Sustainability Assessment and Design Recommendations for the Meijer *Store of Tomorrow*

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Abstract

This project focused on identifying carbon emission abatement strategies for Meijer, specifically addressing lighting, space cooling and heating, and refrigeration, which constitute Meijer's largest demand sectors. Additionally, the project evaluated strategies to reduce water consumption, waste generation and promote customer education of sustainable practices. The project was organized into three phases. In phase I, a comprehensive assessment of sustainable design and technology elements was conducted, which included a review of sustainability initiatives by other retail competitors. During Phase II, solutions were synthesized and reviewed in consultation with Meijer sustainability and design experts. Technological solutions were categorized into five store systems: energy, water and plumbing, sustainable sites, materials and resources, and customer experience elements. A rubric was then created to systematically evaluate strategies for the Market Format and Supercenter Meijer retail stores. Phase III included a detailed environmental and design analysis using the scoring rubric and supporting literature to identify the set of strategies that best reflect Meijer's priorities. This report details the findings of this research and the portfolio of strategies that would help Meijer create the net zero energy, zero waste, and water efficient Store of Tomorrow prototype.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

BPA Bisphenol A
BPS Bisphenol S
CHP Combined Heat and Power
EPA United States Environmental Protection Agency
GHG Greenhouse Gas
GHP Geothermal Heat Pump
GPF Gallons Per Flush
GWP Global Warming Potential
HET High Efficiency Toilets
IPCC Intergovernmental Panel on Climate Change
LCA Life-cycle Assessment
LDPE Low-density Polyethylene
LED Light-emitting Diode
MSCC Michigan State Capital Commission
MSW Municipal Solid Waste
NPV Net Present Value
NREL National Renewable Energy Laboratory
NWPP Non-woven Polypropylene
ODP Ozone Depletion Potential
PPA Power Purchase Agreement
PV Photovoltaics
REC Renewable Energy Credit
RPCs Reusable Plastic Containers
SEAS School for Environment and Sustainability
UNEP United Nations Environment Programme
VPPA Virtual Power Purchase Agreement

Executive Summary

The objective of this project is to evaluate and recommend green design strategies that could reduce Meijer's environmental footprint through a net zero energy, zero waste, water efficient, *Store of Tomorrow* prototype. To perform this analysis, our research team categorized store elements into five systems: Energy, Water and Plumbing, Materials and Resources, Sustainable Sites, and Customer Experience. Ultimately, we incorporated specific strategies into this model to specifically target environmental impact reductions in each of the five systems. **Figure 1** depicts this store system model, which provided the guiding framework for analysis.

This report evaluated existing Meijer sustainability projects and synthesized them with new strategies and technologies through the system diagram and technology review. These strategies were selected after a thorough review of existing strategies from scientific journals, competitors, and other commercial operations to benchmark competitors and identify best practices for sustainability performance. In addition to this review of existing strategies, our team examined innovative and emerging technologies that have not been widely implemented to evaluate their environmental impact reduction potential and feasibility for implementation within the Store of Tomorrow.

With input from our client advisors, we developed a scoring rubric to evaluate the suitability of these strategies for the Market Format and Supercenter store models. More specifically, we evaluated each strategy based on six categories including size and space requirements, ease of implementation, aesthetic appeal, innovation, customer experience, education, Meijer environmental impact reduction, and downstream environmental impact reduction. Each strategy was assigned a red, yellow, or green ranking in each of these categories, and was evaluated separately for the Market and Supercenter store model. Strategies that scored green in a certain category received high rankings for that component and red strategies were considered less desirable, less innovative, or provided less benefit, depending on the criteria of that specific category.

Table I details strategies that scored highly based on this rubric and are recommended for the Supercenter.

Table I. Recommended Strategies for the Supercenter Organized by Store System

System	Strategy	Notes
Energy	*Geothermal*	Highly efficient, good potential in Michigan and sustainable
	LEDs	Inexpensive, efficient and educational
	Low GWP alternatives & Case doors	Reduces carbon intensity, increases efficiency, sustainable, educational and potentially increases product purchases

	Daylighting & Dimming	Reduces lighting load, saves energy, educational, and potentially increases product purchases.
	PPAs	PPAs would enable Meijer to realize its sustainability goals without investing entirely in on-site renewables. Meijer can target PPAs from local renewable energy such as Midwest wind farms. This strategy can be made educational with effective signage.
	Solar PV	Reduces carbon intensity, sustainable, and educational
Water and Plumbing	*Dual Flush Toilets*	Reduce water consumption per flush with liquid and solid waste flush settings
	Low Flow Fixtures	Reduce water flow through efficient faucets
	Smart Irrigation	Cloud-based or sensor-based system to optimize watering schedule
Materials and Waste	*Container Composting*	Process food waste onsite with minimal pest or odor concerns
	Reusable Bags	Phase out single-use plastics
	Plastic Bags and Film with Post-Consumer Recycled Content	Reduce consumption of virgin resin
	Construction Waste Reuse and Recycling	Reduce construction waste and increase waste diversion rate
	Packaging Waste Backhauling and Recycling	Increase packaging waste diversion rate
Sustainable Sites	*Green Infrastructure:*	Slow down runoff and

	Bioswale	infiltrate pollutants, especially in the first flush of rainwater.
	Green Infrastructure: Detention Pond	Slow down stormwater runoff, precipitating infiltrating soil particles in stormwater. Educational and interactive elements can be incorporated.
	Green Infrastructure: Permeable Pavement	Permeable pavement allows the stormwater to infiltrate into the ground, instead of generating runoff.
	Green infrastructure: Rain + pollinator garden (Bioretention Garden)	The rain garden, as a part of the stormwater harvesting system, can be combined with a pollinator garden to infiltrate stormwater while increase biodiversity.
	Wind Break	Enhance building envelope and increase energy efficiency
	Green Wall	The green facade can increase the green areas on building surfaces, to improve the building envelope while serving as a strong visual cue to customers.
	Light Colored Pavement	Reduce Urban Heat Island Effect by increasing Albedo
	Freight Farm	Onsite growing system to cultivate produce year-round. Educational and innovative
Customer Experience	*Printed Signage*	Provide explanations and illustrations about onsite sustainable practices.
	Weekly Promotions	Increase customer awareness about

		sustainability and environmentally friendly practices.
	Product Displays	Provide information about sustainable product selections.
	EV Charging	Potential to attract and retain environmentally cognizant customers, visible effort of Meijer's commitment to sustainability. Meijer can influence Scope 3 emissions.
	Solar Canopy Carports	Visualize onsite renewable energy production process and provide educational opportunities.

Table II outlines strategies we recommend for implementation in the Market Format store.

