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Identifying Gaps in United States Federal Environmental Policy & Practice Through Greening Big Box Infrastructure

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A Dual Degree Capstone

Submitted to the faculty of Clark University, Worcester, Massachusetts, in partial fulfillment of the requirements for the degrees of Master of Science in the Department of International Development, Community, and Environment, and Master of Business Administration in the Graduate School of Management.

And accepted on the recommendation of

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Abstract

Identifying Gaps in Policy & Practice Through Greening Big Box Infrastructure

Elizabeth Kubacki

The purpose of this report is to identify policy and practice gaps in resource consumption reduction in the United States, and doing so by using big box retailers as the case study industry.

Through reviewing the history of U.S. federal resource reduction policies, and standard industry practices for greening big box infrastructure, I explore how regulations on sustainability and consumption agree with the Porter Hypotheses. By using the Porter Hypothesis as a theoretical framework for the regulation of green infrastructure in big box retailers, I will identify gaps in both literature and industry practices that can be filled by following the avenues outlined in the Porter Hypothesis. Private industry's responsibility to implement environmentally sound initiatives has been largely limited to federal policies that demand aggressive reductions in pollution and contamination. This report identifies where the presence of environmental regulation has spurred innovation, and where there are both policy and industry gaps, by using Wal-Mart, Target, and Costco retail stores as case study companies for comparison.

Intended audience: environmental consulting firms, mid-level, sustainably focused, management, corporate retail decision makers

Goals: Consolidate best industry practices for big box stores trying to green their infrastructure, identity gaps in best industry practices and offer solutions for the industry moving forward, using case study examples from Wal-Mart, Target, Costco.

Case Study Companies: Wal-Mart Stores Inc., Target Corporation, Costco Wholesale Corporation - Focus on United States markets only

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ACADEMIC HISTORY

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1.0 Background

In today's society, environmental regulation is often looked upon as a restrictive form of regulation that stifles economic productivity, impedes competition, and is costly. Environmental regulation traditionally focuses on the reduction of already existing pollution, rather than demand less pollution is created in the first place.

Big-box retail companies like Wal-Mart, Target, and Costco are all subject to different levels of federal, environmental regulation that affect their daily business practices, as well as their long-term investments.

Must environmental regulation and economic profitability be mutually exclusive in the big box retail space? No; however, there is currently little regulation that is both economically profitable and environmentally focused in the retail space. This report provides short, mid, and long-term recommendations for federal policy solutions that will reduce the carbon footprint of the big box retail space without sacrificing long-term profits.

1.1 Sustainable Infrastructure

Sustainable infrastructure in a broad context can be used to describe the facilities and systems used in a country, city, or town including, roads, bridges, tunnels, water supply, sewers, electrical grids, etc. For this paper, "sustainable infrastructure" is used more narrowly to describe aspects of infrastructure for big box retailers including, but not limited to: lighting, rooftops, water infrastructure, parking lots, and building materials.

The definition of sustainable development has long been debated, but a common definition is the designing, building, and operating of structural entities in ways that

"do not diminish the social, economic and ecological processes required to maintain human equity, diversity, and the functionality of natural systems" (RILA, 2017). This broad interpretation and/or concept of sustainable infrastructure can be adapted to both large and smaller scale projects; the concept of greening big box infrastructure focuses on designing, building, and operating big box retail stores to ensure that social and ecological pursuits are not forfeited for solely economic gains. Other definitions of sustainable development can be found in the appendix.

Corporations in the United States of America were put under fire in the early 2000's as globalization-generated issues like human rights, labor issues, and sustainability highlighted the self-interest and bottom-line strategies under which many companies operated while ignoring pressing environmental issues (Waddock, 2008). Recent sustainability efforts in corporate America have been fueled by new environmental laws and regulations, the 2008 economic recession, and global competitiveness (NRC, 2011). In 2015, global investment in core infrastructure (power, transport, water and waste, and telecommunications) was estimated at $3.4 trillion per annum, with expectations to increase to $5-6 trillion per annum in the next 15 years (Bhattacharya, 2016). Sustainable and green infrastructure practices such as green roofs, permeable pavement, and bio-retention and filtration systems, are all cost-effective methods for reducing storm-water, energy and water consumption reduction, reducing atmospheric CO_2, improving surrounding communities' livability, and reducing general consumption (CNT, 2010).

1.2 Sustainable infrastructure in big box retailers

Specific definitions of what a big box store is varies from state to state in the United States, however; most definitions tier to the square footage of the building instead of the amount of goods for sale on the inside of the store (Chazan, n.d.). The average big

box store ranges from 100,000 to 150,000 square feet. A store's footprint can be broken down into four components; the building footprint, the transportation footprint, the operational footprint, and the waste footprint (Chazan, n.d.).

Sustainable infrastructure is a big-ticket item for governmental projects and initiatives, and has made way into the retail space in the past decade. The U.S. Environmental Protection Agency (EPA) includes big box retailers as part of the commercial and residential sector, which accounted for 12% of total U.S. greenhouse gas emissions in 2015 (EPA, 2015). Big Box stores like Wal-Mart, Target, Costco, Best Buy, K-Mart and many others are prime examples of the vast applications of sustainable infrastructure due to their large parking lots, flat roof space, lighting needs, and internal water infrastructure. These massive storefronts place huge demands on already overstressed water and sewer systems, are usually built as "stand-alone" structures, require long, if not 24-hour lighting, increase the number of impervious surfaces, which increases erosion and surface runoff, can contribute to species habitat loss and wildlife fragmentation, and require a mammoth amount of construction materials input (Chazan, n.d.).

Figure 1 shown below, illustrates the size of these big box retail stores in comparison to other familiar landmarks (ILSR, 2008).

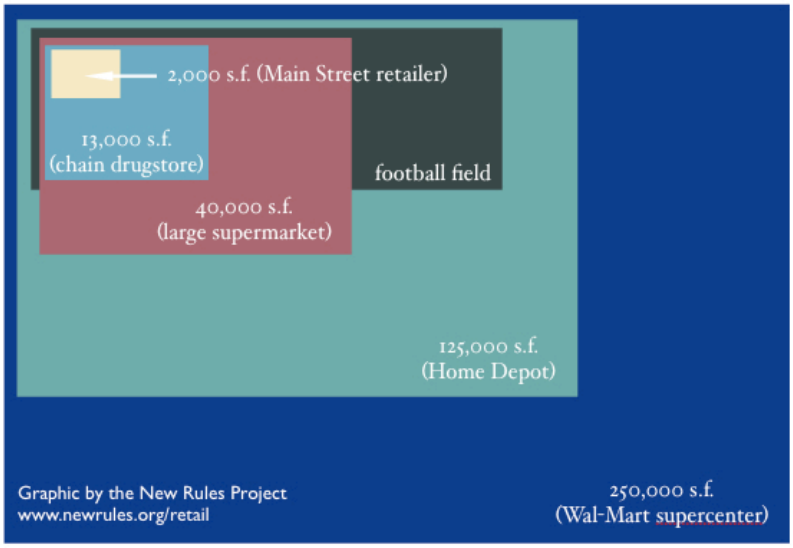


Figure 1 (ILSR, 2008)

A key industry trend in big box retailers is turning costs and risks associated with implementing sustainable infrastructure designs into opportunities for growth. Energy-saving and sustainable infrastructure technologies not only support the bottom line for these retailers by cutting usages and costs, but can also help contribute to customer comfort and a "green" image for the retailer, possibly leading to higher sales in some areas (ESource, 2010). Not bound by intense regulation, these retailers are discovering the increasing business case for sustainable infrastructure, and are beginning to shift focus from the fiscally focused double-bottom line to the social, environmental and financial, triple-bottom-line. The introduction of federal consumption reduction regulation for the big box retail industry would not only create inherent cost-savings, but also spur innovation, competition, and contribute to a more sustainable environment.

The purpose of this paper is to identify policy and practice gaps within U.S. federal regulation on green infrastructure by looking at Wal-Mart, Target, and Costco as case study companies. First, the paper establishes relevance of sustainable infrastructure in the public retail space in specific to big box stores. Next the paper reviews U.S. federal policies and regulation regarding industry infrastructure, and commonly adopted green infrastructure practices for five aspects of infrastructure: lighting, parking lots, water/water infrastructure, and building materials. This paper then applies the Porter Hypothesis as a theoretical framework to highlight the impact that regulation has on the progression of sustainable infrastructure and the creation and implementation of new technologies. This paper will finally identify gaps in policy and practice after reviewing the literature and include suggestions for future federal regulation concerning sustainable infrastructure and consumption.

1.3 Project Relevance

This paper was written in accordance with the Dual Degree master's program at Clark University which combines both a Masters in Business Administration and a Masters in Environmental Science and Policy. Identifying gaps in sustainable infrastructure for big box retailers integrates business management practices and environmental science. The purpose of this paper is to fulfill the dual degree program capstone requirement by combining business and environmental science into one succinct, interdisciplinary paper.

1.4 Theoretical Framework

In Michael Porter's and Claas van der Linde's 1995 article "Toward a New Conception of the Environment-Competitiveness Relationship", the scholars state that there is a misunderstanding of the framing of the relationship between ecology and economic growth (Porter & van der Linde, 1995). Porter argues that economic gains do not have

to be sacrificed to meet environmental goals, but instead suggests that environmental regulation can encourage innovation and competition within industries (Porter & van der Linde, 1995). After sighting numerous examples of where environmental innovation spurred, not hindered, the economics of private business, Porter and Claas van der Linde concluded:

1) Environmental regulations can reveal resource inefficiencies and potential technological improvements;

Porter and van der Linde claim that properly crafted regulation can help industries better understand incomplete utilization of resources, and can help lead to new approaches to minimize waste.

2) Regulation focused on information gathering can achieve major benefits by raising corporate awareness;

The authors state that gathering environmental information leads to environmental improvement "without mandating pollution reductions, sometimes even at lower costs" (Porter & van der Linde, 1995).

3) Regulation reduces the uncertainty that investments to address the environment will be valuable;

The more certain an industry is about an investment, companies are more likely to invest in any area.

4) Regulation creates pressure that motivates innovation and progress;

Porter argues that not any environmental regulation will provide industry pressures or economic benefit, but instead, *properly,* crafted regulation. Outside regulatory pressure can aid the innovation process and foster creative thinking.

5) Regulation levels the transitional playing field (Porter & van der Linde, 1995).

> During an environmental transition, when industry must make investments for compliance, regulation can provide a buffer until new technologies are streamlined and their upfront costs are reduced to ensure that one company does not gain an unfair competitive advantage by avoiding environmental investments.

This view of the relationship between economic growth and environmental regulation is particularly fitting to big box infrastructure due to the traditional lack of environmental regulation for these stores' infrastructure. When examining industries that are not heavily regulated, Porter and van der Linde's fifth finding regarding environmental regulation is particularly interesting; forms of environmental regulation can level the playing field for big box retails who have traditionally been exclusively focused on the double bottom line to shift to more sustainable practices that are potentially costly in the short-term, but have long-term cost savings and environmental benefits. Well-designed environmental regulation can provide both economic and environmental benefits by inherently protecting the environment, while encouraging competitiveness among industry to improve quality of products and services.

Examining how big box retailers can continue to build sustainably without compromising economic profitability, perfectly aligns with the tenets of the Porter Hypothesis. It is important to understand that the Porter Hypothesis is not claiming that all regulations lead to innovation, but that properly crafted regulations can spark competition and innovation. The Porter Hypothesis does not claim that this innovation will always offset the cost of regulation, but that it is possible in some instances. Ambec et al's., revision of the Porter Hypothesis, "The Porter Hypothesis at 20", gives empirical evidence on the impact of environmental regulation and deduces that there

is a positive link between regulation and innovation (Ambec et al., 2011). The Empirical Studies on the Porter Hypothesis chart, taken directly from Ambec et al. can be found in the appendix.

1.5 Research Questions

1. What are the U.S. federal policies/regulations regarding industry infrastructure?
2. What are the current retail industry green infrastructure practices?
3. What are the gaps in federal policy and industry practice for sustainable infrastructure?

