's focus on new withdrawals as opposed to existing withdrawals and consumptive uses severely limits its ability to address adverse impacts on freshwater ecosystems. He further argues that the Compact inappropriately restricts state power to divert water to areas within their state lines but outside the basin. Further, the Compact's ban on out-of-basin diversions may place greater strain on nearby watersheds that have less water to begin with, effectively transferring environmental impacts out of the basin rather than minimizing them. While prohibiting out-of-basin diversions, the Compact does not provide any stipulations on the diversion of water from watershed to watershed within the basin. Because of this, it may not adequately protect from significant ecological impacts in certain areas within the basin, particularly vulnerable upper watersheds (Squillace 2007).

Conclusion

Several decades of negotiations and legislation have led to the creation of the Great Lakes Compact—a unique transboundary, whole-basin approach to water management in the Great Lakes Basin. The Compact highlights a commitment to collaborative management of shared freshwater resources with the aim of preventing the disjointed and ineffective water management seen in many parts of the world. That said, given the highly sensitive nature of water—ecologically, politically, and culturally—the Compact has inevitably led to a wide range of concerns regarding its impacts on the environment, property rights, and states' rights, as well as debates as to whether it is structured in a way that best enables sustainable water use and ecosystem protection. Answers to these questions remain to be seen but will become clearer after the full provisions of the Compact come into effect and are implemented.

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