Table II. Recommended Strategies for the Market Format Organized by Store System

System	**Strategy**	**Notes**
Energy	*PPAs*	PPAs would enable Meijer to realize its sustainability goals without investing entirely in on-site renewables. Meijer can target PPAs from local renewable energy such as Midwest wind farms. This strategy can be made educational with effective signage, especially in Market Format store where there are space constraints for on-site renewables.
	Smart Appliances	Optimizes the store systems, improves maintenance and allows for quicker problem identification

	LEDs	Inexpensive, efficient and educational
	Daylighting & Dimming	Reduces lighting load, saves energy, educational and potentially increases product purchases
	Low GWP alternatives & Case Doors	Reduces carbon intensity, increases efficiency, sustainable, educational and potentially increases product purchases
Water and Plumbing	*Dual Flush Toilets*	Reduce water consumption per flush with liquid and solid waste flushes
	Low Flow Fixtures	Reduce water flow through efficient faucets
Materials and Waste	*Composting with On-Site Pick-Up*	Manage food waste with contracted service
	Reusable Bags	Phase out single-use plastics
	Plastic Bags and Film with Post-Consumer Recycled Content	Reduce consumption of virgin resin
	Construction Waste Reuse and Recycling	Reduce construction waste and increase waste diversion rate
	Packaging Waste Backhauling and Recycling	Increase package waste diversion rate
Sustainable Sites	*Green infrastructure: Cistern*	Reduce stormwater runoff and collect rainwater for usage in grey infrastructure
	Green infrastructure: Rain + Pollinator Garden	Reduce stormwater runoff, infiltrate soil particles in stormwater, provide food and habitat for pollinators and ameliorate storescape.
	Green Roof	Green roofs can improve the building envelope,

		which increases energy efficiency. They are also attractive to customers.
	Light Colored Pavement	Reduce Urban Heat Island Effect by increasing Albedo
	Hydroponics	Innovative in-store growing system with educational and customer experience benefits
Customer Experience	*Digital Displays*	Provide interactive education to customers.
	Weekly Promotions	Increase customer awareness about sustainability of environmentally preferable practices.
	EV Charging	Increase opportunities for customer sustainability, decreasing emissions. Especially beneficial when powered by renewable energy.

In addition to these strategy specific recommendations, we suggest that Meijer emphasize educational components throughout both the Market Format and Supercenter sites to advance customer awareness and understanding of sustainability practices. This will contribute to larger scale change by encouraging customers to adopt green practices and technologies themselves and may make customers more receptive to innovative changes in the long term.

Additionally, we emphasize the importance of continuing to cultivate sustainability values throughout the Meijer company. Further integration of sustainability into company culture will build support for innovation and help secure Meijer's position as a sustainability leader. Support from leadership is critical for advancing sustainability and pursuing the most efficient technologies. Events like employee symposiums, educational training sessions, all staff meetings and webinars offer potential opportunities to advance sustainability understanding at all levels.

We recommend that Meijer pursue innovative strategies to be a leader in the retailer space. Many of the efficient technologies are widely implemented standards. We recommend that Meijer pursue several innovative and cutting-edge technologies to set them apart from competitors and raise the bar in terms of design standards for the industry.

While this research aimed to consider the feasibility of strategies within the Market Format and Supercenter, we recommend that Meijer consider the relative sustainability of these two store models comprehensively. Specifically, we recommend future studies to compare the resource intensity normalized to sales for both stores to determine which model performs with the lowest impact. We acknowledge the limitations of this evaluation based on clientele, product, and site differences between the two models.

We recognize that there are limitations to this study given the project time-frame and make several recommendations for future studies to supplement this report. First, life cycle analysis could be performed for core strategies to further determine their carbon footprints and environmental impacts. In doing so, Meijer can fully evaluate the benefits of the strategy before implementation. Second, a financial analysis, potentially with carbon tax implications, could be done to determine the costs and benefits from a strictly monetary view and business perspective. This report focused primarily on the environmental performance of the strategies. Future studies should also consider Scope 3 components such as transportation, siting to ensure equitable access, supply chain, or stock and sourcing components. Lastly, there could be an analysis of future technologies as they become more viable through improvements in research and development or the emergence of new markets.

This report details the findings of this research and the portfolio of strategies and technologies to help Meijer attain net zero status and produce the Store of Tomorrow prototype.

Introduction

The 2018 Intergovernmental Panel on Climate Change (IPCC) Interim Report called governments, businesses, and individuals to act on climate change and reduce impacts to ecosystems and human health and well-being.[1] Commercial and residential built environment energy usage in the US in 2017, accounted for nearly 40% of the total primary energy consumption of 100 quadrillion BTUs.[2] The typical energy intensive activities in a building include lighting, space heating, space cooling, and refrigeration. In the US, natural gas and electricity are used for space heating, and natural gas is now the dominant fuel for electricity generation. Methane is the primary constituent of natural gas and has a very high Global Warming Potential (GWP). The average greenhouse gas (GHG) emissions per kilowatt-hour of electricity generated in the US is 0.98 pounds of CO_2 equivalent.[3] Refrigeration comes with several challenges especially for commercial entities that operate cold chains. Refrigerants have very high GWPs, contributing to the carbon footprint of these entities, when leaks occur. Research is now focused on identifying and testing alternative natural refrigerants with low GWPs such as ammonia and CO_2 for commercial scale applications.

Energy efficiency is the first step toward achieving energy sustainability. Commercial establishments have been optimizing their energy demand through implementation of efficient lighting and effective insulation, careful selection of building materials, and green building design and orientation. Organizations are also investing in on-site renewable generation units to obtain sustainable and cost-effective energy.

Municipal Solid Waste (MSW) generated through industrial operations remains a challenge to businesses and commercial establishments; and plastic waste is a particular problem given current low recycling rates. Commercial establishments have long been engaged in reducing their waste generation. More recently, attention is shifting to maximizing material reuse through a circular economy approach, which can significantly streamline operations. Adopting material reuse and responsible end-of-life management can also provide financial incentives to firms. Materials research is currently focusing on producing innovative recyclable and compostable materials from renewable feedstock. Many organizations are adopting material reuse, recycling and composting priorities to become more socially responsible.

Retailers use a large amount of energy due to lighting and refrigeration loads. Retail companies can benefit from examining their resource consumption patterns and opportunities for conservation and efficiency improvements. Companies that transition more quickly to a sustainable business model could benefit from competitive advantage, and reduce the risk associated with regulatory uncertainty and compliance mandates that may be imminent.

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[1] Intergovernmental Panel on Climate Change, Interim Report, 2018. Retrieved April 24, 2019, from: https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/

[2] Tayari, Farid. Energy Production and Consumption in the United States. Retrieved From: https://www.e-education.psu.edu/ebf301/node/457

[3] University of Michigan, Center for Sustainable Systems, 2018. "Carbon Footprint Factsheet." Pub. No. CSS09-05. Retrieved from: http://css.umich.edu/sites/default/files/Carbon_Footprint_Factsheet_CSS09-05_e2018_0.pdf

Meijer is a growing multi-billion-dollar retailer with over 240 stores, five distribution centers, and six food manufacturing plants in six states in the US. Through the *Store of Tomorrow*, Meijer aims to utilize our research findings to implement a store rooted in operational sustainability, that has zero net energy consumption, emissions and waste. The *Store of Tomorrow* project is expected to build on Meijer's existing sustainability initiatives, and prior commitments to offer local and sustainable products, reduce waste, lower its carbon footprint and grow responsibly. Our research focused on sustainability pertaining to energy use, waste management, emissions and water use. The *Store of Tomorrow* aims to provide a unique model in the US, based on an optimized design, both in terms of the technology used and the physical characteristics of the store. Efficient lighting, heating and refrigeration systems, on-site and off-site renewable energy supply solutions, effective waste management capabilities, and water reuse through storm water collection and management represent elements of the store model.