1.6 Case Study Companies

1.6.1 Wal-Mart

Wal-Mart Stores Inc. (Wal-Mart) is an American retail company founded by Sam Walton in Arkansas in 1962 (Wal-Mart, 2017). With 11,695 stores worldwide, an annual revenue of US$485.87 billion, operating income of US$22.76 billion, and a net income of US$12.64 billion, the company is not only a household name, but an industry leader in the retail space (NYSE, 2017).

Wal-Mart supercenters, branded as "Wal-Mart" range from 69,000 to 260,000 square feet, and are about 187,000 square feet on average (Wal-Mart, 2017). Graphs 1, 2, & 3 illustrate company comparisons for Wal-Mart, Target, and Costco's annual revenue in 2016, CO_2e in 2013, and number of stores in the United States in 2017 (Costco, 2015) (Target, 2014) (Wal-Mart, n.d.).

1.6.2 Target Corporation

Target Corporation (Target) is the second largest discount retailer store in the United States, second to Wal-Mart Inc., founded as Goodfellow Dry Goods in Minneapolis, Minnesota, in 1902 by George Dayton. As of 2017, there are 1,806 stores in the United

States. Target has an annual revenue of US$69.495 billion, operating income of US$4.969 billion, and net income of US$2.737 billion (Target Corporation, 2017). Target storefronts range in size from 80,000 to 175,000 square feet, and are about 135,000 square feet on average (Wohl, 2012).

1.6.3 Costco

Costco Wholesale Corporation (Costco) is an American retailer company founded in Seattle, Washington in 1976. As of 2015, Costco is the second largest retailer in the world behind Wal-Mart (Target is the second largest *discount* retailer behind Wal-Mart) with 741 warehouses in the U.S., an annual revenue of US$126.2 billion, an operating income of US$3.672, and a net income of US$2.350 billion (Costco, 2016). While Costco differs in terms of retail product category (retailer vs discount retailer), their warehouse sizes are on-par with Wal-Mart and Target, ranging from 77,000 to 205,000 square feet, and averaging 145,000 square feet (Lee, 2015).

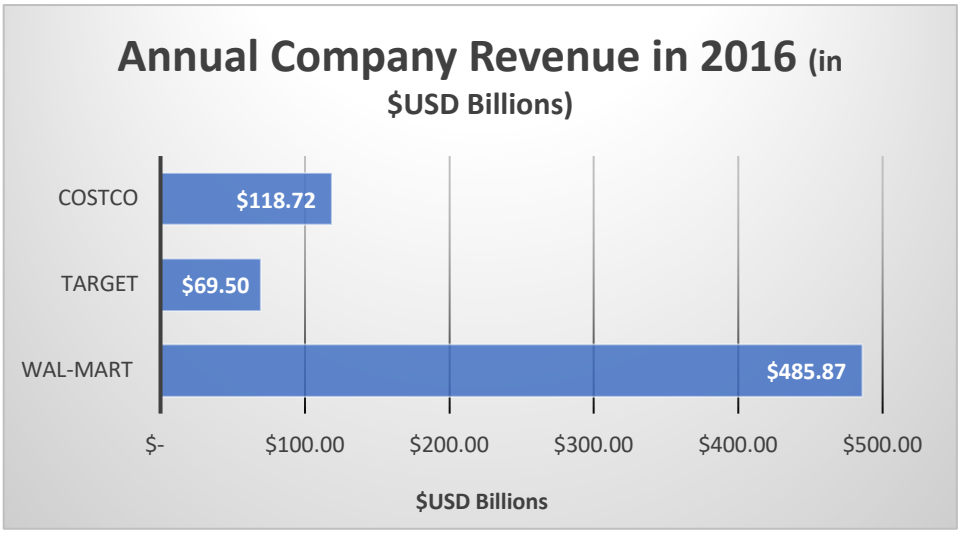


Chart 1 Annual Revenue in 2016 (in $USD billions)

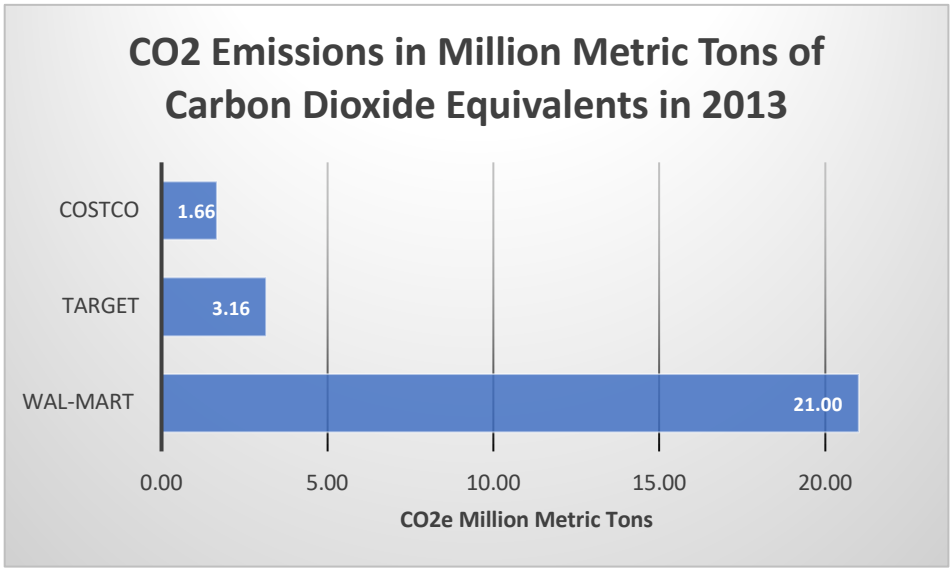


Chart 2 CO2 Emissions in Million Metric Tons of Carbon Dioxide equivalents in 2013

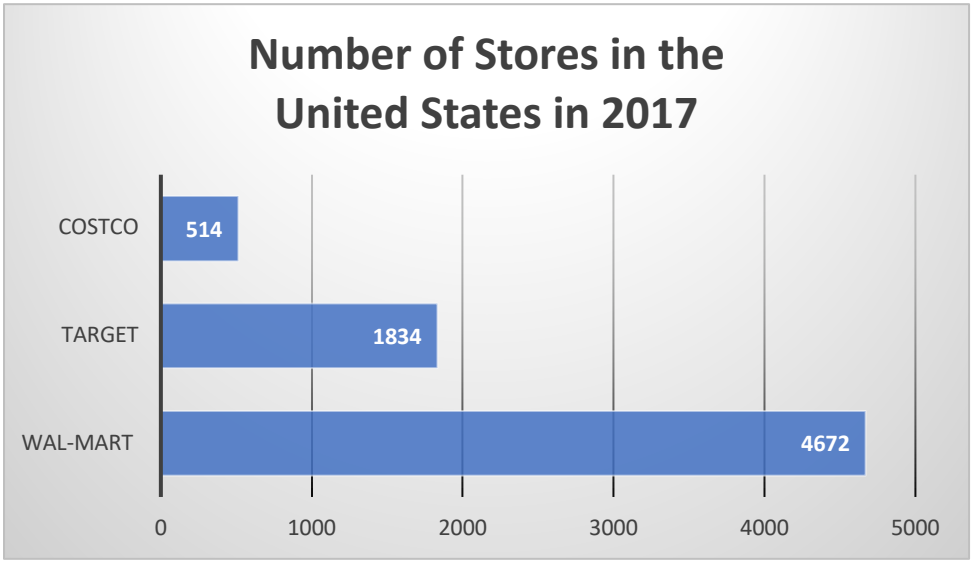


Chart 3 Number of United State Stores in 2017

2.0 Methodology

2.1 Literature Review

Research for this paper was conducted in three stages: a literature review, an analysis of the three case study companies, and information based on industry shifts as to the future of greening infrastructure in big box stores. The literature review informed a brief history of sustainable infrastructure in corporate America, current U.S. policies and environmental regulation, current sustainable infrastructure practices for big box retailers, and rising economic incentives for green infrastructure. This was done by reviewing several publications from corporate organizations dedicated to sustainable infrastructure, academic research institutes, academic papers, and U.S. government agencies. Specifically, these included the Grantham Research Institute on Climate Change and the Environment, Retail Industry Leaders Associations (RILA), papers by Antonio Vaccaro, Dalia Patiño Echeverri, and Petra Christmann on Corporate Transparency and Green Management, and "Best Practices" of Environmental Management on Cost Advantage, the U.S. Environmental Protection Agency (EPA) web publications, and the U.S. Energy Information Administration. This paper will provide in-depth information on current U.S. federal environmental regulation concerning specific aspects of infrastructure, as well as industry practices related to green building infrastructure.

Aspects of infrastructure for this paper will include:

a. Lighting

b. Parking Lots

c. Rooftops

d. Water Infrastructure

e. Building Materials

These specific aspects of infrastructure were strategically chosen as they offer the best opportunities for big box stores to green their infrastructure, in-house.

2.2 Case Study Companies

The purpose of using these companies as case studies is to identify a gaps in big box sustainable infrastructure, and in federal policy by understanding what technologies and methods are currently being used and what technologies and methods are missing. Wal-Mart, Target, and Costco were chosen as case study companies due to brand familiarity, physical size of stores, and revenue ranking based on the 2017 Global Powers of Retailing Report by Deloitte Touche Tohmatsu (Deloitte, 2017). In 2017, Wal-Mart was ranked the world's largest retailer with a fiscal year revenue of US$485.87 billion, followed by Costco at US$69.495 billion (Deloitte, 2017).

3.0 Findings and Discussions

3.1 Research Question 1: What are the U.S. federal policies/regulations regarding industry infrastructure?

This section identifies U.S. policies applicable to each aspect of infrastructure. Only federal acts will be discussed throughout this section; some acts will be listed more than once, as they are applicable to more than one research area. It is important to distinguish between laws and regulations: Laws are written by congress and provide the EPA the authority to write regulations: Regulations explain the technical, operational, and legal details necessary to implement laws (EPA, 2017).

3.1.1 Lighting

U.S. acts, laws, and regulation pertaining to light infrastructure that are relevant to retail stores include;

1) Energy Policy and Conservation Act (1975)- The U.S. Department of Energy (DOE) implements minimum standards for appliances and equipment used in residential and commercial buildings. This act covers requirements for energy and water conservation for appliances (EESI, 2017).

2) Energy Policy Act (2005)- The Energy Policy Act addresses energy production and include standards for: energy efficiency, renewable energy, electricity, and climate change technology. This act essentially provides tax incentives and loan guarantees for energy production of various types (EPA, 2005).

3) Energy Independence and Security Act (2007)- This act aims to, among other energy saving developments: increase production of renewable fuels, and increase efficiency of buildings. One of the key provision of the act are appliance/lighting efficiency standards (EPA, 2007).

4) The Office of Energy Efficiency & Renewable Energy within the DOE has established energy standards for certain lighting products and energy using commercial and industrial products (OEE&RE, 2017).

There are several regulations on energy and lighting efficiency, which include baseline consumption (using LED lightbulbs to reduce the amount of energy consumed for

leaving lights on for the same amount of time), however; there are no requirements to reduce actual lighting/electrical consumption.

3.1.2 Parking Lots

There is no federal regulation specific to parking lots. The most applicable federal law is the Pollution Prevention Act of 1990, described in detail below.

1) Pollution Prevention Act of 1990 (PPA)- This act focuses on reducing the amount of pollution through cost-effective changes in production, operation, and raw materials use via source reduction rather than waste management and/or pollution control. The EPA defines pollution prevention as “practices that increase efficiency in the use of energy, water, or other natural resources, and protect our resource base through conservation”. “Source reduction” includes any practice which; “Reduces the amount of hazardous substances, pollutants, or contaminant entering any waste stream or released into the environment (including fugitive emissions); prior to recycling, treatment or disposal; and reduces the hazards to public health and the environment associated with the release of such substances, pollutants or contaminants”, including the substitution of raw materials (EPA, 1990).

3.1.3 Rooftops

U.S. acts, laws, and regulation pertaining to rooftop infrastructure that are relevant to retail stores include;

1) Pollution Prevention Act of 1990 (PPA)- See Pollution Prevention Act (1990) as described previously in parking lots.

