Technical Brief: Benefits of Using Cold Water for Everyday Laundry in the U.S.

Carole Mars

July 2016

Cold Water Wash Initiative
Home & Personal Care Working Group
The Sustainability Consortium

THE SUSTAINABILITY CONSORTIUM™

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Table of Contents

4 Introduction

5 **Consumer Attitudes**
7 *Consumer Perception*
7 **Environmental Impacts**
9 **Benefits of Cold Water Wash**

10 Effectiveness of Cold Water Wash for Household Laundry

10 **Definition of Cold Water**
12 **Laundry Basics**
14 *Innovation and Cold Water Wash*
16 **Laundry and Hygiene**

20 Conclusion

21 References

25 Annex A: Data Sources and Calculations

25 **Electricity Consumption Calculation**
31 **Cost per Load Calculations**

33 Annex B: Laundry & Hygiene

5 Figure 1: Why cold water wash?
11 Figure 2: U.S. average near-surface groundwater temperature
11 Figure 3: Plot of water temperature vs. time for Phoenix, AZ
13 Figure 4: Sinner Circle
19 Figure 5: Guidance on wash temperatures for different types of clothes

26 Table A1: References for energy consumption calculations
26 Table A2: Consumer washing behavior
27 Table A3: Representative inlet temperature for cold water and number of water heaters per census region
27 Table A4: Energy required to wash 7 loads of laundry weekly for one year
28 Table A5: Energy required by total number of washing machines by census regions
28 Table A6: Energy and carbon emissions savings nationally
31 Table A7: Cost of water per load of laundry
32 Table A8: Total cost of washing clothes per load
32 Table A9: References, Cost of a load of laundry

Introduction

Considering the consequences our society currently faces from climate change, finding points where consumer behavior can decrease current greenhouse gas emissions can provide great benefit for both the environment and society (IPCC, 2014; US EPA, 2015). In 2015, residential energy use represented 20% of the total energy-related greenhouse gasses, with the appliances related to washing steps for laundry (clothes washers, external water heating) accounting for approximately 2% of total residential use (Golden, Subramanian, Irizarri, White, & Meier, 2010). Based on the most recent residential energy consumption survey, washing clothes is responsible for 341 kWh of electricity consumption per household per year and 0.24 metric tons of greenhouse gas (GHG) emissions, which roughly correlates to driving 574 miles in an average passenger car (D&R International, 2012; EIA, 2013; US EPA, 2016). Lower emission rates are seen if a household has a natural gas water heater – 15 therms of gas consumption with 0.08 metric tons of GHGs, or driving 191 miles in a passenger car. These are not impressive numbers alone, but considering 100 million households in the U.S. use a washing machine in their home, changes in behavior related to washing clothes represents a significant opportunity to reduce the total use of electricity. If just one load of laundry per week was washed on cold instead of hot or warm cycles over the course of a year in households doing laundry, 2007 million kWh of electricity, 166 million therms of natural gas, and 2.3 million metric ton of greenhouse gas emissions could be averted, roughly equivalent to driving 5,498 million miles, or the amount of carbon that can be sequestered in 2 million acres of forest in the US. (USEPA, 2016; Figure 1). This space presents an opportunity to engage consumers and lower the overall impact of energy consumption of a US household (EIA, 2013).

The Cold Water Wash Initiative, launched by The Sustainability Consortium® (TSC®) and the American Cleaning Institute® (ACI), brings together a wide range of stakeholders whose interests intersect in the laundry room to develop consumer-facing messaging on the benefits of using the cold wash setting on a clothes washer for most laundry loads. The message will be targeted toward individuals responsible for doing the laundry in households within the United States. This report provides an overview of the challenges and opportunities related to using lower wash temperatures during residential laundry activities and the benefits and tradeoffs of doing so, both to the consumer and the environment.

A note on clothes dryers

Between washers and dryers, the clothes dryer consumes more energy during normal use. A study by Golden and colleagues shows that drying is responsible for 71% of the electricity required to wash and dry a load of clothes (Golden et al., 2010). While not currently directly addressed within this effort, any effort to improve environmental behaviors of consumers needs to take into account the impacts related to drying, as greater than 75% of households report using a clothes dryer with most loads of laundry and, in doing so, contribute to the environmental impact of laundry activities (EIA, 2013). Decreasing the impact of drying clothes does not present many routes for consumer engagement, and the most effective actions, such as line-drying or purchasing a new ENERGY STAR® certified dryer, require much more effort on the part of the consumer, greatly increasing the barrier to successful behavior change. Because of this, activities related to clothes drying are not currently included in the scope of the consumer messaging under development by the Cold Water Wash Initiative.

Consumer Attitudes

Understanding how the consumer launders today is a necessary starting point for determining how to influence consumer behavior. A survey was conducted in 2015 by ACI® to better understand consumer attitudes, perceptions and usage of cold water wash. This survey examined households in the US where laundry is completed on a regular basis, as well as a sample of college students who have the responsibility of washing their own clothes. The responses indicate that US households complete an average of five to six loads of laundry per week (ACI, 2015). The survey results concluded that on average, US households use cold water 45% of the time, warm water 35% of the time and hot water 20% of the time when doing laundry. Further analysis showed that while 13% of consumers say they do not wash in cold water at all, many have already discovered the benefits of cold water wash and claim that their use of cold water is on the rise. In fact, 3 in 10 people surveyed are washing more with cold water now than they were two years ago.

Even though cold water washing is accepted in many cases, the consumer survey found there is still an opportunity to increase the rates of cold water washing (ACI, 2015). After being presented with the message "Washing clothes in cold water saves energy and they still get clean," household and student survey participants both claimed they would wash more in cold water (+9% and +15% respectively). This sentiment was most noted in the group currently washing 26-50% of their loads in cold water. Additionally, about 8 in 10 consumers who plan to do more loads in cold water say they expect the transition to be easy. Even with this transition, the survey respondents acknowledged that there are limitations to cold water wash for purposes of sanitation as well as washing heavily soiled clothing types.