Many traditional retailers have redesigned their storescapes to reduce the decorative portion and emphasize landscape functions such as managing stormwater, crafting pollinator gardens, or providing recreational uses. The Meijer *Store of Tomorrow* will reflect these trends using ecologically beneficial landscape features like native plants, green infrastructure elements and landscapes that integrate educational features.

This innovative project presents proposed elements and recommended technologies for the first net zero food retail store design in the United States and has the potential to revolutionize sustainable design strategy for Meijer. The project could also serve as a model for green building practices by other corporations and sectors. Ultimately, this project has the potential to reduce Meijer's environmental impact as they incorporate net zero elements into the company's network of more than 200 stores, which could lead to a more sustainable food system and healthier environment.

Several key principles guided the research team toward the main project goals. The term *net zero* refers to decreasing a building's energy load as much as possible prior to offsetting any remaining load with (onsite) renewable energy. *Circular Economy* refers to the practice of minimizing the use of resource inputs and creation of waste, pollution and carbon emissions through reuse, sharing, repair, refurbishment, remanufacturing and recycling. *Zero waste* refers to "the conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning, and with no discharges to land, water, or air that threaten the environment or human health" which served as a guiding definition for this research project.[4] The research team relied on these principles throughout the project to identify strategies and technologies and to estimate their performance.

The following sections detail the proposed strategies, best practices and detailed analysis of green building strategies and technologies.

[4] Zero Waste International Alliance, 2018. Retrieved April 24, 2019, from: http://zwia.org/standards/zw-definition/

Objectives and Scope

The objective of this project was to design a portfolio of store design technologies for the Meijer *Store of Tomorrow*, that could also be incorporated to improve the sustainability of existing Meijer stores. To achieve this objective, our research team focused on improving both the Supercenter and Market Format store models to create a collection of technology and design options that could be implemented into a new store prototype or integrated as components of existing stores. To assist Meijer in determining the scope and definition of "net zero", researchers consulted definitions from the National Renewable Energy Laboratory and the Carbon Disclosure Project GHG Protocol, which define GHG emissions into three scope categories.[5] Scope 1 considers the direct combustion of fuels onsite. Scope 2 considers the indirect emissions from purchased electricity. Scope 3 includes indirect emissions from sources like supply chain transportation, customer purchases, goods sold, waste disposal, wastewater treatment, commuting, or business travel. For the purposes of this project, scope 1 and 2 emissions were considered.

This research provides benchmarks of existing and emerging green technologies, as well as a comprehensive set of recommendations based on review and scoring analysis to determine a hierarchy of green technologies. To produce the benchmarks, our team worked to identify Meijer's current baseline emissions and energy consumption in comparison to the efficiency capabilities of emerging technologies. The 2018 Meijer Environmental Footprint Report, as well as internal Meijer data were used to inform the benchmarking process.[6]

A significant portion of the project was devoted to developing a benchmarking system and metrics in order to quantify the environmental impact reductions of different technologies pertaining to energy consumption, water use, and waste management. While focusing on potential improvements to site design, stormwater management, food waste, packaging waste, refrigeration, and HVAC systems. This is detailed in subsequent sections devoted to technology review for each system, and supporting calculations in **Appendix B**. The scoring rubric evaluation metric considered factors like emission abatement and energy efficiency to align with Meijer's current corporate reporting strategies. This allowed us to compare and rank technologies and design elements based on educational merit, environmental performance, and implementation feasibility criteria. Our research team used this rubric to identify and recommend elements for the *Store of Tomorrow* prototype. Meijer can use this prototype later to design for site specific store locations and to adapt and incorporate recommended elements.

Pertaining to project scope, our team considered the environmental footprint of the store envelope and external land elements, but did not consider transportation, supply chain, or retail goods. Our research considered the environmental footprint of utilities (specifically electricity sources such as onsite solar) and compared it to sourcing off-site renewable electricity (power purchase agreements: PPA), building on prior

[5] Environmental Protection Agency, National Overview: Facts and Figures on Materials, Wastes and Recycling. Retrieved April 24, 2019, from: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#Trends1960-Today

[6] Meijer, Environmental Footprint Report, 2016. Retrieved April 24, 2019, from: http://meijercommunity.com/wp-content/uploads/2017/03/2-Meijer-Enviro-Report88-2016-DIGITAL-UPDATE.pdf

company research and findings. Meijer has recommended that PPAs, financial agreements where a provider delivers renewable energy to a customer at a fixed rate over an extended period, could be more feasible than onsite production to meet demand and provide a universal model. This being said, we explored incorporating some on-site generation to raise awareness among customers and serve as an educational tool. The project also evaluated lighting, water, and waste technologies such as LED, refrigeration, and food waste repurposing strategies like compost for hyperlocal food production to incorporate into the store prototype.

For the landscape architecture component, we developed a prototype design that encompasses stormwater management, onsite agriculture with ecological benefits. We provided Meijer ways to enhance ecological aspects in landscape design, such as pollinator habitat, solar flowers, and green infrastructure components. Innovative agricultural practices were also introduced to meet the future trend of vertical hydroponics and freight farms that provide fresh and healthy foods.

Design and customer experience elements will increase customer awareness of sustainability initiatives and provide educational components for customer engagement. Printed signage and digital displays will serve as the primary educational components, used to explain the scientific principles behind each practice. This sustainability education seeks to reduce the customers' environmental footprint. Other elements like product displays, weekly ads/promotions, and quarterly boards would be incorporated into the advertisement campaign to increase customer exposure to Meijer's sustainability practices.

Methodology

System Categorization

The store model was categorized into five key operational systems – Energy, Water and Plumbing, Materials and Resources, Sustainable Sites, and Design and Customer Experience. Figure 1 shows these systems along with the improvement strategies that were studied for each system. The Energy system concerns all energy use within the store, both electrical and thermal. The Water and Plumbing system concerns all water use within and external to the store structure. Materials and Resources concerns the construction of the store, use of materials and resources within the store, and waste generation within the system and through end use of plastic bags. This system does not consider food and merchandise sold or intermediate packaging such as merchandise packaging with the exception of bulk food systems. Sustainable Sites is the system that takes into consideration, design elements outside the store structure that would contribute to Meijer's sustainable operations. Examples of Sustainable Site elements include windbreaks and pollinator gardens. Design and Customer Experience is primarily concerned with communicating Meijer's sustainability initiatives to its customers and enabling Meijer's customers to embrace sustainability through, for instance, the provision of electric vehicle chargers in Meijer's parking lots.