2) New DOE energy conservation standards for commercial air conditioners and heat pumps, commonly called rooftop units (RTU's) took effect on January 1, 2018. The DOE claims these new standards will increase efficiency by as much as 10% in 2018 and 24-30% in 2023 (AchrNews, 2017).

Much like other aspects of infrastructure in this paper, there are no specific standards that require rooftops to reduce material use, size requirements, or any focus on consumption reduction.

3.1.4 Water Infrastructure

Water infrastructure in the United States is mostly governed and controlled by regional or local water utilities. While national standards exist for water pollutant levels, there are no standards restricting the volume of water used for residential or commercial use.

U.S. acts, laws, and regulation pertaining to water infrastructure that are relevant to retail stores include;

1) The Clean Water Act (CWA) (1972)- The CWA regulates the discharges of pollutant into the waters of the United States and regulates quality standards for surface waters. The EPA has implemented pollution control programs for industry and have set water standards for all contaminants in surface waters.

a) National Pollutant Discharge Elimination System (NPDES) program- the EPA regulates point sources that discharge pollutants into waters of the United States (EPA, 1972).

2) Safe Drinking Water Act (SDWA) (1974)- The SWDA focuses on U.S. waters used for public drinking, above or below ground. The act allows the EPA to

establish minimum standards to protect tap water and requires owners and operators to comply with standards (EPA 1974).

3) WaterSense- WaterSense is a voluntary partnership sponsored by the EPA. The partnership program provides a label for water-efficient products, as well as acts as a resource for water-efficient products.

While there are enforcement measures in place by the EPA in terms of fines to ensure that industry is compliant with these regulations, actual compliance can go unnoticed when industry is not required to report on a regular and/or frequent basis.

3.1.5 Building Materials

In the U.S., the main building codes are the International Commercial or Residential (ICC/IRC) for electrical, plumbing, and mechanical codes, adopted by all 50 states and the District of Columbia. Building codes include standards for structure, size, usage, wall assemblies, size/location of rooms, energy efficiencies, etc., but do not set standards on types of materials (local, recycled, reclaimed) that must be used (ICC, 2017).

U.S. acts, laws, and regulation pertaining to building materials that are relevant to retail stores include;

1) Pollution Prevention Act of 1990 (PPA)- See Pollution Prevention Act (1990) as described in parking lots.

2) Toxic Substances Control Act (TSCA) (1976)- This act regulates the introduction of new and existing chemicals. The U.S. EPA has bans on asbestos and products that use asbestos.

3) The Clean Air Act (CCA) (1970)- The CCA primarily controls air pollution at a national level, but also banned asbestos-containing materials such as boilers, hot water tanks, spray-applied surfaces, and materials containing more than 1% asbestos. Several products used in the building of big box stores such as; cement corrugated sheet, cement flat sheet, pipeline wrap, roofing felt, vinyl floor tile, non-roof coatings, and roof coatings are not banned.

Other strategies used to make buildings more energy efficient include building codes, tax credits, utility rebates, and award or certification programs like ENERGY STAR. While these incentives and programs are not mandatory, they have the possibility of attracting some retails to participate based on cost savings.

3.1.6 Notable Regulation Practices

National Enforcement Initiatives (NEI)- Every three years the EPA selects National Enforcement Initiatives to focus on environmental problems where there are significant non-compliance problems. The EPA primarily focuses on protecting safe drinking water, reducing air pollution, and protecting safe and healthy land. There is essentially no federal focus for regulation to reduce consumption for energy, water, or materials for industry, and thus no enforcement.

Table 1 summarizes U.S. Federal Policies as described above.

U.S. Federal Policies	
Lighting	Energy Policy and Conservation Act (1975) Energy Policy Act (2005) Energy Independence and Security Act (2007)
Parking Lots	Pollution Prevention Act of 1990
Rooftops	Pollution Prevention Act of 1990
Water Infrastructure	The Clean Water Act (CWA) (1972) Safe Drinking Water Act (SDWA) (1974)
Building Materials	Pollution Prevention Act of 1990 The Clean Air Act (CCA) (1970) Toxic Substances Control Act (TSCA) (1976)

Table 1 U.S. Federal Policies

3.2 Research Question 2: What are the current, big box industry green infrastructure practices? (General and company specific)

The following research question will help detail big box industry standard practices in general.

3.2.1 Lighting

Big box stores use a sizable amount of lights and lighting systems to keep their buildings adequately and safely lit. Outdoor lighting includes everything from parking lot lights, lights mounted on the building, and logo and brand name signs on the outside of the building. Indoor lighting includes light fixtures for the entire store, emergency lighting, refrigeration and freezer lighting, and electronic displays. Installation of skylights, energy efficient fixtures, and up-to-date lighting controls can greatly reduce the carbon footprint and costs associated with lighting these stores and are common measures that several companies have already taken. Common light forms used in big box stores are detailed below.

a. Daylight with electric light supplement- This is currently the most popular method to reduce lighting needs inside stores. Daylighting focuses on using natural daylight to light products on the floor through skylights in the ceiling or walls. Additional lights are used to provide lighting/night lighting after the sun has gone down or in the absence of natural light. Automated dimming systems allow for a more controlled lighting environment and can reduce electricity usage (ALG, 2012).

1. Clerestories- Clerestories are a form of daylighting where vertical or sloped windows are located at the top of the store walls to admit daylight intermittently across the roof. Figure 2, below depicts the use of clerestories in a big box retail store.

Figure 2 (ALG, 2012)

2. Unit Skylights- these are individual skylights that are placed in the rooftop of a store to distribute daylight over the course of the entire day.

3. Tubular Daylighting Devices (TDD)- TDD's are normally produced as a unit and are domed skylight windows that protrude above the roof with an aluminum tube that redirects morning and afternoon sunlight. TDD's are popular as the aluminum tube absorbs much of the heat instead of being released into the building (ALG, 2012). Figure 3 below, depicts the use of a TTD.

Figure 3 (ALG, 2012)

b. LED lightbulbs- More energy efficient than halogen, linear fluorescent, compact fluorescent or HID lightbulbs, most big box retailers have retrofitted their stores with LED lights inside and out. Many LED bulb manufacturers are on their 4th or 5th generation design with each iteration being more efficient and less expensive. It is the prevailing view among industry lighting leaders that LED lighting will dominate the commercial and institutional lighting markets in a few short years (Burtner, 2016). LED lights in parking lots can not only decrease the environmental footprint of a store, but also lighting and operational costs. Wal-Mart for example, saves over 15 million kWh a year from LED parking lot lighting upgrades across 40 million square feet of parking lot space from 100 store locations (U.S.DOE, n.d.). Switching to LED lighting in parking lots has been shown to result in a 60% reduction of lighting power density, with a 60% energy savings reduction, in less than three years (U.S. DOE, n.d.). While having a higher upfront cost than traditional outdoor lighting, switching to LED outdoor lighting can result in cost savings for big box retailers. John Davison, Senior manager for Systems Design at Wal-Mart stated that the company recovered almost 80% energy savings by using energy

efficient, high intensity discharge lamps and a stream-lined maintenance program. (U.S. DOE, n.d.).

c. Light Layers- Layers of ambient, accent, task, and high bay lighting with separate control panels can reduce electricity usage as lighting can be customized as needed. Task lighting should be used for activities that require higher light levels like check-out counters and refrigeration cases (EarthTronics Inc., 2017).

d. Lighting Controls- Using automatic control panels and light sensors can reduce the need for indoor and outdoor lighting.

1. Daylighting Controls- Daylighting should be the primary source of light in the day time while automatic dimmers can be used to make the transition unnoticeable to customers.

2. Occupancy Sensors- Sensors can be used almost all throughout a store to reduce constant lighting. Offices, restrooms, irregularly occupied spaces, and refrigerators can all be controlled based on occupancy to reduce usage.

3. Refrigeration Monitoring and Control Systems (RMCS)-A RMCS system is usually a combination of time schedules, sensors, and remote access. These systems can be programmed daily, weekly, and annually to best fit a stores lighting needs (ALG, 2012).

Lighting Costs

Energy and electricity retrofits are one of the most common methods used by big box retailers to save money and electricity. According to Schneider Electric, over US$3 billion energy purchase expenditures could be prevented through energy efficient measures in big box stores (RILA, 2015). Lighting accounts for 35% of total energy use

in retail stores in the U.S. and US$1.05 billion in savings across the industry (RILA, 2015). Daylighting reduces the physical number of lights needed in a store and therefore, the upfront cost of the bulbs and the electricity used. Installing LED lightbulbs as discussed earlier, can save up to 50% of lighting costs when replacing traditional lightbulbs in and outside a store. Additional savings accumulate over time as LED bulbs last longer than traditional bulbs, require less maintenance, and have been shown to increase productivity by 3.2% according to the U.S. Green Building Council (RILA, 2015).

In addition to LED lights, daylighting can also help reduce energy costs. Research sponsored by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program exploring deep energy retrofits found that while upfront lighting equipment costs ranged from US$29-$30,000, annual energy cost savings were up to US$9,685 in cold climate zones, and US$6,625 in marine climate zones (RILA, 2011).

Table A1, found in the appendix shows the energy saving estimate for installing daylighting technologies in a big box retail store. Table A2, also found in the appendix, illustrates the total costs and savings in a financial analysis of installing daylighting technologies in a big box retailer. Table 1 provides energy retrofit daylighting estimates, while Table 2 provides a brief financial analysis. Both tables highlight the potential cost savings of utilizing daylighting techniques in different climate zones.

As seen in the financial analysis of Table A2, while hot and dry, and marine climates have negative Net Present Values for daylighting estimates, big box stores in most climates are make back their investments in seven to 11 years. It has been shows that adding skylights to only 3% of the total roof area of an average big box, and only two

daylight-responsive sensors to normal lighting systems can reduce total energy consumption by 13.1% to 19.9% yearly, and yield a total annual cost savings of US$6,800 to US$9,900 (RILA, 2011). When calibrated properly with the additional use of sensors, daylighting has been shown to save about $.024 per square foot in a big box store (RILA, 2011).

3.2.2 Parking Lots

The average Wal-Mart parking lot is equivalent in size to more than 12 football fields (Institute for Local Self-Reliance, 2006). Traditionally built of impervious asphalt for accessibility and masses of customers, big box store parking lots have potential to be transformed into greener and more sustainable spaces that retailers can use. Operational hours of most big box stores are long, if not 24-hours a day, meaning that these expansive parking lots are only occupied for short periods throughout the day. There are several different ways to transform these asphalt oceans into usable, profitable spaces. Current industry practices are described in brief detail in this section.

a. Pervious pavement- Parking lots are usually built of asphalt or concrete (GlobalGilson, 2017). Pervious pavement is an increasingly popular alternative technique to asphalt and concrete. Pervious pavement is a general term given to a range of sustainable materials and techniques that allow for stormwater to run through the surface (Colton, 2013). According to the U.S. EPA, “Permeable pavement transforms areas that were a source of stormwater into a treatment system and can effectively reduce or eliminate runoff that would have been generated from an impervious paved area. The infiltration rate of properly constructed pervious concrete and base generally exceeds the design storm peak rainfall rate.” (EPA, 2009). Benefits of pervious and porous pavement

techniques include; reduced stormwater runoff volume, flow rates, and temperature, increased groundwater infiltration and recharge rates, local flood control, reduced soil erosion and the need for traditional stormwater infrastructure, and increased traction when wet (Charles River Watershed Association, 2008). Figure 4 illustrates the schematics of permeable pavement, as defined and adapted by the University of New Hampshire (Charles River Watershed Association, UNH, 2008).