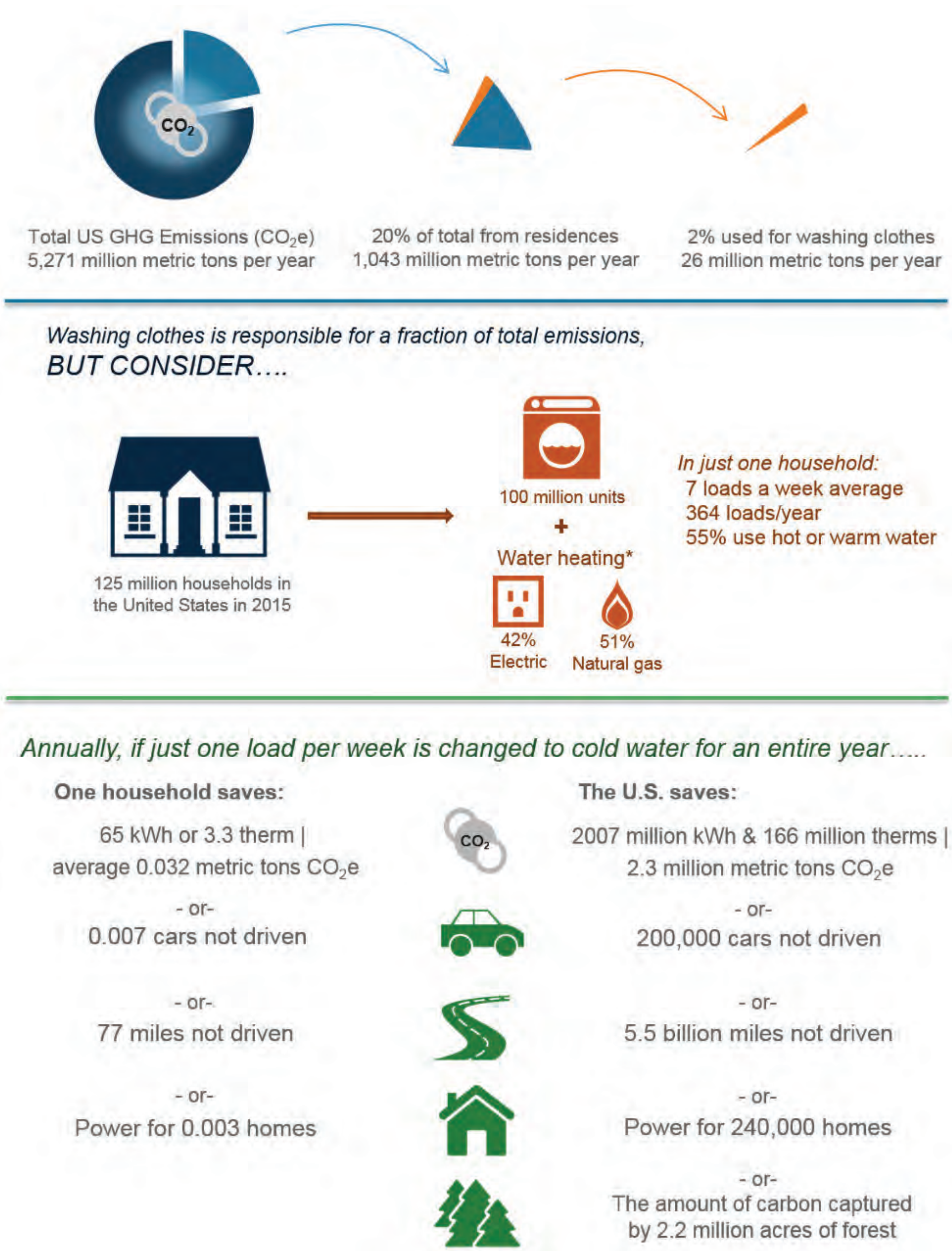

Figure 1: Why cold water wash?

* The 7% of water heaters unaccounted for in this figure use other fuels such as propane, fuel oil or solar as an energy source and are not explicitly included in these calculations. Data: EIA, 2013; EIA, 2016; US EPA, 2016. Calculations can be found in Annex A.

Consumer Perception

Consumers base their preferred water temperature for laundering on their perception of the water temperature's cleaning ability. In ACI's Consumer Survey on Cold Water Washing Habits in the United States, the most common sentiments consumers have about water temperature is that they should wash darks in cold water and whites in hot (ACI, 2015). Respondents also indicated that hot water is perceived by consumers as the best method for removing odors, stains and soils, whereas cold water is perceived to prevent laundry from losing its shape and prevent colors from bleeding and fading. Furthermore, the top reason consumers cite for not washing in cold water is a belief that it does not kill all germs. Perceptions that cold water does not clean as well as warm or hot, and that whites do not stay white when washed in cold, was also a commonly noted perception by consumers.

Environmental Impacts

The motivation for changing consumer behavior lies with the environmental impacts related to heating water for washing clothes. Life Cycle Analysis (LCA) reports from both the apparel industry (Cotton, Inc., 2012; Levi Strauss & Co., 2015) and the home care industry (Dewaele, Pant, Schowanek, & Salducci, 2006; Van Hoof, Schowanek, & Feijtel, 2003) have shown that clothing maintenance, i.e., laundering, is the most environmentally impactful stage of their respective products. The ecological footprints of both industries are impacted by the energy and water consumption of washing machines and dryers during clothes laundering.

In the most recent LCA completed by Levi Strauss & Co., fabric production and consumer care were determined to be the most impactful life cycle stages for both water and energy/climate change, with cotton fiber production contributing heavily to water use as well (Levi Strauss & Co., 2015). This study took into consideration the complete life cycle of a pair of jeans worn by an average U.S. consumer, from cotton cultivation through disposal of the garment at the end of its useful life. It included stages that were not directly controlled by Levi's, such as the consumer use phase. Further analysis of the consumer use phase results shows that the energy impacts derive from a combination of the frequency of washing, the temperature at which the garment is washed and whether the garment is line-dried or put in a dryer. One takeaway from this study is that encouraging the consumer to wash less, use cold water, and line-dry their jeans can significantly reduce both energy and water consumption over the lifetime of the garment, as well as increase the life of the garment.

To assist the cotton industry in better understanding the impacts of cotton textile production and the products made from that material, Cotton, Inc. conducted an LCA that included analysis of the consumer use phase for a knit shirt and woven pants worn and maintained by an average American consumer (Cotton, Inc., 2012). Their results are in line with those found by Levi's: Consumer use and textile manufacturing account for significant water and energy consumption impacts. For water consumption, though, both the use and manufacturing stages are less impactful than the agricultural production of cotton. This study looked at three use scenarios, based on consumer behavior data, when considering clothing maintenance: the worst case, including heated wash (hot or warm water) and machine drying; the best case, including cold water wash and line-dry; and an average case (52-54% cold water loads with the remainder using heated wash water) for American households. The best case scenario found a significant decrease in energy consumption for clothes washing and drying. Based on this study, next steps for this organization include consumer education on clothing maintenance to decrease the environmental impacts of the consumer use phase.

An LCA study conducted for Procter & Gamble in 2003 also shows that the primary water and energy impacts related to the manufacture and use of laundry detergents are found in the consumer use phase (Van Hoof, Schowanek, & Feijtel, 2003). This study compares the full life cycles of different types of laundry detergent (powder, liquid, concentrate, etc.) to determine if any particular type was better or worse for the environment. They determined that there was little to no difference between the formulations, especially considering that the impacts related to the consumer use phase were significantly larger than all other life cycle stages. A second study conducted in 2006 compared the life cycle of a standard formulation of Ariel laundry detergent with that of Ariel detergent formulated for cold water wash (Ariel Actif-à-Froid) in France (Dewaele, Pant, Schowanek, & Salducci, 2006). The results showed that, when the average French consumer used the cold water formulation and followed the instructions provided with the detergent, there was a 27% reduction in primary energy consumption compared to the standard formulation, with no increase in the environmental impacts related to the change in formulation. Taken together, encouraging consumers to use cold water wash can decrease the environmental impact of washing clothes.

Showing that the benefits derived from changing consumer behavior in the laundry room are relevant in other regions, a LCA was conducted for the EPA Victoria and City West Water in Melbourne, Australia (Koerner & Turk, 2010). Here, the goal of the LCA study was to create recommendations for the city on how to “enhance the resource efficiency and reduce environmental impacts associated with domestic clothes washing.” This study found that how consumers washed clothes constituted the largest impact within the appliance life cycle and led to recommendations of using detergents at the correct dosages, using cold water wash cycles, and line-drying when feasible to reduce impacts.

A final study showing the environmental gains related to reduced wash temperature, in particular with respect to carbon emissions, was published by Novozymes in 2010 (Nielsen, Neal, Friis-Jensen, & Malladi, 2010). As part of a North American study to understand environmental and toxicity impacts or benefits when surfactants in liquid detergent formulations are replaced with enzymes, the authors studied the impact difference when the wash temperature was 59^{o}F rather than the baseline assumption of 86ºF. A decrease of 300g of CO_2 equivalents per load was seen for the same formulations at the two temperatures due to the decrease in energy consumed to heat water. Additionally, the study looked at cleaning efficacy of the formulations tested and showed that, with formulation innovations such as including enzymes, consumer can be assured of results as good or better at lower water temperatures as they currently experience with standard formulations and warm water.

When discussing laundry, improvement opportunities lie with the choices of the consumer. Enabling and encouraging consumers to use cold water on the majority of their loads will help counter energy usage and water impacts.

Benefits of Cold Water Wash

Not only does modifying consumer behavior help the environment by reducing energy consumption, it may also help the consumer save money over time. A household may save anywhere from $60 to over $200 a year and save greenhouse gas emissions equivalent to driving approximately 1,000 miles by using cold water wash and rinse instead of hot or warm water for the same functions (Consumer Reports, 2014; Hamm, 2012; US EPA, 2015).