Strategy Conception and Benchmarking

Within each of the above five systems, our team identified a list of strategies. These strategies were developed through a combination of detailed research and industry benchmarking to determine what competitors have already integrated. Each system consists of a set of default strategies – ones that are being commonly employed in the retail space; and innovative strategies – ones that have seen low adoption but which if adopted along with the common strategies, would put Meijer on a sustainable growth trajectory early on. The following section discusses in detail all of the strategies within each store system, benefits and challenges associated with each strategy, and examples of successful applications from the retail industry. Quantitative benchmarking was performed for four technologies in the Energy system. These include Heating and Cooling: geothermal and improved HVAC efficiency, Lighting: LEDs and Refrigeration: alternative refrigerants (see **Appendix B**).

Strategy Evaluation

For each strategy within different store systems, criteria were developed to assess their performance relative to physical requirements, cost of implementation, impact on the customer and contribution to Meijer's sustainability goals.

A scoring rubric was developed wherein, performance against these criteria were defined as Red, Yellow and Green – where Red implies a negative performance, Yellow, a neutral or marginally negative performance and Green, a positive performance. Definitions were developed for each attribute as to what constitutes a negative, neutral or positive performance. A detailed breakdown of the evaluation criteria and scoring rubric is shown in Table 3. Each strategy was assigned a score of Red, Yellow or Green against each criterion and such a scoring was carried out for both Meijer supercenters and market-format stores.

The following is an example of this strategy evaluation method in use (See **Appendix A** for the full scoring sheet).

Example Strategy: On-site Solar PV Panels

Example Criterion: Size and Space Requirements

Example Performance Indices: Red – Prohibitive space requirements; Yellow – Moderate space requirements; Green – Minimal/ Low space requirements

Example Scoring: For the Supercenter – Solar PV is scored Yellow as space requirements is moderate with respect to available store rooftop space; For the Market Format store – Solar PV is scored Red as space requirements are prohibitive with respect to store space availability.

Each strategy within the five store systems were scored similarly and a strategy evaluation score sheet was created to aid Meijer's decision making. A very important consideration here is that all strategies have been scored on their suitability in a newly constructed store and not for the case of retrofitting.

Table III. Detailed breakdown of strategy evaluation criteria and scoring rubric

Criteria	**Interpretation**	**Red**	**Yellow**	**Green**
Size and Space requirements	Space intensiveness of strategy on store property	Strategy is **prohibitive** relative to space availability on the property.	Strategy requires a **moderate** amount of space relative to space availability on the property	Strategy requires **minimal** space relative to space availability on the property
Ease of Implementation	Maturity of technology or extent of infrastructure addition required	Strategy requires **moderate-significant** modification for installation and maintenance	Strategy requires **minimal** modification for installation and maintenance	Strategy requires **little to no** modification for installation and maintenance
Aesthetic Appeal	Pertains to tangible aesthetic appeal of strategy	Strategy is **inherently disruptive** to the store design aesthetic and negatively impacts customer experience visually	Strategy **neither enhances or detracts** from visual aesthetic of store design (ex: HVAC system is enclosed in store envelope)	Strategy visually **enhances** store design and contributes positively to the *Store of Tomorrow* aesthetic for consumers.
Innovation	New, advanced or original ideas shown through strategy (futuristic)	Strategy has **been adopted** in Meijer stores, is standard to industry, or widely implemented across sector	Strategy is **transitional** with few commercially viable installations across the industry	Strategy demonstrates **revolutionary or novel approach** to sustainability and adds a creative or inventive design
Experience	Influence on customer interactive	Strategy **negatively influences**	Strategy has **no positive influence** on	Strategy has a **strong positive influence** on

	experience relevant to strategy	customer shopping experience	customer shopping experience and has negligible negative influence	customer shopping experience
Education	Extent to which strategy advances customer understanding of sustainability or promotes customer engagement with sustainability	Strategy does not advance customer education or **detracts** from *Store of Tomorrow* educational components	**Strategy moderately advances** customer sustainability education (ex: low GWP refrigerants)	Strategy **significantly enhances** consumer understanding of sustainability principles and Meijer Sustainability practices
Meijer Environmental Impact Reduction	Potential for carbon emission reductions or reductions in the quantity of resources consumed	Strategy has **very poor contribution** to resource use and/or carbon emission abatement	Strategy has **moderate contribution** to resource use and/or carbon emission abatement	Strategy has a **very positive contribution** to resource use and/or carbon emissions
Downstream Environmental Impact Reduction (Customers)	Potential for reductions in customer's environmental footprint	Strategy **negatively influences** customer's environmental footprint	Strategy **neither improves or negatively influences** customer's environmental footprint	Strategy **significantly influences** improvement in customer's environmental footprint

System

Ultimately Meijer must balance customer experience, ability to meet basic grocery needs, and customer satisfaction with sustainability goals to reduce waste generation, energy consumption and emissions. The analysis and recommendations are meant to reflect Meijer's sustainability goals and their corporate mission. We aimed to identify design solutions that will maintain and improve customer experience and support the legacy of the Meijer brand. **Figure 1** shows the system diagram that outlines the 5 main systems used to organize and analyze the strategies in the portfolio of store design technologies.

Figure 1. Diagram of Five Primary Systems. The System Diagram outlines our framework for analysis. Store design elements were categorized into five main systems with specific strategies evaluated under their relevant store system.

Technology Review

1. Energy

Energy load presents one of the largest opportunities to reduce carbon intensity and lower emissions in the industry. Energy is a vital input for machinery, heating and cooling, and lighting but it is also a large source of greenhouse gas emissions. This aspect results in a large impact on the environment and drives the goal to transition to renewable sources. To further reduce greenhouse gas emissions in this sector we explored solutions that increase efficiency to reduce the demanded energy load, utilize natural and renewable sources, and integrate automation or smart functionality in the *Store of Tomorrow*. The sector is divided into four sub sections, electricity, lighting, heating & cooling, and refrigeration, which cover the main uses of energy in the store.

Energy Strategies Scoring Sheet

Supercenter

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirement	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Energy	On Site Renewable: Solar PV								
	PPA								
	RECs								
	Smart Appliances*								
	CHP								
	Geothermal								
	Building Envelope Improvement								
	HVAC (increased efficiency)								
	Daylighting*								
	Solar Streetlights								
	LED Motion sensor light*								
	Case Refrigeration								
	Low GWP refrigerants (alternatives)								

Market Format

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirement	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Energy	On Site Renewable: Solar PV								
	PPAs and VPPAs								
	RECs								
	Smart Appliances								
	CHP								
	Geothermal								
	Building Envelope Improvement								
	HVAC (increased efficiency)								
	Daylighting								
	Solar Streetlights								
	LED Motion sensor light								
	Case Refrigeration								
	Low GWP refrigerants (alternatives)								

1.1 Electricity

1.1.1 Electricity: On-site Renewable Electricity Generation

On-site generation of renewable energy, primarily through solar photovoltaics and micro wind, can contribute to Meijer's sustainability goals. The 2019 Meijer Renewable Energy Assessment, developed by a previous SEAS Master's project team, explored this option in detail and determined that upwards of 230 stores and distribution centers can install PV arrays with a favorable Net Present Value (NPV). On-site generation as a potential strategy has advantages and disadvantages.