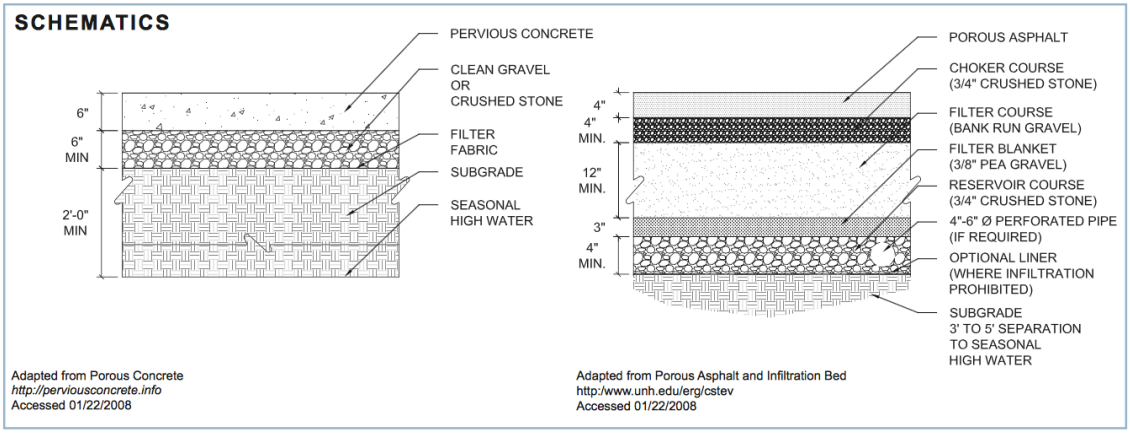
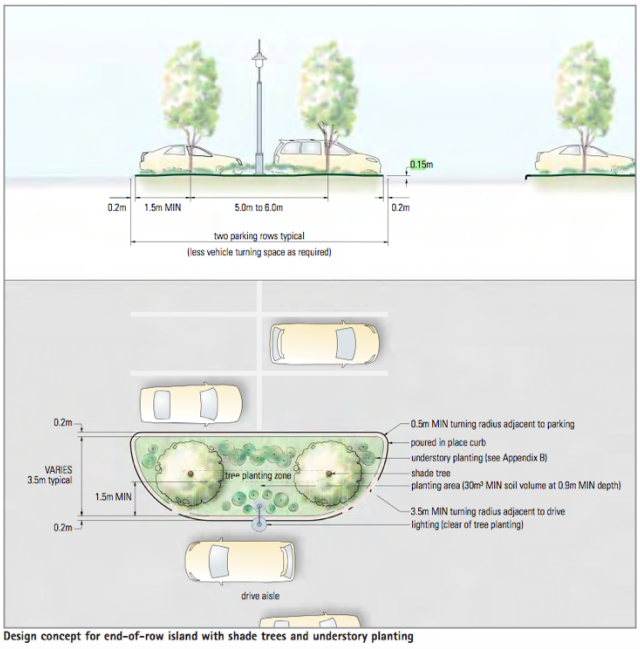


Figure 4 (Charles River Watershed Association, UNH, 2008)

b. Lighting- Discussed in the previous lighting section.

c. Landscaping- In addition to parking lot materials and lighting, landscaping and incorporating vegetation into parking lots can greatly reduce a store's carbon footprint. Trees, vegetation, natural slopes, and native soils can all be used to create a pleasant shopper experience, increase shade and stormwater benefits, and reduce runoff and erosion of the parking lot (Toronto City Planning, 2013). A single tree absorbs approximately 48 pounds of $C0_2$ a year, meaning that if only 10% of a big box parking lot was landscaped with trees, more than 35,520 pounds or 17.76 tons of $C0_2$ would still be absorbed (Toronto City Planning, 2013).

Figures 5 and 6 below, illustrate different design concepts for planting zones, row-to-row islands with tree shade, and landscaped medians, which can all be utilized in big box landscaping infrastructure.



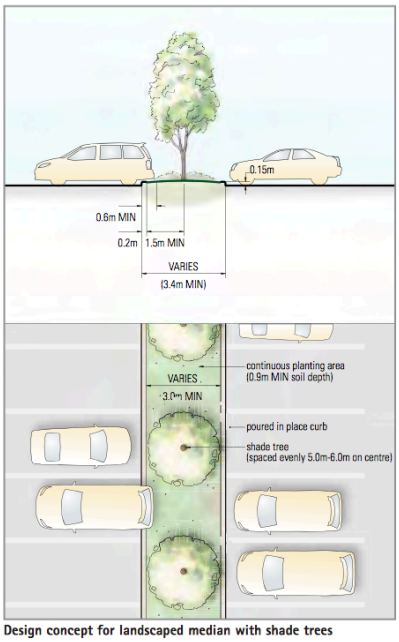


Figure 5 (Toronto City Planning, 2013).

Figure 6 (Toronto City Planning, 2013).

Other ideas that are relevant to big box stores but not discussed at length in this paper include lots being partially transformed into park and leisure spaces, with places for walkers, runners, and bikers to increase community engagement (Erjavec, 2001).

Parking Lot Costs

Due to the expansiveness of big box retail parking lots, pervious pavement techniques are more expensive than traditional building methods, ranging from US$7-$15/square foot. There are however, numerous studies that detail how permeable pavement is more cost effective throughout its lifecycle when considering additional design and

maintenance costs associated with traditional pavements (Colton, 2013). Additional research siting the costs associated with permeable pavement include; The California Stormwater Quality Association states that permeable pavements are 25% cheaper when lack of drainage costs are accounted for; University of New Hampshire Stormwater Center found that costs are 10-20% higher, but are often offset by eliminating the need for stormwater infrastructure all together; and a case study in Lake Country Forest Preserve, Illinois found that over a 25 year period, for a 40,000 square foot parking lot, the total cost of permeable concrete (including installation, maintenance and repairs) was US$190,700, compared to US$275,875 for conventional asphalt and concrete lots (IL, 2003).

3.2.3 Rooftops

An identifying characteristic of big box stores are their flat roofs; hundreds of square feet, usually unused. Big box retailers have started to tap into the potential uses of roof space by creating urban gardens, installing solar panels, and installing rainwater collection technologies. Current industry practices are described in brief detail in this section.

a. Green Roofs- Green roofs are rooftops that are partially or completely covered with several layers of waterproof membrane, root barriers, insulation layers, drainage layers, a growth medium, and vegetation (LIDC, 2005). When installed properly, green roofs require little upkeep, with weeding and soil and plant replacement as the main maintenance tasks (LIDC, 2005). Green roofs can reduce roof runoff volume, are more durable than traditional roofs, absorb noise, and can reduce the energy needed to cool a building (LIDC, 2005).

Case Study Example: City of Minneapolis Target Center Arena (Target Corporation is the original and current rights partner to the arena). In

2009, the City of Minneapolis reroofed the Target Center Arena with a 113,000-square foot green roof (TectaGreen, 2017). According to the city, the roof captures almost one million gallons of stormwater a year and prevents drainage into the Mississippi River (TectaGreen, 2017). The roof is expected to last twice as long as a conventional roof, and was built with a 20-year maintenance guarantee. The arena roof also mitigates the urban heat island effect, provides a wildlife habitat and greens the city view in addition to reducing stormwater runoff.

Figure 7 depicts the roof of the Target Center Arena from TectaGreen, 2017.

Figure 7 (TectaGreen, 2017)

b. Stormwater Catchment Systems- Several big box retails are using massive catchment systems to provide water through seasonally dry times of year. Home Depot has two stores in Florida and the Virgin Islands that capture stormwater into 500,000 gallon tanks that can irrigate 40-60% of the store's garden centers (Klettke, 2016). There are a variety of stormwater catchment

systems that range from simple collection barrels used to irrigate outdoor plants, to greywater, and completely filtered water filtration systems.

c. PV Solar Panels- Solar panels produce energy that can offset energy demand while contributing to cleaner power and a more sustainable power grid. Wal-Mart, Costco, Kohl's, IKEA, and Macy's have all installed rooftop solar, with Wal-Mart generating 142 megawatts of on-site solar energy (Weissman & Burr, 2016). The environmental benefits of installing solar panels are well known, with estimates of more than three million metric tons of CO_2 reductions in California, Texas, and Florida, and 300,000 to three million metric tons across much of the United States (Weissman & Burr, 2016). Figure 8 below illustrates solar panels atop a Wal-Mart in Buckeye, California.

Solar panels on a Walmart in Buckeye, Arizona. Credit: Walmart via Flickr, CC-BY 2.0

Figure 8 (Weissman & Burr, 2016)

Rooftop Costs

Green roof designs can reduce a store's CO_2 emissions, but can be costly and are not necessarily utilized or seen by customers. Unlike the installation of LED lightbulbs which saves money across the industry, the installation of green roofs should be

looked at on a case-by-case basis. Not every big box store should be outfitted with a green roof; factors not limited to but including; climate, usage, funding and costs, size, and maintenance should be taken into consideration when determining whether or not a store should be outfitted with a green roof.

Costs of stormwater catchment systems can be steep, and big box stores are usually only interested in investing in sustainable technologies if there is a significant and quick return on investment via energy, water, and electricity savings. Installation of rainwater catchment systems depends on the location and climate of the store; business cases for systems in stores in arid climates like Texas, New Mexico, Arizona, and California can be made as these states all experience long periods of drought, however; stores in the Pacific North West are less likely to need rainwater systems due to the climate.

The National Renewable Energy Laboratory estimates that the U.S. has the potential to generate nearly 25% of the nation's electricity demand through rooftop solar installations (Weissman & Burr, 2016). As of 2016, big box stores in America have the capability to host 62.3 gigawatts of photovoltaic capacity, equivalent to the electricity used by more than seven million average homes in the U.S. (Weissman & Burr, 2016). Industry estimates include annual electricity savings of 42% from rooftop solar panels, saving companies up to US$8.2 billion annually on their electricity bills (Weissman & Burr, 2016). Figure 9 illustrates the potential solar PV capacity on big box stores and shopping centers by state.

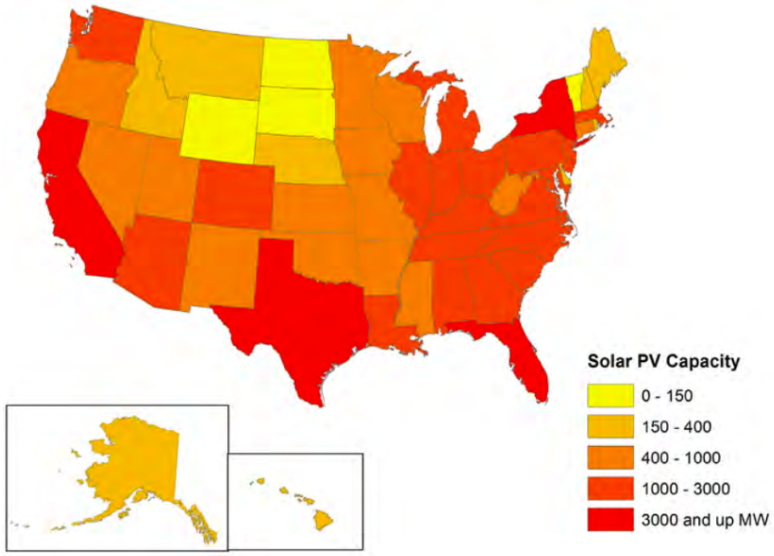


Figure 9 (Weissman & Burr, 2016)

In comparison, Figure 10 illustrates the annual reduction in CO_2 emissions with solar panels on available big box stores and shopping centers, by state.

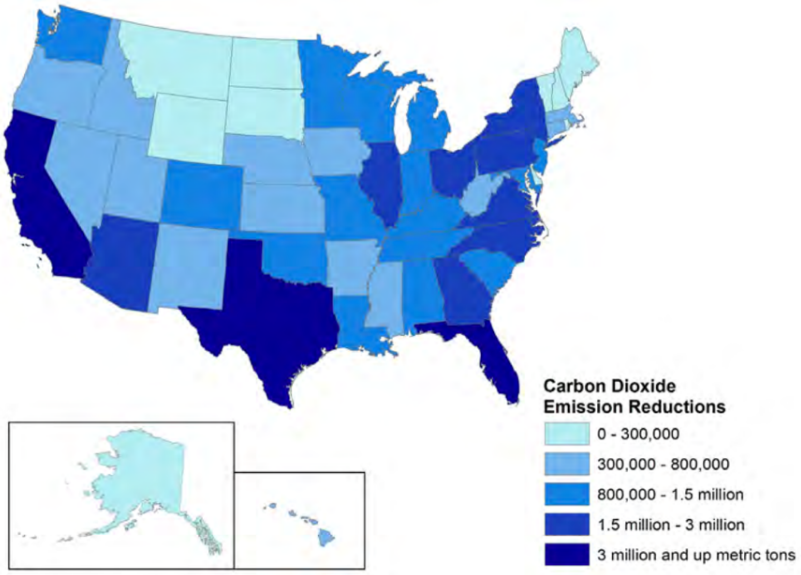


Figure 10 (Weissman & Burr, 2016)

3.2.4 Water Infrastructure

According to the U.S. General Services Administration, over 400 billion gallons of water are used every day in the U.S., which is the equivalent to 70,000 Olympic sized swimming pools (GSA, 2015). Like the electric grid, the U.S. has invested billions of dollars to build a network of pipes for drinking, waste, and stormwater.