For the consumer, using the cold water setting on their machine is associated with maintaining the fit and feel of their clothes, especially those considered delicate. A study by Easter and Ankenman investigated the impact of cold wash cycles on textiles in the context of washing machine technology changes driven by energy efficiency standards (2006). The researchers determined that lowering wash temperature from 90ºF to 70ºF "does not affect color retention, fuzzing and pilling, and soil redeposition". They also noted that another 10º drop in water temperature showed mild adverse effects on the test textiles. A second study further investigated how different wash temperatures and detergent types in different types of washing machines influenced color retention, pilling, shrinkage, moisture content, residual moisture content, and stain removal (Easter, Cinnamon, & Baker, 2012). Using full consumer loads of different textile compositions, they determined cold water cycles and using high efficiency cold water detergents performed best when considering color transfer, shrinkage and fabric smoothness retention. When considering stain removal, the cold water conditions did not perform as well.

Similar results were noted in a study by Laitala and colleagues that at the lower temperature, there was less change in the textiles themselves, especially with respect to color retention and shrinkage of the material samples. Drying was also studied, showing that tumble drying produced softer textiles (compared to line drying) and reduced pilling of material, but caused shrinkage and decrease in fabric strength, in at least some of the different types of materials tested (Laitala, Boks, & Klepp, 2011).

Effectiveness of Cold Water Wash for Household Laundry

Washing clothes using heated water (hot and warm cycles) and machine-drying clothes consumes significant amounts of energy, and both actions have alternatives readily available to the average consumer. Over the last ten years, the technology found in the laundry room has evolved, making low temperature wash cycles more effective than in the past.

Definition of Cold Water

Determining the actual temperature of water in a washing machine in the United States is challenging. Rather than selecting an absolute temperature as in some parts of the world, consumers here have generic temperature setting options – essentially cold, warm, and hot. The actual water temperatures that correspond to these generic settings vary widely, and may impact the cleaning and sanitizing effects on a load of laundry if not accounted for appropriately, as is discussed in the Laundry Hygiene section below. Because of this, defining and understanding what is "cold" in the United States is necessary for an effective discussion on the opportunities associated with behavior change around laundry temperature settings.

Household hot water wash temperatures in the United States are determined by the temperature set point on the water heater. The U.S. Consumer Product Safety Council recommends that water heaters be set to 120ºF in order to avoid scalding household water users, which sets the upper limit for water temperature in a household (CPSC, 2012). "Cold" water wash temperature, referred to as "tap cold" on some machines, is the inlet temperature of water delivered to a residence from the water mains. The actual temperature of cold water entering a household varies significantly based on the source of the water (e.g., on-site groundwater well versus public water supply), the time of year, and how deep pipes are buried between the source and the residence. The average inlet temperature can range from 37ºF in Anchorage, AK to 82ºF in Phoenix, AZ (GTX Technologies, 2001). The scale of potential temperature variation is reflected in Figure 2, which shows how average groundwater temperatures vary across the U.S. These values do not necessarily represent water temperature in a residence, as noted by the delivered temperature to an average household in Mesa, AZ, a suburb of Phoenix. Figure 3 further underscores the difficulty in accurately describing household cold water temperature by providing the temperature of water in Phoenix, AZ over the course of two years when stored at the surface or conveyed to a household in pipes at three different depths (Burch & Christensen, 2007).

Defining warm is more complicated. One familiar source of information regarding wash temperature for consumers is the fabric care symbols on clothing tags. Defined

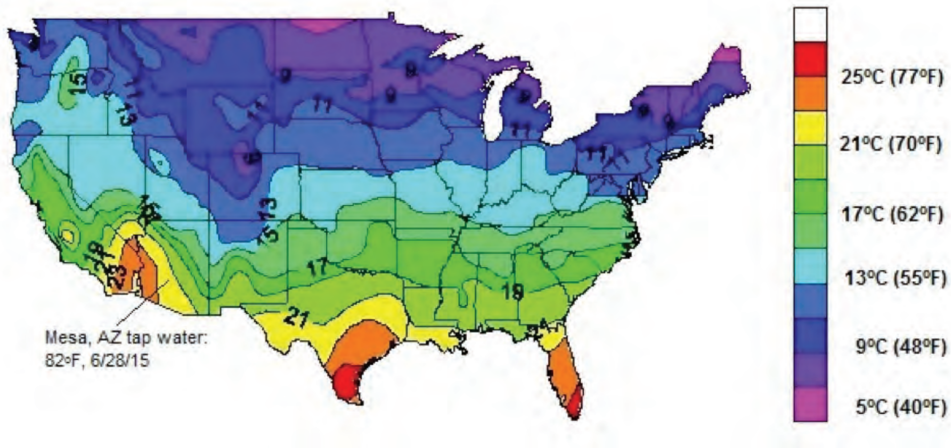

Figure 2: U.S. average near-surface groundwater temperature (oC) (SMU, n.d.)

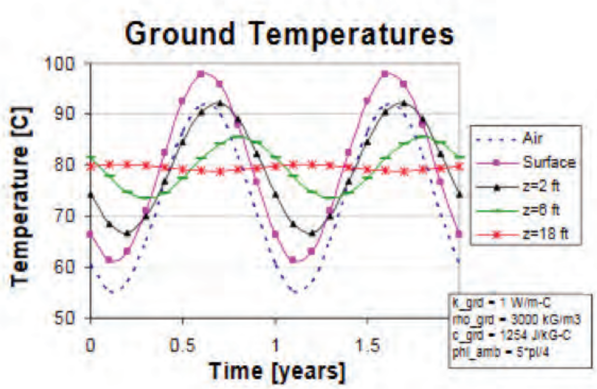

Figure 3: Plot of water temperature vs. time for Phoenix, AZ (Burch & Christensen, 2007)

by ASTM D5489-14 and regulated by the Federal Trade Commission, the "Machine Wash, Warm" symbol indicates that the initial water temperature should not exceed 105ºF (FTC, n.d.; Textile Affairs, 2010). The lower boundary of the warm water range is 85ºF, which is the upper bound for cold wash water. Consumer Reports®, when testing laundry detergent, uses 90ºF for warm water test loads (Consumer Reports, 2016a).

These values represent expected ranges of temperatures for warm wash cycle water, the actual temperature is controlled by the washing machine itself. On the majority of machines on the market since 2007, automatic temperature control (ATC) has been a standard feature (Mauer, deLaski, Nadel, Fryer, & Young, 2013). This feature mixes incoming hot and cold water to reach a target temperature set by the manufacturer, which allows the machine to compensate for colder incoming water temperatures. This not only controls the warm water temperature, but can modify the cold and hot water temperature as well. Previously, warm water was just hot and cold water mixed in a preset ratio without any temperature feedback loops (GE, 2016; Samsung, 2015a). The target temperatures vary by manufacturer, and can often be difficult to determine, as this value may not be reported in the owner's manual (GE, 2015a; LG, n.d.; Maytag, 2015; Samsung, 2013). Reports on repair forums and other troubleshooting sites indicate that the warm water cycle target temperature on older machines is in the 80°F – 100°F, whereas newer models are set for target temperatures around 75°F to meet new energy efficiency standards (GE, n.d.; Mange my Life, 2011; Samsung, 2015b).

The 2009 Residential Energy Consumption Survey (RECS), conducted by the Energy Information Administration (EIA), shows that the majority of washing machines in residential homes are between two and fourteen years old (EIA, 2013). Since the current lifespan of washing machines is expected to be seven to ten years, older models are still in use and provide a significant opportunity to decrease the environmental footprint of washing clothes. As the current install base of washing machines change over to newer, more energy efficient models, wash water temperatures traditionally associated with cool or cold water wash cycles will be more common even if the consumer opts to use a warm water setting. Education on this fact, and that cold water still gets clothes clean, will become increasingly important.

Households in other parts of the world, such as Europe and Japan, do not rely on central water heaters. Appliances sold in those regions traditionally have water heaters integrated into the washer units, so the user adjusts the water temperature by selecting a specific temperature. In this situation, the user has far more control over temperatures, especially at lower settings, than in the United States. This means that the lower bound of "cold" in the United States could be significantly lower than in these countries. Thus, tying a message to a particular temperature is not feasible, and the successful "I prefer 30°" campaign in Europe (I Prefer 30, 2015), where 30°C (86°F) refers to the common temperature for "cold" wash settings, wouldn't translate to the American market.