The costs for commercial solar PV and small wind are falling significantly. Over the last decade, the all-in capital costs for commercial PV has fallen by nearly 50 percent.[7] NREL estimates that 2018 all-in cost for commercial solar PV stands at $2.10/ W-AC while that for small wind stands at $2/ W-AC.

On-site solar generation results in substantial cost savings for big box stores. According to a report prepared by Environment America, big box stores have the potential for an annual electricity expense reduction of almost 42 percent by investing in commercial rooftop solar.[8] The 2019 Meijer Renewable Energy Assessment carried out by previous SEAS Master's students has identified several million dollars of operational cost savings to Meijer if on-site renewable energy generation is pursued by Meijer. However, on-site solar PV would certainly require considerable amounts of capital investment. In addition to the cost of the panels, changes may have to be made to the store structure – for instance, adding steel reinforcements to the store roofs to house the solar panels. These costs need to be accounted for, and a present value economic assessment can be performed to determine the suitability of on-site solar for specific stores. Additionally, big box stores can achieve further savings through integrating energy storage, which can help reduce peak demand charges.

On-site solar generation has significant emission reduction potential. Electricity generation in the Midwest results in 0.8 kg CO_2 eq. emissions per kWh of electricity generated.[9] Installing on-site renewable energy would partially offset Meijer's electricity consumption from the Midwest grid and would result in emission savings of the same amount per kWh consumed. The 2019 Meijer Renewable Energy Assessment carried out by previous SEAS Master's students has estimated thousands of metric tons of carbon emission savings should Meijer pursue on-site renewable energy generation. For a sample store that has electricity consumption equaling 5 GWh/ year, the previous SEAS master's project team identified a 25 percent reduction in electricity related emissions with on-site solar PV. The PV system was estimated to provide 25 percent of

[7] SEIA. Available at: https://www.seia.org/sites/default/files/inline-images/SEIA-SolarIndustryTrends-2019Q4-3-FallingPrices.gif
[8] Environment America, 2016. Available at: https://environmentamerica.org/sites/environment/files/reports/AME%20Solar%20Stores%20Feb16.pdf
[9] EPA Emissions Factors, 2018. Available at: https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

store electricity demand, bringing down emissions from a baseline figure of 6.6 million lbs. of CO_2e to 4.9 million lbs. of CO_2e.The baseline figure was estimated from eGRID data and the assumptions regarding solar PV were made from computations carried out by the previous Meijer master's project team.

On-site renewable energy generation also results in many community benefits by helping to reduce local air pollution, create local jobs, reducing customer expenses due to improved operational expenses etc.

On-site generation contributes directly to additionality. While purchasing voluntary RECs would enable Meijer to claim the same level of emission abatement as on-site generation, commissioning on-site generation would have a direct additional effect on renewable energy generation. This is primarily because US REC markets are categorized into compliance and voluntary. Compliance RECs are primarily purchased by utilities which operate in markets with Renewable Portfolio Standards while voluntary RECs are tradable throughout the US and can be purchased to offset electricity related emissions. At present, voluntary RECs are priced so low (consistently less than $1/ MWh) that it would have very limited influence on furthering installed capacity of renewable energy.[10]

Investments made by Meijer to advance on-site renewable energy capacity would be a visible effort in its pursuit of improved sustainability. The improved image through such a visible measure could help Meijer attract more customers and retain the patronage of existing customers. Effective marketing campaigns could highlight Meijer's initiatives (a few examples of which are detailed in a later section). On-site solar was assigned scores of green in the environmental impact reduction, customer education and engagement and aesthetics criteria. Scores of yellow were assigned for 1) size and space requirements given the moderate to large space requirements; 2) ease of implementation given the need for store structure modification to include panels on the rooftop; 3) and innovation since there are several commercially viable solar PV installations in existence in the retail space.

The major drawback is the fact that the US Midwest has modest solar resource availability. The National Renewable Energy Laboratory (NREL) places the annual average solar resource availability in most parts of the Midwest between 4 and 4.25 kWh/ m^2/ day for flat-plate solar collectors.[11] This is considerably lower when compared with solar-resource rich western states that receive upwards of 5.75 kWh/ m^2/ day. The resource constraint implies that the investment towards on-site solar would be slower to pay back than other regions of the US that are richer in solar resource.

[10] US EPA, Renewable Electricity Market. Available at: https://www.epa.gov/greenpower/us-renewable-electricity-market
[11] NREL. Available at: https://www.nrel.gov/gis/images/solar/solar_ghi_2018_usa_scale_01.jpg

Several prominent retailers have implemented on-site solar PV energy generation. Target and Ikea are the leading retailers embracing on-site renewable energy. Target has already installed rooftop PV in 500 of its buildings including distribution centers and big box stores to date, several of which are in Hawaii, Arizona and Colorado[12] In total, Target has added approximately 240 MW of on-site solar generation with each installation offsetting as much as 40 percent of the building's energy needs.[13] Ikea has rooftop solar installed in 90 percent of its buildings in the US including stores and warehouses. As early as 2011, Ikea installed a 573-kW solar PV system in its West Sacramento store capable of generating almost 800 MWh annually and with emissions equivalent to removing 109 cars off the road.[14]

1.1.2 Electricity: PPAs and VPPAs

Power purchase agreements (PPA) and virtual power purchase agreements (VPPA) are both forms of long-term contracts to purchase energy and are often applied specifically to renewable energy. In a traditional, or physical, PPA a developer arranges and carries out all aspects of the development of a renewable energy project on site or in a nearby location to the customer or offtaker. The customer then purchases the electricity generated from the development at a long-term agreed upon price. Prices are set through a variety of mechanisms, including a fixed price with or without an annual escalator, or a guaranteed percentage below retail prices. PPA contracts are commonly 10 to 25 years in length. In recent times, corporate PPAs timelines have been in the 5-8-year range. The medium term, fixed price nature of the contracts with little to no operational and maintenance responsibilities on the part of the offtaker, means PPAs present limited risk to the customer. While PPAs have various benefits, they also require significant space on or near the property of the offtaker.

Virtual PPAs, often referred to as a contract for differences, are a long-term financial contract associated with renewable energy developments that allow the customer to claim credit for renewable power generated, but do not require generation to be onsite. This system allows for greater flexibility, as well as the ability to construct renewables in regions with greater wind or solar resources. In a VPPA, the buyer still receives electricity from the physical grid they are connected to. The buyer pays a fixed strike price to the developer. The developer sells energy into the wholesale market and pays the customer a variable rate based on the wholesale prices they receive. Thus, when wholesale rates are higher than the fixed strike price the customer receives money, thereby simulating a savings on their energy bill that would likely come with a traditional PPAs in similar market conditions.