Water infrastructure for utility companies and providers is heavily regulated in the U.S., however; there is not much literature on the regulation (if any) for retail businesses. While there are strict federal and state-wide regulations on materials that can and cannot pass through waterways, pipes, and U.S. waters, there are no required regulations for sustainable water infrastructure or resource reduction standards. Current industry practices are described in brief detail in this section.

a. LEED Certification- Leadership in Energy and Environmental Design (LEED) is a rating system designed by the United States Green Building Council (USGBC) to evaluate buildings based on environmental performance. LEED Certification is an optional certification and is not mandated (USGBC, 2017). LEED certification has five categories of water efficiency: 1) Outdoor water use reduction, 2) Indoor water use reduction, 3) Building-level water metering, 4) Cooling tower water use, and 5) Water metering (USGBC, 2017).

b. High-Efficiency Fixtures- High-efficiency fixtures are those that save energy and money from reduced water heating (GSA, 2015). Fixtures include toilets, faucets, and showerheads. Almost 80% of total water consumption from typical buildings in the U.S. is used for indoor usage (GSA, 2015). High-efficiency fixtures save more water than low-flow fixtures; high-efficiency

fixtures include 1.28 gallon per flush (gpf) toilets, and .05 gpf urinals, while low-flow fixtures refer to 1.6 gpf toilets, and 1.0 gpf urinals (GSA, 2015).

Water Infrastructure Costs

It is estimated that if widely implemented, high-efficiency fixtures could conserve 255-550 BTU's and an annual cost savings of US$8-10 million for the big box retail industry (GSA, 2015). While these fixtures usually have a higher upfront cost, the payback period is very short; on average, a 1.0 gpf toilet has a payback period of 2.7 years when replacing the industry standard 1.6 gpf toilet (GSA, 2015). Water and cost savings are variable and dependent on local water and sewer rates. While LEED certification includes water reduction techniques and technologies that have a higher upfront cost, those costs are mitigated over time through lower maintenance costs and lower energy and water usage.

3.2.5 Building Materials

Construction costs for U.S. buildings in general are on the rise. A freestanding big box store, (including concrete slabs, structural steel, structured masonry, a roof, HVAC, exterior wall assembly and insulation) runs an average of US$48.00 per square foot (Wilson, 2013). Research by Leo J. Shaprio & Associates showed that top concerns in material purchasing for big box retailers are life-cycle costs of materials, energy efficiency, maintenance concerns, and upfront costs of materials, respectively (Wilson, 2013). Compared to convenience, supermarkets, home centers, and specialty apparel stores, big box stores are the largest users of green construction materials with 88.9% of stores using green materials in some form. Certification does not seem to be a large driver of sustainable building materials as only 11.1% of big box stores are pursuing LEED or Energy star certification (Wilson, 2013). Current industry practices of building materials are described in brief detail in this section.

a. Steel- Steel is the most recycled material in the world with a 95% water reuse rate, and 100% recyclability rate (Whirlwind Team, 2015). Most retail stores are built out of steel due to the quick construction time, power efficiency, low maintenance costs, durability, and fire resistant nature of the material. Steel has a short return on investment and its common usage in buildings makes it a familiar material for construction crews.

b. Roofing Materials- Single-ply membrane rooftops are the most common among big box retailers; roofs are installed in one layer, are flexible in usage, and more UV radiation resistant compared to other roofing materials. Membrane materials include thermosets, neoprene, and thermoplastic membranes made of PVC and TPC with a reinforced layer of polyester or fiberglass (Rodriguez, 2017). Built-up roofs are another style commonly used in big box stores, generally composed of alternating layers of bitumen and reinforcing fabrics, also referred to as “tar and gravel” roofs. Not as common, but still used, are metal and asphalt rooftops.

c. Ceiling Materials- 2x4 foot acoustical panels are the most commonly used types of ceilings in big box stores, followed by open deck/plenum ceilings, and drywall/plaster, respectively. 2x4 foot acoustical panels are usually made from mineral fibers or fiberglass and are used due to their ability to absorb sound and reflect light. Open deck ceilings are increasingly popular as they better fit custom HVAC systems and are more flexible, dependent on a store’s needs, than traditional acoustical panels. There are a few private companies that offer state-of-the-art metal ceiling tiles from recycled content, but there are no comprehensive, sustainable ceiling options on the market today.

d. Flooring- The most common flooring materials are vinyl or resilient (VCT), carpet, ceramic tile, and wood. Types of materials used are variable depending on the climate, weather conditions, and usage each building is intended to receive, however; cost is the largest driver of flooring material used.

Building Material Costs

Using recycled materials to construct big box stores does not have to be more expensive than using traditional materials. Unlike lighting and water, there are no federal regulations for what big box stores must be constructed from, making cost the number one driver of using sustainable and recycled materials. If the upfront costs are too high, or the company does not accept the return on investment timeframe, sustainable building techniques are less likely to be adopted than techniques that are currently regulated and accepted.

Ceiling Costs

Studies have found that acoustical panel ceilings costs range from 15-22% more than exposed, open deck ceilings upfront, however; while stores would save the average US$2.25-3.00 per square foot costs for the ceiling panels with an open design, the additional costs associated with custom HVAC, lighting, and painting add up to make an exposed ceiling, more expensive overall (Armstrong, 2012). To justify the larger upfront cost associated with panel ceilings, big box stores should look for designs that are energy efficient, easy to maintain, and do not increase renovation costs.

Flooring Costs

Table 2 details the average cost per square foot of different, commonly used flooring materials in big box stores, the average assumed square footage of a store, and the total costs. Total costs do not include installation costs.

Material	**Vinyl**	**Carpet**	**Wood**	**Ceramic**
Average Cost per square foot	$2.50-$3.30	$2.00	$8-10	$1.30
Square footage of big box store	125,000	125,000	125,000	125,000
Total Costs	$312,500-$412,500	$250,000	$1-1.25million	$162,500

Table 2 (HomeAdvisor, Inc. 2017)

Table 3 summarizes the current green infrastructure practices described in detail above.

Current Green Infrastructure Practices	
Lighting	Daylighting- Clerestories, Unit Lights, Tubular Devices LED (Indoor and Outdoor) Lighting Layers & Controls
Parking Lots	Pervious Pavement Lighting Controls (Indoor/Outdoor) Landscaping
Rooftops	Green Roof Stormwater Catchment Systems PV Solar Panels
Water Infrastructure	LEED Certification High-Efficiency Fixtures
Building Materials	Support- Steel Roofing- Singly-Ply, Neoprene, Thermoplastics Ceilings- Acoustical Panels, Open Deck, Drywall

Table 3 Current Green Infrastructure Practices

3.3 Research Question 3: Where are the gaps in current industry standards for sustainable infrastructure?

3.3.1 Policy Gaps

The literature shows that while there are federal policies that cover portions of each aspect of infrastructure, there are no federally mandated acts or policies that focus specifically on resource reduction or consumption. In a liberal market economy like the U.S. where market mechanics determine the coordination between suppliers, customers, and financers, industry can be somewhat at odds with government and regulation. People and companies will accept regulation which requires new and more efficient technology for economic or environmental benefit, but have a harder time accepting regulations that mandate's how much of a commodity they can consume (especially in for-profit industries). Historically, the government has had a proactive role in protecting the rights of people, and a retroactive role in protecting the rights of the environment. This is seen from the subsequent environmental regulation of the 1960's in response to abysmal environmental conditions, to the lack of regulation following the warning messages of the Intergovernmental Panel on Climate Change's (IPCC) dangers of climate change and rising CO_2 emissions.

Practice gaps occur where there is no clear economic incentive for business to implement sustainable infrastructure, and additionally, where there is no federal policy. Areas like water and lighting have many more regulatory processes, initiatives, and support than focus areas like green building materials and parking lots, however; across the board there is no real enforceable act or regulatory standard for the reduction of materials, energy, or water. The language in the Pollution Prevention Act of 1990 is vague, making enforcement almost impossible. The retail industry and big box stores have proven to be innovative on occasion, however; it is clear through

identification of costs savings and environmental policy that industry rises to the occasion when an initiative is profitable and/or regulations are set in place.

3.3.2 Industry Practice Gaps

Through the analysis of Wal-Mart, Target, and Costco it is clear, that the retail industry has a set of informal standards for improving energy and water efficiency, and for materials usage as they are competitors, but there are no set guidelines (internal or otherwise) that demand an inherent reduction of materials, energy, or water. Due to the lack of documented profitability that can be associated with consumption reduction, big box retailers essentially have no incentive to reduce consumption; this is further exacerbated by a lack of regulation, which instead focuses on energy and water efficiency, recycled materials, and pollution prevention. If big box retailers believed that consumption reduction would save money, they would most likely consume less, regardless if federal policies mandated such or not; consumption reduction policies would merely be a catalyst for the big box retail industry to begin this type of reduction.

3.3.3 Analyzing policy and practice through the Porter Hypothesis

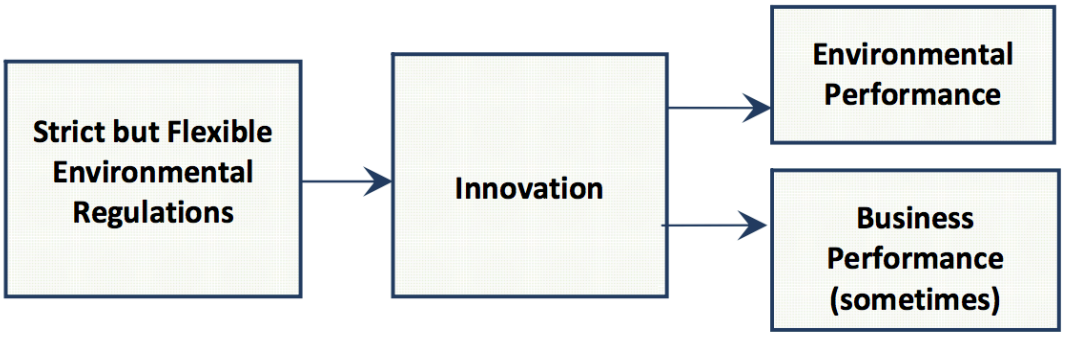


Figure 11 Porter Hypothesis (Ambec et al., 2011)

The regulatory history surrounding the retail industry and specifically big box stores and the innovations and sustainability measures taken from these regulations largely supports the premise of the Porter Hypothesis. The Porter Hypothesis states that properly crafted environmental regulation can spark innovation, which in turn can lead to improved environmental and business performance. This process is demonstrated in Figure 1. Federal regulations as well as cost savings on energy, water, and building materials, catalyzed the innovation of the retail industry, while the social pressure to improve corporate social responsibility fueled further environmental initiatives. Implementation of energy and water saving technologies have reduced resource demand once needed to perform the same tasks, and have catalyzed innovation for technology to further reduce energy, water, and materials. Below is a review of how the regulatory history of sustainable infrastructure aligns with the five principles of the Porter Hypothesis.

Five principles of the Porter Hypothesis (Ambec et al., 2001):

1) Environmental regulations can reveal resource inefficiencies and potential technological improvements;

General Discussion:

Environmental regulation pre-1970's was almost non-existent; environmental activists of the 1970's sparked the environmental movement, which lead to regulations like the Clean Air Act, The Clean Water Act, Safe Drinking Water Act, the Energy Policy and Conservation Act, and the Toxic Substances Control Act. These acts identified gaps between the regulatory process and industry practices. Carbon reduction and water saving technologies were developed, as well as

non-toxic building materials were introduced, that are now industry standard.