Laundry Basics

Cleaning, in the context of laundry, is the removal of stains, soils and other materials from clothes and other textiles. Removing soils, stains, dirt and other sources of contaminants from surfaces or objects occurs through the interactions of four factors: temperature, time, mechanical action and chemical action (AISE, 2013; Sinner, 1960).

- Chemical action: The reaction of the dissolved detergent or laundry additives with soils on the clothes or other textiles in the wash. These reactions can be impacted by water temperature, the level of friction between textile surfaces and the length of the wash cycle. Detergents provide different chemical ingredients, such as surfactants, builders, polymers and enzymes, that remove the soil from the fabric, then suspend these materials in the wash water so they can be rinsed away.

- Mechanical action: Created by the agitation and spinning of the drum in the washing machine, which creates friction and pressure. This action distributes the water with dissolved detergent throughout the load and creates a mild scrubbing action among the fabrics during the wash cycle.

- Temperature: The temperature of the water used. Warmer wash temperatures enable detergents to clean tough stains and heavily soiled materials better and may be necessary for proper sanitization of clothes and other textiles that have been exposed to pathogens or bodily fluids, such as blood and urine.

- Time: Machine cycle time. Longer wash cycles increase cleaning because the detergent has a longer time to come into contact with soils and remove them.

The relationships among these four factors were originally described by Dr. Herbert Sinner and illustrated in the Sinner Circle (Figure 4; Sinner, 1960). For a given level of cleaning efficacy, the sum of the parts of the circle must equal 100%. If one component, such as wash temperature, is decreased, one or more of the other factors must increase to compensate for it. When considering these factors as related to laundry, choosing cold water reallocates a part of the burden of cleaning to the detergent and the washing machine. An updated version of the Sinner Circle presented by Stamminger in 2010 includes water as a fifth cleaning factor (A.I.S.E., 2013; Stamminger, 2010). This acknowledges the key role water plays during cleaning. It is responsible for dissolving and dispersing the detergent, enabling clothes to more effectively move against each other through the mechanical action, and for rinsing away the soils and extra detergent at the end of the laundry cycle (Lasic, 2014).

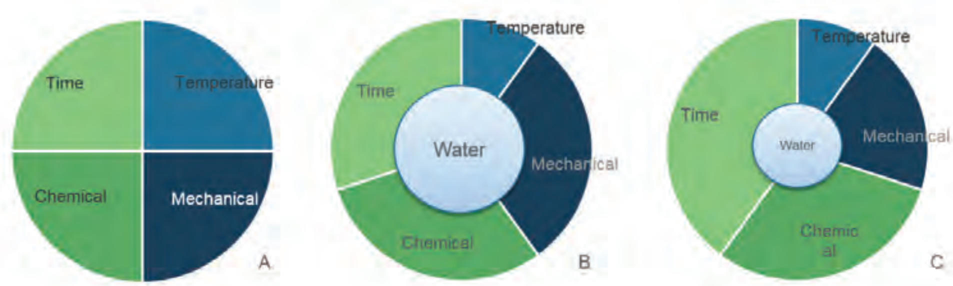

Figure 4: Sinner Circle

(A) Standard Sinner Circle describing the relative relationship between factors necessary for cleaning; (B) Sinner Circle adjusted for low temperature wash in top-loading machine, including water; (C) Sinner Circle for front-loading machine

For illustrative purposes only; actual ratios will differ based on laundry processes used.

Explicit inclusion also illustrates the trade-offs that can occur with different washing machine configurations and when lower wash temperatures are used (Figure 4). Top-load machines tend to use more water and energy to heat the water than front-load machines (Bluejay, 2016; Janeway, 2015). Front-loading and high efficiency (HE) top-load machines were found overall to use significantly less water and less energy per wash cycle for the same cleaning results as a standard top-load agitator washer, but at the cost of cycle time. The listed top-load agitator models had an average cycle time of 49 minutes, while front-load and HE top-load machines average 79 and 82 minutes respectively (Consumer Reports, 2016).The impulse to decrease cycle time to save energy can negatively affect the cleaning performance of front-load and HE top-load machines, even though the longer cycle times are considered as a part of energy efficiency measurements. Correlating the change in water use with move to cooler wash temperatures is not as clear. The indication is that less water is used per cycle, excluding additional rinse cycles added by a consumer, to increase the mechanical factor of clothes rubbing against each other (Chan, 2015).

Innovation and Cold Water Wash

The lack of a known lower temperature boundary for household water temperature creates challenges for both detergent and appliance manufacturers. Lower temperatures can cause the chemical reactions between the ingredients in detergents and soiling on clothes to take longer or the removed soil to redeposit on the clothes before the rinse cycle (Cameron, 2007).

Detergent formulation has evolved to improve cleaning performance at lower temperatures. In the ten years since cold water formulations were first introduced to the market, the chemistry responsible for cleaning clothes has evolved to ensure that regardless of what temperature a load of laundry is washed at, the detergent will be effective. This is achieved by using surfactants active at different water temperatures (the ingredient responsible for removing the proteins, fats, and sugars that make up stains) in the same formulation, so there are some surfactants that are always working at a given water temperature (Baguley & McDonald, 2015; Dvorsky, 2015). Cleaning action is further enhanced by the addition of polymers that help keep the removed fats and proteins in the wash water, so they can be rinsed away (Dvorsky, 2015).

The inclusion of enzymes designed to work at low water temperatures has further improved detergent cleaning performance by more effectively breaking down different types of stains to enable the surfactants and polymers to better capture and keep these materials and keep them in the wash water (Do, Attaphong, Scamehorn, & Sabatini, 2014; Hauthal, 2014; A.I.S.E., 2013; Schiebel, 2004). Different enzymes can also improve the appearance of fabrics. As enzymes are usually function-specific, blends of different enzyme types can be created and added to a detergent to optimize the effectiveness of the formulation for particular applications, such as low temperature wash (Nielsen, 2005; Novozymes, 2010).

Even detergents not formulated specifically for use in cold water have benefitted from the chemistry advancements noted above. In the United States, the Consumers Union® tests all laundry detergents on a cool water setting (75ºF) and has shown that modern detergent formulations, regardless of whether they are designated as

Sidebar: How much does laundry cost?

Data and calculation details in Annex A

Per-load costs for an average electric top-loading washing machine:

Wash Cycle*	Electricity: Machine	Electricity: Water heating	Water	Detergent	Cost per load
Cold	$0.03	$0.00	$0.33	$0.25	$0.61
Warm	$0.03	$0.15	$0.33	$0.25	$0.76
Hot	$0.03	$0.35	$0.33	$0.25	$0.95
			(40 gallons per load at $8.20/1000 gallons)	(per load)	

* *Assumes all rinse cycles are run with cold water*

Average household

Loads:
3 cold cycles
3 warm cycles
1 hot cycle
= $ 5.08 per week
= $ 264 per year

With one more cold load:
4 cold cycles
2 warm cycle
1 hot cycle
= $ 4.93 per week
= $ 257 per year

cold water formulations, work well at this temperature (Consumer Reports, 2016a). Testing covers cleaning efficacy of widely-available laundry detergents, and give each formulation an overall score based on the “cool, hard-water washing performance of cotton swatches heavily soiled with blood, mud, chocolate, ice cream, grass, red wine, ring around the collar, and tea”, the results of which are published in their magazine, “Consumer Reports®” (Consumer Reports, 2016a). In their most recent ratings, the top ten detergents were rated either “Excellent” or “Very Good” for their cool water cleanability (Consumer Reports, 2016b). They do note that for washing in lower temperatures such as 60ºF, the cold water formulations do show superior cleaning capability, so may still be the better choice for most cold water wash cycle settings (DiClerico, 2014). Cost is often brought up as an additional barrier to adopting cold water formulated detergents. At one time, this may have been a concern, but today’s formulations are equivalent to other formulations on a per-load basis by cost (Consumer Reports, 2014). The sidebar, “How much does a load of laundry cost?” looks at what a consumer can expect to spend on a per-load basis.