Both PPA and VPPAs have the primary advantage of additionality, meaning that power purchase agreements of distributed renewable energy tend to be for new renewable

[12] Target, Inc. Available at: https://corporate.target.com/article/2017/04/solar-power-update
[13] Solar Power World, 2019. Available at: https://www.solarpowerworldonline.com/2019/11/target-installs-solar-on-its-500th-location/
[14] Business Wire, 2011. Available at: https://www.businesswire.com/news/home/20110628006442/en/System-Complete-IKEA-Powers-Solar-West-Sacramento

energy capacity, and not existing renewable generation. Thus, these contracts are more beneficial in greening the electricity grid than the purchase of RECs or offsets.

Target has been very successful in furthering their renewable energy goals through PPAs. Target has PPAs for its stores across the US, an example of which is the 450,000 MWh annual contract from the Lone Tree Wind Farm in Illinois.[15] In 2018, Walmart signed a PPA deal with EDP Renewables to enable the construction of nearly 233 MW of new wind energy – helping both Walmart's clean energy and emission abatement goals and the communities in Indiana and Illinois where these projects would be located.

Meijer can outline such PPA deals with wind developers across the Midwest and VPPAs with solar developers in the western states to positively influence both its own goals and the advancement of renewable energy generation across the US.

PPAs and VPPAs score green in the environmental impact, size and space requirements and ease of implementation criteria but score yellow in the customer experience, innovation and education criteria. For supercenter stores, combining on-site solar PV with PPAs would ensure considerable environmental benefits and would help showcase Meijer's initiative to customers.

1.1.3 Electricity: Renewable Energy Certificates

Renewable Energy Certificates (RECs) represent the "greenness" of clean energy. RECs are a way for corporate customers and utilities to claim clean electricity usage by essentially purchasing the environmental benefits associated with producing or consuming 1 Megawatt hour (MWh) of clean energy. Electricity can be claimed to be renewable only when bundled with the associated RECs and unbundled electricity is no longer considered green, with the owner of the RECs being able to claim clean energy consumption even while maintaining the same consumption sources.

RECs are tradable certificates with a unique identification code. Most RECs in the US renewable energy market are certified by Green-e. Certified RECs can change hands several times until it is purchased and retired by a consumer, effectively taking it off the market. Green-e ensures that traded RECs are from new projects, verified to validate project owner claims and are not double-counted among customers or toward satisfying state Renewable Portfolio Standards (RPSs) in the case of utilities.

RECs are traded in the US in mandatory and voluntary markets. Mandatory markets represent RECs traded to satisfy state and local RPSs while voluntary markets typically comprise of corporations and educational institutions with independent renewable energy procurement or carbon reduction goals.

[15] Target, 2019. Available at: https://corporate.target.com/article/2019/06/renewable-electricity

RECs are simple financial tools to assert clean energy use. Meijer could assert green electricity consumption purely through the purchase of RECs without needing to alter their current electricity procurement contracts. Voluntary RECs in the US have been consistently trading below 1$/ MWh with recent signs of increase. Purchasing RECs presents an economical option for Meijer.

RECs are often not additional, as they do not directly lead to additional energy capacity development. The effect that Meijer would have on communities through voluntary RECs would be minimal.

A claim of renewable energy consumption and emission offsetting on the part of Meijer through the purchase of RECs makes it difficult for Meijer to make its sustainability case. On-site generation or PPAs of local renewable energy projects on the other hand, enhance Meijer's credibility significantly and elevate the visibility of its sustainability actions.

Research suggests that prominent retailers are not considering RECs as part of their sustainability goals. Walmart has, and in its report titled 'Walmart's Approach to Renewable Energy', clearly stated that they will not consider RECs as a potential sustainability strategy. Walmart believes that RECs simply transfer ownership of greenness and do not positively influence renewable energy additionality.[16]

Meijer should consider taking a similar approach in satisfying its sustainability goals. RECs should ideally be avoided in long-term sustainability strategies in favor of more impactful strategies. RECs score green in the environmental impact criteria but yellow or red in the customer experience, education and innovation criteria. Carefully procured RECs screened by Green-e could form a small portion of the suite of energy strategies to help with overall economics.

1.1.4 Electricity: Smart Appliances

Smart appliances allow for more efficient use of the building's operating system which saves on energy use. For example, a Wireless Sensor Network identifies areas of inefficiencies and potential improvement for a building's lighting system.[17] When tested in an office building the system identified lighting savings ranging from 50-70%. Meijer could apply this system or a similar one to their offices and store employee areas to identify energy savings in lighting from efficiency improvement and optimization of the control system.[18] This automated approach could generate savings for Meijer by reducing O&M costs.[19] In this system, sensors help identify areas of potential machine failure and provide the opportunity for preventative maintenance as well as faster trouble shooting in some cases due to increased equipment data[19]. These smart sensors

[16] Walmart. Available at: https://cdn.corporate.walmart.com/eb/80/4c32210b44ccbae634ddedd18a27/walmarts-approach-to-renewable-energy.pdf

[17] Delaney, D. T., O'Hare, G. M., & Ruzzelli, A. G. (2009, November). Evaluation of energy-efficiency in lighting systems using sensor networks. In Proceedings of the First ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Buildings (pp. 61-66). ACM.

[18] Wu, X., Hu, C., Zheng, C., & Zhang, Q. (2016, June). Solar street lamp system using GPRS and ZIGBEE technology. In 2016 IEEE 11th Conference on Industrial Electronics and Applications (ICIEA) (pp. 2561-2564). IEEE. Accessed

[19] Rockwell Automation, Allen-Bradley, 2016. Integrated Smart Sensors. Accessed https://literature.rockwellautomation.com/idc/groups/literature/documents/br/sensor-br002_-en-p.pdf

could be deployed in Meijer's Distribution Centers for better monitoring and prevention of machine failure. Smart energy networks aid in commercial device control, automation and energy efficiency and management.[20] Additional examples from the industry include Target's smart building energy management systems which capture building efficiencies[21] Kroger's increase in efficiency and monitoring of leaks[22], and a power management setting at Argonne National Lab to shut down electronics when not in use.

1.1.5 Electricity/Heating & Cooling: Combined Heat and Power

Combined Heat and Power (CHP) uses a fossil-based fuel (sometimes in combination with organic dry waste) to generate thermal energy and electrical energy. CHP systems have higher efficiencies when compared with Separate Heat and Power (SHP) systems. CHP systems are very useful for large commercial operations such as big box retail stores.

CHP systems have high thermal efficiencies. Because waste heat is utilized in CHP systems, the thermal efficiencies of CHP systems can be as high as 60 to 80 percent. The most common CHP systems have thermal efficiencies of 80% (steam turbine)[23], 75-80% (reciprocating engine), 65-70% (combustion turbine), 60-70% (microturbine) and 55-80% (fuel cell). This results in significant energy savings and related emission reduction.

Small to medium sized packaged CHP systems are available, which greatly reduces installation times, space requirements and capital expense.[24]

CHP systems are situated on-site and can keep critical retail infrastructure such as food storage freezers and space heating running in the event of an outage.