Application in Big Box Retail:

Due to these environmental regulations, big box retailers have been challenged (from a corporate social responsibility standpoint, rather than from a legal standpoint) to identify resource inefficiencies and combat these weaknesses with new, innovative designs for their stores; examples include, automated lighting systems, use of daylighting, use of organic and non-toxic materials in construction, stormwater management, and pollution prevention. Without regulatory and social pressures, these corporations would have little incentive to invest in these expensive technologies up-front, when "business as usual" practices are more cost effective. However, as stated before, there is a strong business case for big box retailers to transition to sustainable practices in some areas due to profitability. Unfortunately, there are currently no federally mandated regulations concerning consumption reduction that spark the transition to general consumption reduction for with which big box retailers could comply. While consumption reduction has already been identified as a policy gap, creation of consumption reduction regulation could further reveal inefficiencies in industry and push companies to reduce.

2) Regulation focused on information gathering can increase corporate awareness;

General Discussion:

Energy and water reporting regulations were passed to better understand consumption and usage of electricity and water. Implementing these regulations and technologies involves multiple stakeholders including government, private and public industry, and consumers. The R&D associated with developing these new technologies to comply with regulation increases awareness, usage, and promotion of efficient and green technologies within the public sector and their consumer base.

Application in Big Box Retail:

Through annual financial and environmental reporting, Big Box retailers are better able to understand their usage and consumption patterns, which can not only be used to innovate, but to also shed light on potentially overlooked areas within the industry. This can be seen in big box industry through energy and water consumption reporting. Once retailers like Wal-Mart, Target, and Costco began to understand how much of a resource they were using, they were better able to reduce their usage, which saved hundreds of thousands of dollars, as seen in the case of LED light bulbs for example. Although, consumption data collection has been collected through industry self-reporting, regulation does not have specific ratchet down requirements for water, lighting, or materials consumption.

3) Regulation reduces uncertainty that investments to address environmental concerns will be valuable;

General Discussion:

Federal regulations have stated demands for electricity, water, and materials standards that have reduced the amount of electricity needed to produce the same amount of light, water needed to produce same results, and toxins needed to produce reliable building materials, respectively. Technological advancements reduce costs of green infrastructure and practices yearly. Environmental regulation usually sets deadlines when goals must be met which incentivizes industry to invest in green technologies and practices to avoid fines and remain compliant. Proven savings from efficient lighting and water infrastructure further reduce uncertainty that investments to address environmental concerns will be valuable. Industry data clearly shows the cost savings associated with switching/investing in sustainable infrastructure.

Application in Big Box Retail:

Federal regulations for energy efficient lightbulbs, toilets, sinks, stormwater management techniques, etc. all ensure that overhead investments are valuable and can, in some cases, save companies money. LED lightbulbs are a classic example of a larger upfront cost that is more cost effective in the long term than traditional incandescent bulbs due to the lifespan of the LED bulbs. While the use of LED lightbulbs themselves were not federally mandated, the energy efficiency of LED's made them an attractive, inexpensive method to

reduce consumption and save on electricity costs. Industry is not currently being challenged by regulatory pressures to reduce consumption of any material or medium. Consumption reduction attempts have been limited to the efficiency of products rather than reducing usage. As seen with other environmental regulations like the CWA and CAA, regulation and investing in sustainable technologies can be profitable to industry and can reduce the uncertainty of economic profitability as every company must make similar investments.

4) Regulation creates pressure that motivates innovation and progress;

General Application:

The establishment of the Clear Air and Water Acts, the Pollution Prevention Act in 1990, and optional federal programs for energy and water efficiency like EnergyStar and WaterSense have paved the road for future progress for sustainable infrastructure. These regulations have resulted in an entire industry shift as seen in the implementation of green technologies in big box stores around the country, as well as the development of a new industry entirely based around developing sustainable infrastructure, materials, and technologies.

Application in Big Box Retail:

A combination of social, market, and regulatory pressures has shifted even Wal-Mart to a more sustainable mindset. Just ten years ago, big box retailers were not required to report any environmental benchmarks, nor were they self-reporting. Today, these large retail stores are held accountable (dependent on the regulation), for their consumption and sustainability efforts through federal and social

pressures. As seen in the company overviews, each retailer has partnerships and collaborations with outside organizations to try and focus on sustainability in attempts to reduce carbon emissions and save on the triple bottom line. Coupled with capitalist competition, proper environmental regulation has been seen to prompt innovation and progress within the big box retail industry. As seen with industrial development following the Energy Policy and Conservation Act, Energy Policy Act, and Safe Drinking Water Act, green technologies are more rapidly developed when industry is held accountable via regulation.

5) Regulation levels the transitional playing field;

General Application:

The introduction of environmental regulation required all industries to comply with federal mandates. Retailers across the nation were subject to adhere to the regulations and were all equally faced with the same challenges to implement and develop sustainable infrastructure that best fit their uses and needs. While certain companies began this environmental transition before others, the implementation of environmental regulation catalyzed efforts across the industry to develop technologies that would save time, money, and resources.

Application in Big Box Retail:

The ability of environmental regulation to level the transitional playing field for big box retailers is perhaps Porter's most applicable principle to the industry. Before regulations were set in place, large companies had little economic incentive to transition to more sustainable infrastructure that was more expensive upfront, regardless of environmental or long

term economic benefit. If there was no immediate economic incentive to implement or develop more sustainable technologies, companies were not going to invest. Target began releasing their Corporate Social Responsibility in 2007, followed by Wal-Mart and Target in 2009. Prior to social and federal regulatory pressures that demanded the industry to be more transparent in how they were giving back, companies had no incentive to reveal their tactics to one another and risk sacrificing market share. Porters fifth principle can also be seen at work in other areas of the big box retail space, such as companies investing in rooftop solar, rainwater catchment systems, permeable parking lots, and other sustainable technologies, all within a short time from one another. As regulation demands that all of industry must comply, one company is not disadvantaged by investing or implementing sustainable infrastructure. The introduction of properly crafted, federal consumption reduction regulation for the retail industry would most certainly level the playing field as all companies would be expected to comply, regardless of status or size.

3.4 Case Study Company Snapshots

3.4.1 Wal-Mart

A. Sustainability Reporting

Since 2009, Wal-Mart has released a customizable Global Sustainability Report. The Reports include company performance highlights, messages from the CEO and SCO, how Wal-Mart is leveraging their strengths to help others, a stakeholder engagement report, enhancing sustainability, promoting good governance, and a Global Reporting Index (Wal-Mart Sustainability Report 2017). Wal-Mart's current sustainable priority is to "enhance sustainability of global supply chains", by focusing on cost of goods sold, operating expenses, and supply security (Wal-Mart Sustainability Report 2017).

2017 self-reported company highlights are show in Figure 11, below.

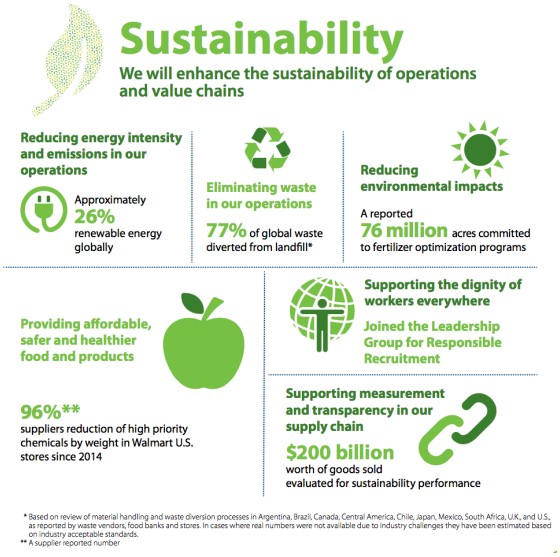


Figure 11 (Wal-Mart, 2017)

Since 2010, energy efficient measures have reduced energy use per square foot by 12% as of quarter three in fiscal year (FY) 2017 (Wal-Mart Sustainability Report 2017). At the end of FY2017, Wal-Mart upgraded parking lot lighting at 1,900 stores in the

U.S., and 5,919 high-efficiency rooftop heating and cooling units (RTUs) in 2015. 620,000 solar PV panels have been installed at Wal-Mart facilities in the U.S. since 2007.

Wal-Mart's relevant sustainability commitments for 2017 include; to be supplied by 100% renewable energy, to produce or procure seven billion kWh of renewable global energy, to reduce total kWh-per-square-foot energy intensity to power stores globally, and to double the number of on-site solar projects at U.S. stores, all by 2020 (Wal-Mart Sustainability Report 2017). The report lists, "pressure to develop land and use water supplies" as a challenge to reducing environmental impacts.

B. Implemented sustainability measures (Moseley, 2014)

Previous sustainability measures Wal-Mart has already implemented in stores, include (this is a general snapshot and not completely inclusive):

1) Switching from compact CFL lightbulbs to LED's in freezer and refrigerator cases in all new stores after a trial test in a Texas store in 2005 (Moseley, 2014). All newly constructed stores, nationwide, use exclusively LED's lighting inside and outside the building.

2) Rainwater collection in underground tanks in areas under water stress. New stores use high-efficiency urinals that reduce water consumption by 87% and high-efficiency toilets that use 20% less than required EPA standards.

3) Concrete flooring in some (but not all) newly constructed stores, which minimizes the use for chemical cleaners, waxes, and strippers.

4) Newly constructed stores are installed with white membrane rooftops to increase reflectivity and help reduce energy consumption from HVAC systems.

5) Skylights are used in congruence with timed artificial lighting to utilize daylight hours in many stores. For a typical Wal-Mart Supercenter, Wal-Mart claims this can save up to 25% of the energy used to light up sales floor.

6) Heat reclaimers in some (but not all) stores to recycle waste heat from the refrigeration system to heat hot water for restrooms and food preparation areas. The waste heat is sometimes used to warm interior spaces and cool buildings during the summer.

7) Over 1,100 stores have irrigation systems that monitor real-time weather, have site-specific water instructions, and include real-time remote controls. Wal-Mart claims these irrigation systems reduce water consumption needs by more than 32% per site.

8) Newly constructed stores use steel and other metals that can be easily recycled to build store frames. Wal-Mart claims that many of the adhesives and seals used are selected for high performance standards and minimum environmental impacts.

9) Wal-Mart is number one on the Solar Energy Industries Association (SEIA) list for producing 65,000 kW of soar power with more than 200 solar installations around the country.

C. Sustainability goals moving forward:

Since 2005, Wal-Mart has stated they are working toward operating on 100% renewable energy with half their operations being sourced from renewables by 2025. They are the first retailer with goals approved by the Science Based Targets initiative (see appendix). By 2025, Wal-Mart aims to reduce their emissions in internal operations by 18% and are working with their suppliers to reduce CO_2 emissions by one gigaton by 2030. Wal-Mart plans to have 1,000 solar installations by 2020.

D. Policy Conclusions

The internal literature does not state that Wal-Mart is attempting to lower their GHG emissions, energy intensity, or consumption due to environmental regulation, but rather due to costs savings, industry standards, and social corporate responsibility.