Using lower wash temperatures has been shown to be as effective on the light and moderately soiled clothing that the average household would produce. Under conditions common in Europe, Laitala, Boks, & Klepp showed that there was little difference in the cleaning effect of modern detergents in lower temperature water (30ºC versus 40ºC or 60ºC) when measured using standard reflectance measurements as described by EN60456, the standard used to determine washing machine performance for energy labeling purposes in Europe (Laitala, Boks, & Klepp, 2011).

Washing machines have also evolved, so that they are more water and energy efficient, and have a wider range of options available to the consumer to tailor the laundry process to their specific needs. In addition to ATC feature discussed previously, washing machines use significantly less water to wash an average load, and do provide the consumer with a wider range of options to enable all loads of laundry to be effectively cleaned. Partial motivators in improving washing machine water and energy efficiency innovation are the regulatory landscape and voluntary standards such as ENERGY STAR®. The Energy Independence and Security Act of 2007 added minimum water efficiency requirements to the existing minimum energy efficiency requirements (ASAP, 2016). ENERGY STAR certified machines meet more rigorous performance levels, resulting in a 40% reduction in water use and a 25% reduction in energy use over non-certified machines (ENERGY STAR, 2016). The two factors used are the Water Factor (WF), which is the amount of water used per cycle versus the total capacity of the washing machine, and the Modified Energy Factor (MEF) that considers the capacity of the machine versus the amount of energy needed to heat the water, run the washer, and dry the laundry load. The more efficient a machine is, the lower the WF and higher the MEF. In May of 2012, both water and energy factors were revised to account for standby and off-mode power consumption by clothes washers, which are now used in the latest ENERGY STAR requirements (ASAP, 2016). Additionally, new energy efficiency standards announced in 2012 that came into effect in 2015 will drive further innovation and lower overall wash temperatures as the newest washing machines become common in the market (DOE, 2012; GE, 2015b).

Laundry and Hygiene

The question of whether using cold water can provide an adequate level of hygiene for laundry is of increasing concern to the consumer (Borreli, 2013; Foster, 2013). These concerns were reflected in the results of the Consumer Survey on Cold Water Washing Habits in the United States, conducted by ACI and referenced at the beginning of this paper (ACI, 2015), where the largest barrier identified by respondents to using cold water was the perception that it did not clean as well as warmer temperatures and did not "kill germs".

"Germs", or pathogens, are the microorganisms that cause infectious diseases. Pathogens may be bacteria, fungi, viruses, or other organisms that can be transmitted from a sick individual to others through direct contact between individuals or by individuals coming into contact with textiles or surfaces that have been contaminated by these materials (Bloomfield et al., 2013; Gerba & Kennedy, 2007; Sehulster, 2015). Clothes and other textiles that have been in contact with a sick individual are considered “high risk” for spreading disease. Because more individuals are involved with the in-home care of susceptible populations, such as the elderly or those with compromised immune systems, as well as a broader fear of the spread of antibiotic-resistant bacteria through the general population, ensuring that textiles are hygienically clean (free of pathogens in sufficient numbers to cause human illness) is of paramount importance (ANSI/AAMI, 2013).

To get hygienically clean textiles, three factors are active. Water temperature is the first factor, as the standard methods of disinfection include a minimum water temperature of 140ºF plus detergent (Bloomfield, Exner, Signorelli, Nath, & Scott, 2011; Sehulster, 2015). Full disinfection, where all pathogens are rendered inactive, requires temperatures in excess of 190ºF, which is not feasible or recommended outside commercial laundry facilities (Bloomfield et al., 2011). The second factor is chemical use, as the performance of a given method can be greatly improved by the addition of a laundry additive, such as bleach or other oxidizing chemicals. A summary of the different types of additives available and their effectiveness is presented in Sehulster, 2015. The third factor in textile disinfection is dilution. With each replacement of the wash water (pre-rinse or pre-wash, followed by the wash cycle, followed by one or more rinses), more of the pathogens that have been removed from the textiles are rinsed away, reducing pathogen redeposition onto the clean laundry (Sehulster, 2015; Murdock, 2011).

An additional point made by Gerba & Kennedy is that in most households, the water temperature at the washing machine may not reach 140ºF, even if the hot wash cycle is selected, because the high temperature can be bounded by energy efficient settings on home water heaters, and the temperature drops as the water travels from the heater to the point of use (Gerba & Kennedy, 2007). Consequently, relying solely on temperature and detergent to disinfect laundry may not be effective for the average household. Recently, washing machine manufacturers have added a “Sanitization” cycle, where washer models with automatic temperature control systems are able to heat the water to temperatures appropriate for disinfection (GE, 2015; Maytag, 2015; Samsung, 2014).

Research into the factors necessary to hygienically clean textiles has focused on situations where there are high levels of pathogens with high potential for human infection, such as in hospitals, nursing homes, and daycare centers. These studies, discussed in Annex B, generally recommend that textiles that have been used by sick people, or those that are heavily soiled with bodily fluids be washed at temperatures above 140ºF with an appropriate detergent and additives if necessary. Lower temperatures can be used, particularly with longer cycle times and oxidizing additives such as bleach, but this increases the importance of mechanical drying to ensure the textiles are heated enough to destroy any pathogens (Bloomfield, Exner, Signorelli, Nath, & Scott, 2011; Sehulster, 2015). None of these references address the actions that could be taken when using cold water temperatures below 70ºF, which is a laundering condition that can be experienced in most of the U.S.

No studies were found examining connections between the use of cold water for household laundering and rates of infection. One study has examined relationships between household infections and laundering in communal facilities such as laundry rooms in urban housing, and found statistically significant differences in infection rates between certain laundering conditions, most notably with and without the use of bleach in laundry loads. Wash temperatures were not standardized or recorded in this study (Larson & Gomez Duarte, 2001). Other studies focused on laundry in single-family residences shows that there are potential infection routes by way of laundering processes, and that using the warm or hot water setting and bleach can inactivate the majority of pathogens and allergens household textiles would be exposed to (Choi, et al., 2008, Gerba & Kennedy, 2007; Kagan, Aiello, & Larson, 2002; Stajitz & Grohmann, 2011). More recently, Honisch and co-authors determined that in water temperatures as low as 20.5ºC (69ºF), a combination of longer wash cycles and detergents that contain activated oxygen bleach can reduce pathogens on laundry as effectively as traditional warm or hot water cycles (Honisch, Stamminger, & Bockmuhl, 2014).

A.I.S.E., the International Association for Soaps, Detergents and Maintenance Products in Europe, commissioned a study from the International Scientific Forum on Home Hygiene (IFH) to better understand hygiene in conditions more likely to be found in the average household. (Bloomfield et al., 2013). The outcomes of this study, along with the results of an expert consultation, are summarized by A.I.S.E. in their report, The Case for the "A.I.S.E. Low Temperature Washing" Initiative Substantiation Dossier (A.I.S.E., 2013). From this work, the following conclusion was drawn:

> "IFH recommends that laundering of fabrics in the home should, in addition to making clothes fresh and visibly clean, also help prevent transmission of microorganisms that may be involved in infectious disease. The level of this risk is however considered to be lower than other circumstances involving transmission of microbes in the home, such as direct contact with food contact surfaces. Further, no direct causal relationships have been demonstrated between laundry effectiveness and the occurrence of infections in the home. Nevertheless, due to the overall uncertainty and difficulty to quantify the actual risk, A.I.S.E. recommends that the potential risk be suitably managed." (A.I.S.E., 2013)

The one caveat for households in the U.S. is that the studies performed to date do not test conditions at temperatures below 70ºF, so additional work is needed to test efficacy of removal of infectious agents at lower wash temperatures.

A summary of current best practices for household laundry is shown in Figure 5 based on currently available guidance, although best practice recommendations regarding laundry vary greatly (Dvorsky, 2015; Leverette, n.d.; Mitchell, 2015). The one step that all recommendations agreed on is that the individual washing clothes should always check the care label first and follow the instructions of the manufacturer for best laundry results (ACI, n.d.).