On-site CHP systems can help reduce the load needed by the store or transition entirely away from outdated local power plants that produce criteria air pollutants.[25]

CHP systems can be downsized and combined with on-site solar PV or small wind resulting in an energy system optimized for reliability and cleanliness.

Recently the application of CHP generation through biomass is being explored.[23] This would decrease emissions as the fuel source transitions away from fossil fuels to cleaner alternatives.

CHP systems, although comparatively more efficient and capable of lowering emissions, still operate on fossil resources. When compared to a standalone heat and power system, CHP systems can lower combined electricity and thermal related emissions by almost

[20] Target Sustainability Report (2019).Accessed https://corporate.target.com/_media/TargetCorp/csr/pdf/2018_corporate_responsibility_report.pdf
[21] Target Sustainability Report (2019).Accessed https://corporate.target.com/_media/TargetCorp/csr/pdf/2018_corporate_responsibility_report.pdf
[22] Kroger Sustainability Report (2019). Accessed http://sustainability.kroger.com/Kroger_CSR2018.pdf
[23] EPA. Combined Heat and Power Partnership. Available at: https://www.epa.gov/chp/chp-benefits
[24] EPA. Combined Heat and Power Partnership. Available at: https://www.epa.gov/chp/chp-benefits
[25] EPA. Catalog of CHP Technologies. Available at https://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies_section_1._introduction.pdf

40 percent per year of operation.[26] This estimation by the U.S. EPA corresponds to a 5 MW CHP system with an assumed thermal efficiency of 80 percent. Meijer can also employ the CHP Emissions Calculator developed by the EPA to make decisions for each of their stores.[27]

Exhaust from the CHP system could mar the customer shopping experience and also negatively affect the community around the store.

Food Lion, a food retail chain in the Southeast and Mid-Atlantic, has installed units at six North Carolina stores. These projects produce almost 2.4 MW of electricity and has improved energy efficiency in stores by 25 percent. Whole Foods Market has installed a CHP system at its Brooklyn, New York, location. The 157-KW unit provides heating and chilled water year-round and is meant for reliable service during potential blackouts. Whole Foods claims that this store is 60 percent more efficient than an average food retail store.[28]

Meijer could consider installing CHP systems in supercenter stores that traditionally have high energy use and also have more space available on-site. Market Format stores would likely not have the space to house large CHP systems. However, modular CHP systems in smaller sizes which are pre-packaged, might be a good strategy for Market Format stores. The Midwest states in which Meijer operates have medium to high commercial electricity rates ranging from 10.5 to 12.5 cents/ kWh. Given these prices, Meijer would be able to achieve a reasonable payback period. The large electricity demands and heating requirements within the store also makes CHP suitable for Meijer stores. Additionally, absorption chillers can be combined with the CHP system to partially satisfy the refrigeration load and space cooling loads in summer months. Having on-site CHP systems would enable Meijer to be resilient to grid outages from weather and natural disasters, which in turn benefits the communities that depend on Meijer.

[26] US EPA. Available at: https://www.epa.gov/chp/chp-benefits

[27] US EPA CHP Emissions Calculator. Available at: https://www.epa.gov/chp/chp-energy-and-emissions-savings-calculator

[28] Pew Trust, 2015. Available at: https://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2015/06/combined-heat-and-power-helps-groceries-reduce-costs-and-increase-resiliency

1.2 Heating & Cooling

1.2.1 Heating & Cooling: Geothermal Energy

Geothermal energy is a renewable source of thermal energy that can be used for space heating and cooling. Because subsurface temperatures are relatively stable, they are used as either a heat source or sink, depending on the season. In the winter, the heat energy from below ground is used to pull in heat for space heating, while heat is dumped back into the ground during the summer when space cooling is performed.

The carbon footprint of geothermal energy is significantly less than natural gas fired thermal systems. Emissions reductions through using a Geothermal Heat Pump (GHP) could be as much as 65 percent as compared to a baseline HVAC unit.[29] It was found during the summer internship that a GHP system could offset 553 MT of CO_2e from a Meijer store's heating and cooling load (Appendix B).

Geothermal energy is very efficient. A standard GHP can deliver a heating COP of 3.3 which implies that the thermal energy output is 3.3 times the electricity input when measured in the same unit. Additionally, GHPs also deliver a cooling Energy Efficiency Ratio (EER) of 14.1. This makes GHP's substantially more efficient than conventional HVAC systems.[30]

Geothermal energy is very reliable, as sub-surface temperatures are very stable. Studies have shown that geothermal energy has high suitability in the US Midwest owing to significant temperature ranges across locations and depths and relatively high stability.[31] The availability of geothermal resources can vary significantly by location and is very sensitive to the prevailing physical nature of the ground at any location.

A standard GHP system can range anywhere between $2,800 to $5,500 per ton of capacity, depending on the configuration of installation. In comparison, central air source heat pumps cost between $1450 and $2300 per ton.[32]

Geothermal requires careful zoning considerations. Geothermal systems have substantial space requirements and the utility rights of way could pose constraints to the size of the system. Careful considerations of zoning permits is essential in planning geothermal boreholes.

A notable success story of geothermal implementation is that of the Michigan State Capitol in Lansing. The project is currently underway and is part of a $70 million state infrastructure enhancement plan. The system will comprise of 224 bores of approximately 500ft in depth to obtain high steady temperatures. The system is configured as a closed vertical loop resulting in high spatial use efficiencies. The Michigan State Capitol Commission (MSCC) has estimated that the annual savings

[29] EERE, 2015. Available at: https://www.energy.gov/eere/articles/making-difference-geothermal-heat-pumps
[30] *EERE, 2009. Available at: https://www1.eere.energy.gov/geothermal/pdfs/gshp_overview.pdf*
[31] ISEE at the UIUC, 2019. Available at: https://sustainability.illinois.edu/geothermal-energy-coming-to-a-midwest-state-near-you-part-i/
[32] US DOE, EERE. Available at: https://www1.eere.energy.gov/geothermal/pdfs/gshp_overview.pdf

would be between $250,000 and $300,000 and that the system would break even in 7 years.[33]

Geothermal systems score green in the environmental impact, customer education and innovation categories. Given the large space requirements for geothermal boreholes, we envision this strategy as being applicable only for supercenter stores. A combination of geothermal and conventional HVAC systems with alternative refrigerants could also be a potential route for Meijer to consider.