3.4.2 Target

A. Sustainability Reporting

Since 2007, Target has released a Corporate Social Responsibility report, in which the company self-reports sustainability efforts and goals. Their most recent report, 2016, has identified four areas in which their sustainability efforts revolve around: 1) Products, 2) Teams, 3) Communities, and 4) Planet. In addition to their annual Corporate Social Responsibility report, Target also publishes a Climate Change and Water report through the Climate Disclosure Project (CDP). Much of their sustainability efforts are focused on greening products and community engagement, and is thus outside the parameters of this paper and will not be mentioned. The 2016 Corporate Social Responsibility report lists several goals and which focus area they fall under. Goals and company reported progress relevant to the parameters of this paper are highlighted below in Table 4:

Goal- Focus Area Planet	Year	Progress	Next Steps
Achieve ENERGY STAR certification in 80% of buildings by 2020	2016	In progress	Next Steps: Achieved ENERGY STAR certification in 1,409 of buildings. Pursue ENERGY STAR certification. Anticipate meeting goal earlier than expected.
Reduce energy intensity per square foot in stores 10% by 2020	2010-2016	In Progress	Next Steps: Reduce energy intensity per square foot by pursuing efficiency projects in HVAC, lighting and refrigeration.
Add solar rooftop panels to 500 stores and distribution centers by 2020	2014-2016	In Progress	Next Steps: Installed solar arrays at 350 locations as of 2016. Named the No. 1 corporate solar installer in the U.S. by Solar Energy Industry Association. 2016 installations-entered Colorado, Maine, Michigan, New Hampshire and Wisconsin.
Reduce water use by 10 percent per square foot in stores by 2020	2010-2016	Exceeded	Next Steps: Achieved 2020 goal in 2016. Future initiatives include reducing water use by utilizing more efficient restroom fixtures and constantly innovating irrigation strategy to improve asset efficiency

Table 4 (Target Corporation, 2016)

Target's 2017 goals focus on responsible sourcing and packaging. Interestingly, the most recent CDP report, the Water 2015 Information Request Target Corporation, states that "Sufficient amounts of recycled, brackish and/or produced water available

for use" is rated as "Not very important" when asked "Please rate the importance (current and future) of water quality and water quantity to the success of your organization" (CDP, 2015).

B. Implemented Sustainability Measures

1) Rooftop solar panels on 350 buildings (157 sites in 2016) for a total capacity of 166.3 megawatts.

2) Many stores have implemented storm water systems in parking lots and grounds to collect rainwater. In 2016, Target incorporated native landscaping in 75% of landscape areas of all new stores.

3) Opening smaller format stores in urban areas to reduce environmental footprints in already densely populated cities and areas.

4) Interior Lighting Campaign Award for Highest Absolute Annual savings for Troffer lighting new construction by the Department of Energy.

C. Sustainability goals moving forward:

1) Achieve ENERGY STAR certification in 80% of buildings by 2020
2) Reduce energy intensity per square foot in stores 10% by 2020
3) Add solar rooftop panels to 500 stores and distribution centers by 2020
4) Reduce water use by 10% per square foot in stores by 2020

D. Policy Conclusions

The internal literature does not state that Target is attempting to lower their GHG emissions or energy intensity due to environmental regulation, but instead to satisfy the demands of the increasingly conscience consumer and cut costs.

3.4.3 Costco

Since 2009, Costco has published a Corporate Sustainability Report every three years. Costco's website states that they have three Sustainability Principles; 1) For Costco to thrive, the world needs to thrive. We are committed to doing our part to help, 2) We focus on issues related to our business and to where we can contribute to real, result-driven positive impact, and 3) We do not have all the answers, are learning as we go and seek continuous improvement (Costco, 2015).

Costco's website states their Sustainability Responsibilities: 1) Take care of employees, 2) Support the communities where our employees and members live and work, 3) Operate efficiently and in an environmentally responsible manner, and 4) Strategically source our merchandise in a sustainable manner.

A. Sustainability Reporting

The most recent report is from 2015 and includes a climate change statement, a carbon emissions footprint, development and site design, energy management, packaging designs and recycling and waste stream management (Costco, 2015).

Under the Climate Change Statement, Costco states that legislation and regulation on carbon dioxide emissions could affect compliance costs affecting energy inputs in the U.S. and could materially affect the company's profitability (Costco, 2015). The, development and site design section of the report highlight measures like automated

HVAC systems, skylight and daylighting techniques to reduce energy consumption, using energy efficient lighting, utilizing recycled materials, non-VOC floor sealants, and steel utilization techniques for building materials, heat reclaim tanks, and high efficiency restroom fixtures for water savings (Costco, 2015).

Unlike the sustainability reports of Wal-Mart and Target that are more focused on supply chains, and community engagement and development, Costco's sustainability report focuses on development and construction, and highlights measures that the company has already taken in their stores.

B. Implemented sustainability measures

1) Five stores across the U.S. are LEED certified (Varying degrees of Green, Silver, and Gold)

2) Property rehabilitation in Coralville, Iowa, and Queens, New York. Figure 12 illustrates the Costco store in Iowa. Figure 13 illustrates the Queens store

3) Bioswale pollution prevention

4) Bio-retention rain garden in Issaquah, Washington

5) Stormwater Management

6) Pervious pavement in Wilmington, North Carolina

7) Indoor/outdoor LED lighting

8) 38,900 kW of solar power on 60 stores with an average of 500 kW per store as of 2013. This amount of solar provides about 22% of each of the 60 stores energy needs (Finnigan, 2013).

9) Water sensors in over 50 buildings in the U.S. and Mexico that help cut water usage per store by 22% (Fehrenbacher, 2015).

Figure 12 Property Rehabilitation in Coralville, Iowa. (Costco, 2015)

Figure 13 Property Rehabilitation in Queens, New York. (Costco, 2015)

C. Sustainability goals moving forward

There is little information available on sustainable initiatives between three year reporting periods, and no relevant information to this paper on Costco's forward looking sustainability plans.

D. Policy Conclusions

Costco's sustainability report focuses on building infrastructure and greening measures the company has already taken. The 2015 sustainability report sites U.S. policies and regulations regarding climate change and those regulations having a possible detrimental effect on their bottom line, as a reason to invest in sustainable infrastructure.

3.5 Case Study Comparisons

In comparison to Wal-Mart and Target, Costco seems to be much more focused on reducing their carbon footprint via green infrastructure due to regulation. Costco's sustainability report explicitly highlights environmental regulation, factors associated with climate change that could adversely affect their business model, clearly states their emission sources, sustainability goals, and sustainable infrastructure projects such as property rehabilitation and bioswale pollution reduction. It is important to note that while all three companies are considered big box retailers, but that Costco focuses on bulk sales while Wal-Mart and Target do not. According to Costco, this model is inherently more carbon friendly than other retailers, as customers do not need to make as many trips to the store because they are buying in bulk.

Costco takes an interesting position regarding environmental regulation. While other retailers seem to regard regulation as restrictive to business practices, Costco points out that climate change is a significant topic for their clients and investors, and to better satisfy their needs, they take long-term, carbon reducing options seriously. When comparing the three company's sustainability reports, Costco is the most focused on greening infrastructure and seemingly more interested in environmental regulation than Wal-Mart or Target. Without consumption reduction policies in place, it is easy for companies to implement "low hanging fruit" solutions like replacing

lightbulbs to LED's and automation; Costco has taken the next step to implement full-blown, sustainably focused projects at a national level. This difference in focus on sustainable infrastructure could be because Costco only has 514 stores in the U.S. comparative to Wal-Mart with 4,672 stores and Target with 1,834 stores. Having fewer stores and higher revenues than Target, for example, allows Costco to focus on larger scale projects that require a higher upfront cost, but will pay themselves off over time. Coupled with environmental regulation, Costco has chosen to stray from the greening supply chain trend, and focus on their physical infrastructure because they have the resources and bandwidth.

4.0 Conclusion

The Porter Hypothesis identifies five avenues in which proper environmental regulation can stimulate competition and economic profitability in addition to being environmentally friendly. The big box industry is chiefly motivated by profit; any change in status-quo that has not been done before or does not show almost immediate return on investment will not be adopted by most industry leaders. It is clear though, that when environmental regulation has been passed, the big box retail industry has risen to the challenge of compliance and has met all five of Porters' principles, even if their primary motivation was economic and not environmental. The economic benefits of regulations like the CWA, CAA, PPA, and others can be seen in the cost savings for technologies such as LED lightbulbs, daylighting techniques, permeable parking lots, rooftop solar projects, improvement of water infrastructure, open designed ceilings, and ceramic flooring materials. The big box retail industry is an example of how properly crafted environmental regulation can spur innovation and competition, without sacrificing economic stability or growth.

It is important to explicitly state that there are currently no regulations concerning energy efficiency in big box retailers. According to the Energy Policy and Conservation Act of 1975, the U.S. Department of Energy establishes minimum efficiency standards for appliances and equipment used in residential and commercial buildings (EESI, 2017). Consumption reduction regulation is both the largest policy and practice gap in the industry, as examined through The Porter Hypothesis.

The implementation and development of federal regulation that addresses consumption is a cost-effective method to reducing energy, water, and materials in the retail sector as well as other sectors of industry. New technologies have reduced the amount of energy, water, and materials once needed to produce the same amount of output, however; this behavior does not encourage an actual reduction of consumption, instead only increased efficiency. Where there has been economic benefit, and environmental regulation to reduce pollution, waste, and other inefficiencies, industry R&D has risen to the challenge to compete on a global level. Consumption reduction regulation not only inherently reduces the amount of resources consumed, but can also continue to spur efficiency innovation.

5.0 Recommendations

To develop sustainable, consumption reduction regulation, the recommendations below provide a framework of best practices moving forward based on an accumulation of current industry regulations and practices, as well as regulation and practice gaps. Consumption reduction measures for big box stores can be categorized into three timeframes; Short-term, Medium-term, and Long-term solutions.

5.1. Short-term

Low-cost, short-term measures that help reduce environmental footprints and consumption; energy management, use of biodegradable cleaners, energy-efficient appliances, and turning off equipment. Short-term solutions are the “low hanging fruit" of consumption reduction. Energy management, biodegradable cleaners, and energy efficient applies all help to reduce the amount of energy, water, and materials used. Short-term solutions are the most cost effect method of reducing consumption immediately, as they do not require cutting-edge R&D or investments in new technologies. Much of the technology that is suitable to these short-term solutions has been in the market for years and have proven to be cost-effective solutions.

5.2. Mid-term

Physical, mid-term solutions require upfront expenditures but are more likely to result in larger cost savings and significant improvements in reducing the carbon footprint of the store such as installing water efficient toilets, climate control systems, improved insulation, installing skylights, creating stormwater absorption systems, building new energy-efficient and eco-friendly buildings, reducing parking lot sizes, introducing stormwater systems, using rainwater, and reusing materials as much as possible (Chazan, n.d.). Industry retailers at this point should also begin to use environmental reporting and tracking to their advantage, to better understand their consumption habits. Installing resource-efficient, bolt-on technologies in addition to building new store fronts with these efficient technologies is only one part of the solution; retailers must begin to develop strategic consumption profiles to be able to reduce inherent energy, water, and materials consumption in the future.

5.3. Long-term

These measures are solutions that engage stakeholders at all levels and focus on energy management and sustainable design. Long-term solutions focus on the actual reduction of materials and lowering consumption of energy and water. Industry leaders should collaborate with federal regulators to design effective consumption reduction policies that are cost-effective, timely, and enforceable. There are several barriers to introducing a consumption reduction framework that are not discussed in this paper and include but are not limited to: the creation of a “consumption credit” similar to a “carbon credit” for resource consumption, federal and state mandates, industry by industry regulation, public and private buy-in, and overall challenges to the efficacy of a consumption reduction mandate.

Table 5 below, lists the aspects of infrastructure, viable future regulations, and viable future industry practices based on findings and conclusions.

Aspect of Infrastructure	Viable Future Regulations	Viable Future Industry Practices
Lighting	• Expand efficiency standards beyond appliances and equipment • Develop industry wide standards to help overall electricity consumption • Establish deadlines for consumption reduction of electricity usage with a ratchet down schedule	• Commit to achievable reductions in electricity usage • Increase use of daylighting techniques and automation • Commitment to EnergyStar requirements for all appliances and equipment
Parking Lots	• Establish federal guidelines for new parking lot materials and sizes • Creation of recommended, sustainable materials which can be used to build new lots • Establish federal recommendations specific to parking lot landscapes	• Commitment to use pervious pavement when building new parking lots • Reduce outdoor lighting (following recommendations from *Lighting* • Commitment to increased landscaping when building new parking lots
Rooftops	• Establish federal guidelines for percentage of rooftop that must incorporate sustainable developments (gardens, rainwater catchment systems, rooftop solar, etc.) • Approved materials building future rooftops	• Industry commitment to using sustainable materials to build new rooftops • Industry commitment to using a percentage of the rooftop for sustainable projects • Develop a standard to use less materials to provide same amount of structural integrity
Water Infrastructure	• Establish a ratchet down program (similar to carbon credits) for water usage specific to each industry • Mandatory WaterSense requirements instead of a voluntary program	• Commit to industry standards of overall water consumption reduction • Industry commitment to WaterSence requirements for appliances and equipment
Building Materials	• Develop industry standards for external/partially recycled/local materials for building construction • Establish limits for raw materials that can be used in the building process	• Industry commitment to use more recycled/local building materials in flooring, roofing, and ceiling

Table 5 Summary of Areas of Focus' Current Policies and Viable Future Options

6.0 Limitations and Future Work

Limitations of this study included the use of secondary data sources to collect and compile general industry practices and associated costs, and a lack of available data on what federal regulation enforcement standards. Big box retail building trends are rapidly changing, and companies are already transiting to smaller, urban storefronts to appeal to city-dwelling consumers. Green infrastructure and consumption reduction is a constantly changing field with no, one consistent database for information on regulation at a federal or state level. A database that outlines federal and state policies on consumption reduction, who they are applicable to, reporting measure, compliance levels, and enforcement measures is recommended to improve information and data collection. As energy, water, and materials becomes scarcer, there is an increasing opportunity for industry to drive innovation, industry standards, and regulation through a ratchet-down on consumption, voluntary commitment program (much like carbon commitments today).