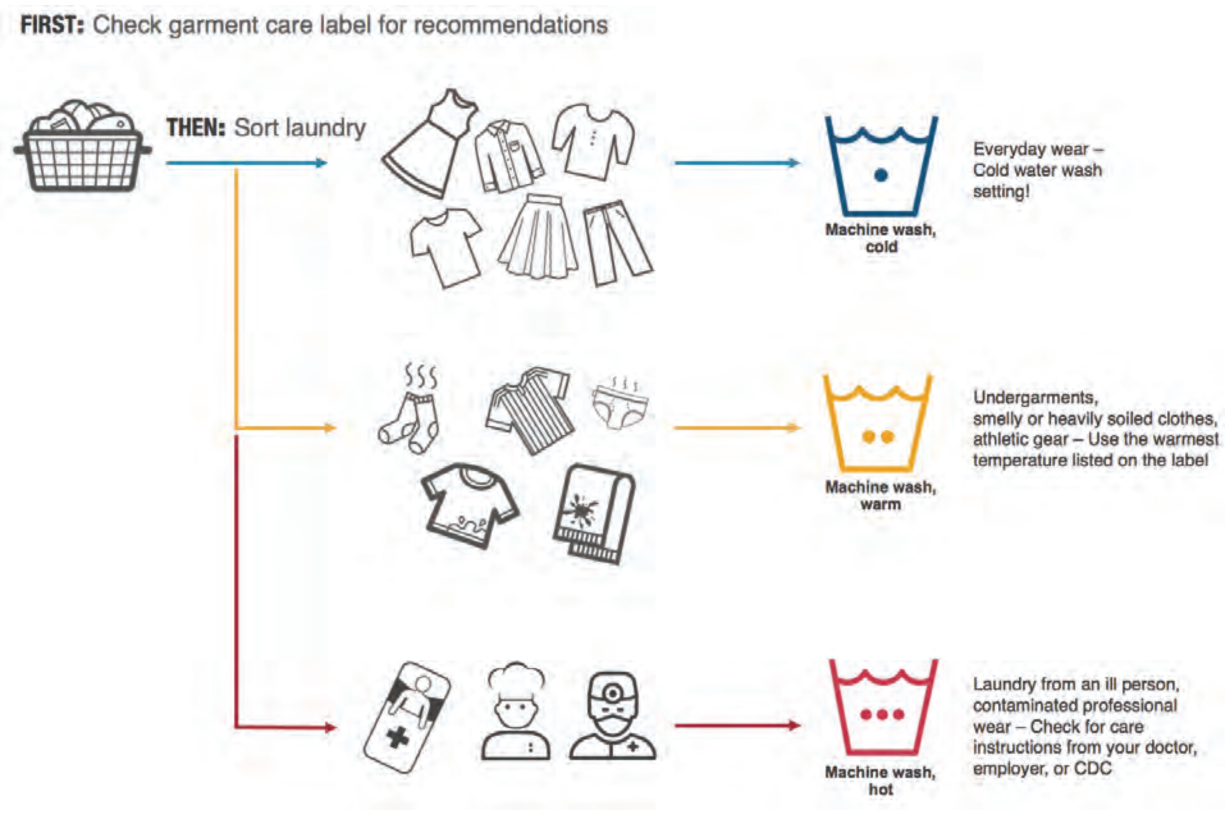

Figure 5: Guidance on wash temperatures for different types of clothes

Conclusion

Consumer behavior around how clothing is maintained has been identified as having a substantial environmental impact due to the energy required to wash and dry clothes. The different industries that connect in the laundry room (the large appliance, apparel and home care industries) all have a vested interest to improve consumer behavior in the laundry room. In all three industries, washing and drying clothes account for some of the largest environmental impacts due to the energy consumed during these processes. Proper use of laundry detergents and washing machines at low temperature settings combine to gently clean soiled clothes and extend their fit and function for the consumer. This benefits all three industries by providing a positive consumer experience that also offsets the impacts of their products across a garment's life cycle. Additionally, industry can partner with government agencies, NGOs and retailers in order to reach an even greater portion of the consumer community than is possible as individual companies.

Continuous evolution of both detergents and washing machines have succeeded in greatly improving not only the consumer experience but the efficacy and efficiency of laundry. By combining the science of formulation using purpose-designed ingredients such as enzymes, with engineering design in washing machines to use water and energy more efficiently to effectively clean clothes, the reality of washing most laundry loads in low temperature water ensures a positive consumer experience and increases the sustainability of the laundry room. The largest barrier to using cold water for laundry identified by consumers during the ACI survey is the perception that cold water will not get clothes clean. Effectively addressing this negative perception will be necessary for any successful coordinated effort around raising consumer awareness.

Through the network of The Sustainability Consortium, an opportunity exists for collaboration around creating an effective message geared toward raising consumer awareness of the benefits of cold water wash with a long term goal of changing consumer behavior around wash temperature. The coming together of a wide range of organizations to share the cold water wash message can positively impact the environment by decreasing energy use while helping consumers extend the life of their clothing.

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Annex A: Data Sources and Calculations

Electricity Consumption Calculation

The calculations described in this section support Figure 1, "Why cold water wash?". Energy consumption during clothes washing is primarily dependent on the amount of energy required to heat the right amount of water for a load of laundry. This varies by the type of water heater used in a given household and the temperature of water entering the home. The calculation below considers the amount of energy required to heat water to a pre-determined temperature using either a natural gas or electric water heater. In Figure 1 of this brief, the data presented is only for the median inlet temperature in the United States. Tables A3 through A6 provide this same calculation for the 10 regional divisions of the US used by the US Census Bureau, which is also how the Energy Information Agency (EIA) presents data from the Residential Energy Consumption Survey (RECS; EIA, 2013).

In Figure 1, the top line represents the estimated greenhouse gas emissions for the United States in 2015. According to the EIA, approximately 20% of these emissions can be traced to energy consumption (including both gas and electricity) in the residential sector. The amount of emissions attributed to laundry (washing machine operation plus water heating) is estimated to be 2%, as reported in the work published by Golden et al. in 2010. This top-down approach provides an idea of what emissions are today. The following calculations are built up from data collected by the EIA in 2009 and published by the Department of Energy in the Building Energy Data Book, 2011 (D&R International, 2012; EIA, 2013). These results are heavily dependent on the amount of water used per load, the target temperatures for hot and warm water wash cycles, the efficiency of water heaters, and the number of loads washed by an average household per week. The values used represent an average scenario, and does not consider the impact of ENERGY STAR-certified appliances. The Better Appliances report published by the Appliance Standard Awareness Project and ENERGY STAR criteria guidance documentation provide information on energy efficiency standards and ENERGY STAR can impact laundry energy consumption (Mauer, 2013; ENERGY STAR, 2008).

A more accurate representation of carbon emissions based on per-load energy consumption would require updated appliance install base for water heaters and washing machines, including ENERGY STAR certified appliances, how much water is used per wash cycle for different types of washing machines, and a more complete understanding of the target temperatures set by washing machines for warm and hot cycles and how this correlated to actual hot water use during the laundering process.

Table A1: References for energy consumption calculations

ENERGY CONSUMPTION	
0.28 kWh/load	Washing machine operation only (D&R International, 2012)
variable	Type and number of water heaters in the US by census region (EIA 2013)
WASHING MACHINE	
80%	Percent of households with washing machines in 2009 (EIA, 2013)
82%/18%	Top load/ Front Load; Distribution of washer types in 2009 (EIA, 2013)
125 million	Households in U.S. in 2015 (est.; McCue, 2015)
7 loads/week	Average laundry frequency (ACI, 2015; EIA, 2013; D&R International, 2012)
40 gallons water/load	Standard top-loading washer (Home water works, n.d.)
20 gallons water/load	Standard front-loading washer or HE washer (Home water works, n.d.)
120ºF	Hot water temperature, water heater setting (CPSC, 2012)
50%	Assumption for amount of heated water used in 1 hot wash cycle with cold water rinse
85ºF	Warm water temperature per clothing care label (Textile Affairs, 2010)
WATER HEATER	
42%/51%	Installed electric/gas water heaters in US residences; remaining 7% attributed to fuel sources not accounted for in this calculation (EIA, 2013)
0.92	Energy Factor (EF) for electric storage water heaters (Bradford White, 2015; ENERGY STAR, 2008)
0.62	Energy Factor (EF) for gas electric storage water heaters (Bradford White, 2015; ENERGY STAR, 2008)

Table A2: Consumer washing behavior

	Percentage of loads for a given temperature setting: (ACI, 2015)	Assuming 7 loads/wk for average household:
Cold	0.45	3.15 (round to 3 loads/wk)
Warm	0.35	2.45 (round to 3 loads/wk)
Hot	0.2	1.40 (round to 1 load/wk)

Table A3: Representative inlet temperature for cold water and number of water heaters per census region

CENSUS REGION DIVISION	HOUSEHOLDS	REPRESENTATIVE CITY	INLET TEMP, COLD WATER	NUMBER OF WATER HEATERS (MILLIONS)*	
	Millions		ºF	Gas	Electric
New England	5.5	Concord, NH	66	2.3	1.4
Middle Atlantic	15.3	Rochester, NY	57	9.1	3.6
East North Central	17.9	Columbus, OH	55	12.1	4.8
West North Central	8.1	Minneapolis, MN	46	4.7	2.8
South Atlantic	22.2	Raliegh, NC	72	5.5	16.1
East South Central	7.1	Biloxi, MS	64	2	4.9
West South Central	12.8	Dallas, TX	69	6.1	6.2
Mountain North	3.9	Denver, CO	61	2.6	0.9
Mountain South	4	Mesa, AZ	82	2.2	1.6
Pacific	16.9	Seattle, WA	41	11.7	4.4

*Number of water heaters do not sum to total households as there are a small number of households who use an alternative type of fuel (e.g., propane, fuel oil, solar) for water heating.

Table A4: Energy required to wash 7 loads of laundry weekly for one year

	TOP-LOADING MACHINE				FRONT LOADING MACHINE			
	3 cold / 3 warm / 1 hot		4 cold / 2 warm / 1 hot		3 cold / 3 warm / 1 hot		4 cold / 2 warm / 1 hot	
Census Division	kWh	therms	kWh	therms	kWh	therms	kWh	therms
New England	294.0	12.8	241.3	10.1	152.9	7.8	126.5	6.5
Middle Atlantic	383.1	17.0	308.2	13.1	198.5	10.2	161.0	8.2
EN Central	405.8	18.0	325.1	13.9	210.0	10.7	169.6	8.7
WN Central	508.2	22.9	400.8	17.4	262.2	13.4	208.5	10.7
S Atlantic	227.1	9.6	191.7	7.8	118.8	6.1	101.1	5.2
ES Central	311.0	13.6	254.3	10.7	161.6	8.3	133.3	6.8
WS Central	259.0	11.1	215.4	8.9	135.1	6.9	113.3	5.8
Mountain N	342.0	15.0	277.5	11.7	177.4	9.1	145.2	7.4
Mountain S	119.6	4.5	111.6	4.1	63.9	3.3	59.9	3.1
Pacific	565.0	25.6	442.9	19.3	285.1	14.6	226.1	11.6

Table A5: Energy required by total number of washing machines by census regions; 7 loads per week for one year

	WASHERS (MILLIONS)				TOP-LOADING MACHINES				FRONT-LOADING MACHINES (HE)			
Census Division	Gas - top	Gas - front	Electric - top	Electric - front	3 cold/3 warm/1 hot		4 cold/2 warm/ 1 hot		3 cold/3 warm/1 hot		4 cold/2 warm/ 1 hot	
					kWh (millions)	therms (millions)	kWh (millions)	therms (millions)	kWh (millions)	therms (millions)	kWh (millions)	therms (millions)
New England	1.5	0.3	0.9	0.2	270.0	19.3	221.6	15.2	30.8	2.6	25.5	2.1
Middle Atlantic	6.0	1.3	2.4	0.5	904.8	101.2	728.0	78.4	102.9	13.3	83.5	10.8
EN Central	7.9	1.7	3.1	0.7	1277.9	143.2	1023.5	110.4	145.2	18.7	117.3	15.1
WN Central	3.1	0.7	1.8	0.4	933.5	70.6	736.3	53.7	105.7	9.1	84.1	7.2
S Atlantic	3.6	0.8	10.6	2.3	2399.0	34.7	2024.4	28.1	275.5	4.8	234.4	4.1
ES Central	1.3	0.3	3.2	0.7	999.6	17.8	817.3	14.0	114.0	2.4	94.0	2.0
WS Central	4.0	0.9	4.1	0.9	1053.4	44.5	876.2	35.5	120.6	6.1	101.1	5.1
Mountain N	1.7	0.4	0.6	0.1	201.9	25.6	163.8	20.0	23.0	3.4	18.8	2.8
Mountain S	1.4	0.3	1.0	0.2	125.5	6.5	117.1	5.9	14.7	1.0	13.8	1.0
Pacific	7.7	1.7	2.9	0.6	1630.7	196.4	1278.3	148.5	180.6	24.6	143.2	19.5

Table A6: Energy and carbon emissions savings nationally with one load less of warm water per household per week

	TOTAL ELECTRICITY (MILLION KWH)	TOTAL NATURAL GAS (MILLION THERMS)
3 cold/3 warm/1 hot	10,909	746
4 cold/2 warm/ 1 hot	8,902	579
Savings	2,007	166
Savings, CO_2e*	**1.41mmt**	**0.88mmt**

*CO_2e = carbon dioxide equivalents, the units in which greenhouse gas emissions are reported; mmt = million metric tons.

The methodology described below is based on the methods used by Michael Bluejay on his web page "Saving Electricity: How much does it cost to run a washing machine?" and in the work of Golden et al. (Bluejay, 2015; Golden, Subramanian, Irizarri, White, & Meier, 2010).

For the calculations presented in Tables A4 through A6, all cycles were assumed to have cold water as the rinse temperature, so no additional heating was required. Because the energy to run the machines regardless of temperature are constant across all values, the electricity to run the washer is not included. The efficiency of water heaters using different fuel sources is accounted for in the calculations. The Energy Factor (EF) is the measure of how efficiently a given water heating technology converts the energy in fuel to heat. Electric water heaters are more efficient that gas ones, and this is factored in during the calculation of Btus used per wash cycle. Due to the lack of information on what percentage of water used for a given wash cycle can be attributed to washing versus rinsing, calculations assume that 50% of the water per load goes to each stage of the cycle. This calculation does not take into account any warm or hot water used for pre-soaks, or for water used for multiple rinses. For most washing machines in the United States, warm water is created by mixing hot water from the water heater with cold water at the inlet temperature to reach a pre-determined set point. This set point may be set at the factory or managed by active temperature control (ATC) system on the washing machine. The ratio of hot water to cold water needed to reach the target temperature is derived from the specific heat formula (C_p).

$$C_p = \text{(heat gain or loss)} / \text{(mass x temperature change required)}$$

Since the amount of heat that is gained by the cold water equals that released by the hot water, the equations for each can be set equal to each other:

$$[C_p \text{ x mass x (cold water temperature – target temperature)}] = \\ - [C_p \text{ x mass x (hot water temperature – target temperature)}]$$

Cp and the mass of the water are constant and cancel each other out, leaving:

$$\text{(hot water temperature – target temperature)} = \\ \text{(target temperature – cold water temperature)}$$

This equivalency can be expressed as a ratio that provides the number of parts of hot water needed to mix with parts of cold water to reach 85°F (after Hofstetter, 2014). The ratio will vary with the temperature of the residential water inlet temperature used for cold water cycles. Hot water is assumed to be 120°F regardless of region. Lower inlet water temperatures will require more hot water, and therefore more energy, to reach the target warm temperature.