It should be mentioned that the future of big box retail has been questioned in recent decades as an entirely unsustainable practice that is losing steam. With Wal-Mart rolling out smaller, “Express” locations in 2011 to expand into the city market, big box retailers have begun to face the challenges of not being able to compete with city and online based retailers (Wal-Mart, n.d). Future work that looks outside the scope of this paper could include a projection of the practicality of the future of the big box retail industry.

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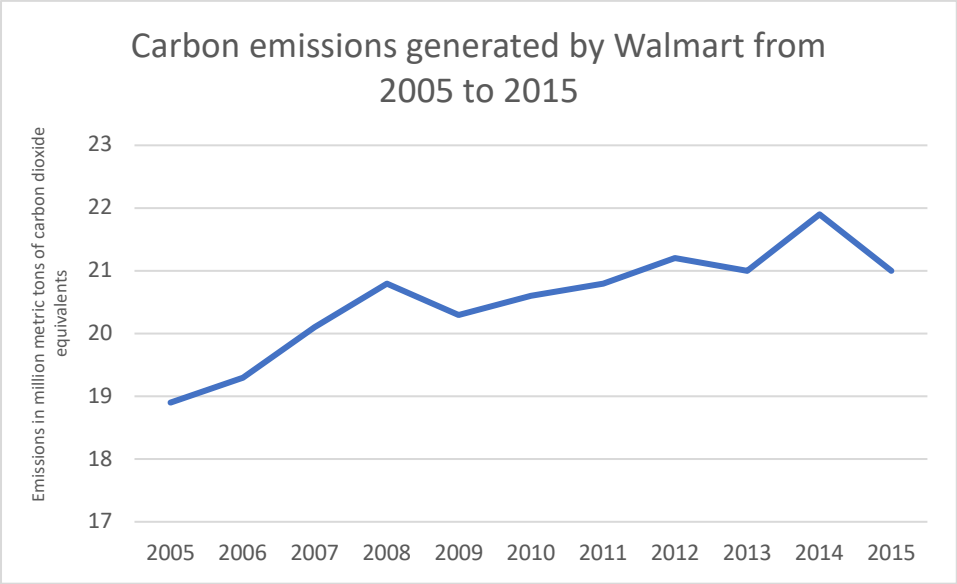
Appendix A

Carbon emissions generated by Walmart from 2005 to 2015 (Wal-Mart, n.d.)



Appendix B

Table A1: Advanced Energy Retrofit Daylighting Estimates (RILA, 2011)

Climate Zone	Electricity Savings (annual kWh)	Electric Demand Savings (peak kW)	Gas Savings (annual therms)	Site EUI Savings (kBtu/sf/yr)	Savings as % of Total Site Usage
Hot & Humid	$133,303	3	(2)	18.4	19.9%
Hot & Dry	$100,328	3	(70)	13.6	15.5%
Marine	$91,086	10	(189)	11.8	15.2%
Cold	$108,581	2	(398)	13.4	15.7%
Very Cold	$108,581	(2)	(789)	11.2	13.1%

Table A24: Financial Analysis (RILA, 2011)

Climate Zone	Equipment Cost	Install Cost	Total Cost	Total Annual Energy Cost Savings	Annual O&M* Cost Savings	Total Annual Savings	Simple Payback (years)	NPV
Hot & Humid	$29,456	$28,529	$57,985	$8,818	$217	$9,035	7	$26,151
Hot & Dry	$29,721	$40,890	$70,610	$7,499	$255	$7,754	10	$(1,125)
Marine	$30,780	$37,620	$68,400	$6,625	$250	$6,875	11	$(7,250)
Cold	$29,132	$49,441	$78,573	$9,685	$277	$9,962	9	$12,914
Very Cold	$29,014	$41,177	$70,192	$8,532	$252	$8,784	9	$10,210

*O&M represents operations and maintenance cost savings in Chart 2

Appendix C

Empirical Studies on the Porter Hypothesis (Ambec et al., 2011)

STUDY	DATA	METHODOLOGY	MAIN RESULTS
I. Impact of Environmental Regulations (ERs) on Innovation and Technology			
Jaffe and Palmer (1997)	▪ Panel of U.S. manufacturing industries, 1973–1991	▪Reduced form model ▪Innovation proxy: R&D investments and number of successful patent applications ▪ERs proxy: pollution control capital costs	▪ R&D significantly increases with ERs (elasticity: +0.15) ▪ No significant impact of ERs on number of patents
Brunnermeier and Cohen (2003)	▪ Panel of 146 U.S. manufacturing industries, 1983–1992	▪Reduced form model ▪Innovation proxy: number of environmentally related successful patent applications ▪ERs: pollution control operating costs and number of air and water pollution control inspections	▪ Small but significant impact of pollution operating cost on number of patents ▪ No impact of inspections
Nelson et al. (1993)	▪ 44 U.S. electric utilities, 1969–1983	▪Three-equation model: (1) age of capital (2) emissions; and (3) regulatory expenditures ▪Model includes two ER proxies: air pollution cost and total pollution control costs per KW capacity	▪ ERs significantly increase age of capital (elasticity: +0.15) ▪Age of capital has no statistically significant impact on emissions ▪Regulation has affected emissions levels
Arimura et al.	▪ Survey of 4,000	▪ Bivariate probit model with (1)	▪The perceived ER

(2007)	manufacturing facilities in 7 OECD countries	environmental R&D dummy regressed on various measures of environmental policy (perceived stringency, standards, taxes), an environmental accounting dummy, and other management practices control variables; and (2) environmental accounting dummy regressed on same variables	stringency has a positive and significant impact on the probability to run an environmental R&D program ▪The type of ER (standard or tax) has no significant effects on environmental R&D
Popp (2003)	▪ Patent data and performance measures of flue gas desulfurization units ("scrubbers") of 186 plants in U.S., 1972–1997	▪SO2 removal efficiency of new scrubbers regressed on the flow of knowledge (measured by patents) and policy variables ▪Operating and maintenance cost of scrubbers regressed on same variables	▪ The new SO2 emissions permit regulation introduced in 1990 increased SO2 removal efficiency and lowered operating and removal costs
Popp (2006)	▪ Patent data from the U.S., Japan, and Germany, 1967–2001	▪Impact of SO2 (U.S.) and NOX (Germany and Japan) ERs on patenting and patent citations ▪ERs: timing of the introduction of new ERs ▪Estimate the cross-country spillovers using patent citation origins	▪ERs followed by an increase of patenting from domestic firms but not from foreign firms ▪Earlier ERs for NOX in Germany and Japan are important components of U.S. patents for pollution control technologies to reduce NOx emissions
II. Impact of ERs on Productivity			

Gollop and Roberts (1983)	▪ 56 U.S. electric utilities, 1973– 1979.	▪ Productivity measure: derived from the estimation of a cost function that includes the ERs proxy ▪ERs: the intensity of SO2 regulations based on actual emissions, state standard, and the utility estimated unconstrained emissions levels	▪ ERs reduce productivity growth by 43%
Smith and Sims (1985)	▪ 4 Canadian beer breweries, 1971–1980.	▪Productivity measure: derived from the estimation of a cost function ▪Two breweries were submitted to an effluent surcharge and two breweries were not	▪Average productivity growth regulated breweries –0.08% compared to +1.6% for the unregulated plants
Gray (1987)	▪ 450 U.S. manufacturing industries, 1958–1978	▪ Change in average annual total factor productivity growth between the 1959–1969 period and the 1973–1978 period regresses on pollution control operating costs.	▪ 30% of the decline in productivity growth in the 1970s due to ERs
Barbera and Mc Connell (1990)	▪ 5 U.S. pollution-intensive industries (paper, chemical, stone- clay-glass, iron-steel, nonferrous metals), 1960–	▪ Derive the direct (abatement cost growth) and indirect (changes in other inputs and production process) effects of pollution control capital using a cost function approach	▪ Overall, abatement capital requirements reduce productivity growth by 10% to 30% ▪Indirect effect sometimes positive

	1980		
Dufour et al. (1998)	▪ 19 Quebec manufacturing industries, 1985- 1988.	▪ Total factor productivity growth regressed on changes in the ratio of the value of investment in pollution control equipment to total cost	▪ ERs have a significantly negative impact on productivity growth rate
Berman and Bui (2001)	▪ U.S. petroleum refining industry, 1987–1995	▪Comparison of total factor productivity of California South Coast refineries (submitted to stricter air pollution regulations) with other U.S. refineries ▪ ERs severity is measured by the number of environmental regulations each refinery is submitted to	▪Stricter regulations imply higher abatement costs; however, these investments appear to increase productivity
Lanoie et al. (2008)	▪ 17 Quebec manufacturing industries, 1985–1994	▪ Total factor productivity growth regressed on lagged changes in the ratio of the value of investment in pollution control equipment to total cost.	▪ ERs have a significantly positive impact on productivity growth rate, using lagged results, especially in the sectors highly exposed to outside competition.
Alpay et al. (2002)	▪ Mexican and U.S. processed food sectors, 1962–1994	▪ Productivity measure obtained through the estimation of a profit function that includes pollution abatement expenditures (US) and inspection frequency (Mexico) as proxies for ERs.	▪ US: negligible effect of ERs on both profit and productivity. ▪Mexico: ERs have a negative impact on profits but a positive impact on productivity.

Gray and Shadbegian (2003)	▪ 116 U.S. paper mills, 1979–1990	▪Regression of total factor productivity on pollution abatement operating costs, technology and vintage dummies and interaction terms between the dummies and the abatement variable. ▪ Estimation of a production function that includes beside input prices, pollution abatement costs and other control variables	▪ Significant reduction in productivity associated with abatement efforts particularly in integrated paper mills.
Managi (2004)	▪ U.S. state-level data, 1973– 1996, agricultural sector	▪ Regression analysis of Luenberger productivity indexes	▪ Mixed results
Crotty and Smith (2008)	▪ 37 firms in the UK automotive sector	▪ Qualitative questionnaire to verify the strategic response to a new regulation	▪ No support for Porter hypothesis
Rassier and Earnhart (2010)	▪ 73 U.S. chemical firms, 1995– 2001	▪ Regression of returns on sales on permitted wastewater discharge limits	▪Tighter regulations meaningfully lower profitability
Lanoie et al. (2010)	▪ 4,200 manufacturing facilities in 7 OECD countries, 2003	▪ Mail survey ▪ Three equations estimated with dependent variables: (1) presence of environmental R&D, (2) environmental performance, (3) business performance ▪ Key independent variables include perceived regulatory stringency and policy mechanisms	▪ Tighter ER increases R&D, which improves business performance; however, direct effect of ER is negative, and combined impact is negative (innovation offsets do not offset cost of ER)

Appendix D

Definitions of Sustainable Development

In 1987, the report by the World Commission on Environment and Development (WCED) defined sustainable development as “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs”(Rachuri, 2009); the U.S. National Research Council defines sustainable development as “the level of human consumption and activity, which can continue into the foreseeable future, so that the systems that provide goods and services to the humans, persists indefinitely” (Rachuri, 2009).