Using this approach, the amount of hot water that is needed to raise cold water to a specific warm water temperature is calculated by:

(hot water temperature – target temperature) = (target temperature – cold water temperature)
Divide both sides by lower number for ratio of hot to cold water, sum to determine total number of parts
Gallons of hot water needed = parts of hot water x (total gallons for wash cycle/total number of parts)

Water heating calculation:
For 1 gallon of water:

> Degrees to raise temperature = hot water temperature (oF) - inlet water temperature (oF)
> Btus to heat 1 gallon of water: Degrees temperature raised x 8.34lbs/gallon of water
> Btus for wash cycle = (Btus for 1 gallon water/water heater EFenergy type) x gallons of hot water per cycle per machine type
> 1 Btu = 0.000293kWh = 1x10-5 therms

Energy (kWh or therms) for weekly wash = (3 x energy for warm water) + (1 x hot water); Table A4
Energy (kWh or therms) for weekly wash, one load warm to cold = (2 x energy for warm water) + (1 x hot water); Table A4.

National energy consumption calculation:
Since this calculation focuses on the energy used to heat water, scaling the energy use from an individual household to a national value uses the number of water heaters using gas or electricity as a fuel. 80% of households have washing machines, so the number of a given type of water heater is multiplied by 0.8 to determine how many of a given type of water heater is paired with a washing machine. The number of washing machines is then weighted by the percent of machines that are top-loading (82%) versus front-loading (18%) models. This produces the first four columns in Table A5.

Washers (energy source, top loader) = (number of water heaters using energy source x 0.80) x 0.82
Washers (energy source, front loader) = (number of water heaters using energy source x 0.80) x 0.18

To determine the energy that can be saved if households with a washing machine switched one load from warm water cycle to cold water cycle per week for a year, the number of washers is multiplied by the energy required by one household for the given mix of loads (3 or 2 loads of warm water cycles per week). This completes the columns in Table A5.

Energy consumption per region = Number of washers (energy source, load mix) x Weekly consumption (energy source, load mix)

Table A6 reports the final totals of annual energy used nationally for the two types of load mixes using different types of fuel sources for water heating, and the energy and carbon emissions that can be saved by decreasing the number of warm wash cycle loads by one.

Total energy = [Sum of regional top-loader energy consumption (energy source)] + [Sum of regional front-loader energy consumption (energy source)]

Energy saved = Total energy for typical wash (energy source) – Total energy for less 1 warm load (energy source)

Greenhouse gas emissions related to energy use was calculated using the greenhouse gas equivalencies calculator developed by the US EPA (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator). This website was also used to estimate equivalencies presented in Figure 1.

Cost per Load Calculations

The calculations presented here support the information presented in the sidebar, "How much does laundry cost?"

The calculations made to estimate the cost of a single load of laundry are based on the methodology used by Michael Bluejay on his website: "Saving Electricity: How much does it cost to run a washing machine?" (Bluejay, 2015). Details on how cost per load was calculated can be found at: http://michaelbluejay.com/electricity/laundry-sources.html.

The price for electricity used here is $0.12 per kWh, the current national average for residential retail electricity (EIA, 2015b). The price of water varies significantly across the United States. The value of $8.17/1000 gallons of water is the average of one of the highest cost of water (San Diego, CA) and of one of the lowest costs of water (Mesa, AZ) in the United States. These calculations include the cost of wastewater charged to the average residence in these two cities.

Total Water Costs (per 1000 gallons):
High estimate = $10.80/month, San Diego, CA
Low estimate = $5.55/month, Mesa, AZ
Average = $8.17/month

Table A7: Cost of water per load of laundry

	PER GALLON OF WATER	TOP-LOADER COST PER LOAD	FRONT-LOADER COST PER LOAD
Gallons of water per load		40	20
Cost, High estimate	$0.01	$0.43	$0.22
Cost, Low estimate	$0.008	$0.22	$0.11
Average Costs per load		$0.33	$0.16

Table A8: Total cost of washing clothes per load

WASH CYCLE	KWH	COST ELECTRICITY – MACHINE	COST ELECTRICITY – WATER HEATING	COST WATER[1]	COST DETERGENT[2]	TOTAL COST PER LOAD[3]
Cold, top-loader	0.28	$0.03	$0.00	$0.33	$0.25	$0.61
Cold Budget detergent	0.28	$0.03	$0.00	$0.33	$0.114	$0.47
Warm, top-loader	1.24	$0.03	$0.15	$0.33	$0.25	$0.76
Hot, top-loader	2.84	$0.03	$0.34	$0.33	$0.25	$0.95
Cold, front-loader	0.28	$0.03	$0.00	$0.16	$0.25	$0.44
Warm, front-loader	0.89	$0.03	$0.11	$0.16	$0.25	$0.52
Hot, front-loader	1.54	$0.03	$0.18	$0.16	$0.25	$0.59

[1] Cost of water per load is less for front-loaders as less water is used per wash cycle.
[2] Cost of detergents per load; from Consumer Reports Laundry Detergent Ratings. Note: no cost difference was reported between regular detergents and those formulated specifically for cold water wash.
[3] Total cost per load is the sum of the cost of electricity, water, and detergent. It excludes the capital cost of the washing machine itself.
[4] Budget detergents are defined by Consumer Reports as generic or house brands, which are less expensive than national name-brand detergents.

Table A9: References, Cost of a load of laundry

Water rate, San Diego, CA	https://www.sandiego.gov/water/rates/rates https://www.sandiego.gov/mwwd/rates/singlefamily (municipal wastewater)
Water rate, Mesa, AZ	http://www.mesaaz.gov/city-hall/office-of-management-budget/utility-rates
Water use per load	http://www.home-water-works.org/indoor-use/clothes-washer
Electricity use per load, machine only	2011 Building Data Book; http://buildingsdatabook.eren.doe.gov/ChapterIntro2.aspx
National average price of electricity	https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a
Cost of laundry detergents	http://www.consumerreports.org/cro/laundry-detergents.htm

Annex B: Laundry & Hygiene

Extreme cases of pathogen contamination occur in hospitals, where the load of potential pathogens on the large volume of laundry generated greatly exceeds that experienced by the average household. In these facilities, multiple studies have been conducted to determine if there are conditions where lower temperature water (71°F-77°F) can be used with the appropriate cycle times and laundry chemicals (detergents plus additives) to the same effect as the higher water temperatures. Lower water temperatures, when combined with the appropriate cycle times, chemicals and rinses, were found to decrease pathogen loads below the benchmark value for disinfection set by the US EPA (US EPA, 2013). Further improvements highlighted in the review article by Sehulster include the use of bleach and other oxidizing chemicals as laundry additives (Altenbaher, Sostar Turk, & Fijan, 2011; Honisch, Stamminger, & Bockmuhl, 2014; Bloomfield et al., 2013; Smith, Neil, Davidson, & Davidson, 1987) as well as mechanical drying cycles and ironing (Bloomfield et al., 2013; Lackdawala, Pham, Shah, & Holton, 2011; Patel, Murray-Leonard, & Wilson, 2006). Balancing these factors to achieve hygienically clean laundry is an application of the Sinner cycle, where the chemicals and action of the washing machine compensate for the reduced temperature (Altenbaher et al., 2011).

These results provide guidance for how hygienically clean textiles can be reached in similar fashion as in institutional laundry contexts for an average household, where the pathogen level will be much lower. Literature for domestic laundry focuses on the home laundering of hospital scrubs and shows that, under normal residential laundry conditions, most pathogens can be removed or inactivated using warm water temperatures with or without a bleaching agent (Honisch et al., 2014; Kagan, Aiello, & Larson, 2002; Nordstrom, Reynolds, & Gerba, 2012; Patel et al., 2006). Particularly resilient viruses, such as those responsible for diarrhea and some respiratory illnesses (enteric viruses), require warm water and bleaching agents and mechanical drying cycles to be eliminated (Gerba & Kennedy, 2007). The temperatures reached during the drying process can effectively destroy or deactivate allergens and potential pathogens that are not removed during the washing process (Bloomfield, Exner, Signorelli, & Scott, 2013; Choi et al., 2008; Patel, Murray-Leonard, & Wilson, 2006). Line-drying laundry outside may also provide disinfection activity due to the UV component of sunlight. Line-drying in general, indoors or out, is considered to be environmentally preferable because it removes the need for energy to run the dryer, but it can leave clothes stiff and is dependent on climate and local regulations regarding outdoor clothes lines (Fischer & Kaufman, 2013; Geoghegen, 2010; Koerner & Turk, 2010).