1.2.2 Heating & Cooling: Building Envelope Improvements

The EPA defines the building envelope as elements of the building, including all external building materials, windows and walls, that enclose the internal space. Envelope improvement presents one of the largest opportunities to reduce energy load. The building envelope can be improved by reducing the amount of lost heating and cooling and subsequently the energy load that is used to replace it through increased thermal performance.[34] Solutions that result in energy savings include insulation, improved envelope tightness, low emissivity windows, lighting, high efficiency HVAC, and passive cooling and heating like a solar heating system has been used in public buildings.[35] As insulation and the envelope improves, the HVAC system can be downsized as the load needed to provide comfort heating and cooling is reduced.[36] Some cases include Target's efficient buildings through Energy Star certification, high performance sustainable buildings from Argonne National Lab achieved by high-efficiency building materials, lighting and mechanical equipment, new heat recovery, and from NREL waste heat capture, evaporative cooling, and radiant heating and cooling technologies.[21]

Aligning air change rates to the approved code levels offers additional opportunities for potential energy savings however, there must be enough outdoor air to dilute indoor contaminants and replace exhaust air from fans and other mechanical equipment.[34] This is accomplished through a set infiltration rate which is dependent on envelope tightness, windows, or ventilation. The infiltrated air may increase energy load as it requires conditioning to meet comfort standards.[34] In order to meet the building code and health standards there will always be an energy load associated with this strategy, but it is still possible to reduce emissions further through a cleaner grid mix and a shift to renewable energy sources to cover the baseload.

1.2.3 Heating & Cooling: Improved HVAC Efficiency

Seasonality and temperature largely drive the HVAC system's energy use. This is measured through the number of heating degree days (HDD), the number of days the average temperature is below 65F, and cooling degree days (CDD), the number of days

[33] Michigan Battle of the Buildings, 2018. Available at: https://michiganbattleofthebuildings.org/geothermal-energy-comes-michigans-state-capitol-building/
[34] Mudarri, D. H. (2010). Building codes and indoor air quality. US EPA. Accessed https://www.epa.gov/sites/production/files/2014-08/documents/building_codes_and_iaq.pdf
[35] Ardente, F., Beccali, M., Cellura, M., & Mistretta, M. (2011). Energy and environmental benefits in public buildings as a result of retrofit actions. Renewable and Sustainable Energy Reviews, 15(1), 460-470. Accessed https://www.sciencedirect.com/science/article/pii/S1364032110003096
[36] Sadineni, S. B., Madala, S., & Boehm, R. F. (2011). Passive building energy savings: A review of building envelope components. Renewable and sustainable energy reviews, 15(8), 3617-3631.

the average temperature is above 65F, in a one-year period. It operates under the assumption that no heating or cooling is needed when the temperature is 65F.[37] The number of HDD represents when heating is required and likewise CDD represents when cooling is required. However, the seasonality of HDD and CDD may change in the wake of climate change as temperatures rise and become more variable. To mitigate this risk, more adaptable systems (e.g. balanced ventilation systems) may be installed. Although, these systems tend to have higher capital costs than current systems (EPA, 2010) which makes them more challenging to adopt in a business setting.[35] It is important to note that the cost may change as technology improves and becomes more readily available in the future through advancements.

Since HVAC is used year-round it provides an opportunity for energy savings through an improvement in efficiency.[34] During the summer, we calculated the impact of increasing the system's efficiency using an increase in the Energy Efficiency Ratio. The Energy Efficiency Ratio (EER) is established by ASHRAE, and higher ratios mean more efficient units. We examined three scenarios to determine savings in annual energy consumption using an online rooftop unit comparison calculator from Pacific Northwest National Laboratory. [38] The first scenario had an EER of 17 and represented the maximum possible energy savings through efficiency improvement. The second scenario, an EER of 13.5. In the third scenario an EER of 11.6 was the most feasible as according to an AAON professional, "the larger HVAC units do not currently have different efficiency options to switch to. Although it is expected that they will in the near future." [39] The percentage of HVAC energy savings and emissions reduction from the average store baseline per scenario 1, 2 and 3 respectively were 25.6% (64.8 MT of CO_2e), 13.5% (30.5 MT of CO_2e) and 4.7% (2.8 MT of CO_2e) (**Appendix B**).

Walmart's plan to upgrade their HVAC equipment for their sustainability initiatives,[40] Target's use of Energy Recovery Ventilation and Variable Frequency Drives on their HVAC units[21] and Simons' energy-efficient HVAC systems represent other use cases across the industry.[41]

1.3 Lighting

1.3.1 Lighting: Daylighting

Daylighting is the concept of admitting natural light into a building in a controlled fashion to aid the dynamic lighting requirements of the building over the course of a day. Daylighting can deliver substantial energy savings and also positively affect indoor productivity.[42] This strategy is very suitable for Supercenter and Market Format Meijer stores.

[37] National Weather Service and NOAA. Accessed https://www.weather.gov/key/climate_heat_cool
[38] Pacific Northwest National Laboratory. Rooftop Unit Comparison Calculator. https://www.pnnl.gov/uac/
[39] Todd AAON, RE: High Efficiency Units email, 7/11/2019
[40] Walmart Sustainability Report (2018). Accessed https://corporate.walmart.com/media-library/document/2018-grr-summary/_proxyDocument?id=00000162-e4a5-db25-a97f-f7fd785a0001
[41] Simons Sustainability Report (2018). Accessed https://simon-malls.cld.bz/Simon-Sustainability-Report-2018/22-23/
[42] WGBC. Available at: https://www.buildings.com/article-details/articleid/19755/title/3-daylighting-strategies-for-existing-buildings

The US Office of Energy Efficiency and Renewable Energy (EERE) estimates that daylighting has the potential to reduce the primary energy consumption in big box retail stores in the US Midwest by 28 kBTU/ yr-ft^2. [43]

Daylighting further can reduce lighting energy demand in big box retail stores in the Midwest by 35% annually.

Skylights are required to cover approximately 4% of the roof area for big box retail stores to obtain the desired energy effect. This costs around $50,000 for big box retail stores with an additional $9,000 for enabling controls to limit daylighting aperture. EERE estimates that the energy related savings can help repay the initial expenses in as little as 5 years.[44]

Daylighting also improves customer experience and enhances sales figures. A California Energy Commission funded study has identified that daylighting can substantially improve the retail shopping experience for a customer. Retail revenues from similar products were found to be greater by almost 40 % over the study period, in a store with daylighting.[45]

Several retailers have successfully implemented daylighting in their stores including Walmart and Costco. Walmart has been operating skylights with controls in several of its stores since 1995. In addition to energy savings, portions of the store with the skylight has seen improved sales volumes – something Walmart uses to its advantage when planning impulse sales. Costco has seen energy use reductions of about 37 % in its stores with daylighting, resulting in annual savings of $23,000. Other smaller retail chains in the Midwest have also implemented daylighting given the energy use reductions and related savings.[46]

1.3.2 Lighting: Solar Street Lights

Street lights improve the safety within the store perimeter for customers and employees. Street lights consume a smaller amount of energy when compared with systems such as HVAC but are important to consider as they run the entire year overnight. Street lights are becoming more viable as the cost of their components have decreased.[47] Solar street lights can be standalone operating off of a PV cell and battery that charges during the day. Or they can be connected to a microgrid powered by renewable energy. [48] Transitioning street lights to a renewable energy source would allow Meijer to offset, at least partially, the grid-purchased electricity required to operate them. This strategy has little to no impact on the store aesthetic and customer experience as it is not apparent to the customer while still providing necessary lighting .

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[43] EERE, 2009. Available at: https://www1.eere.energy.gov/buildings/publications/pdfs/commercial_initiative/toplighting_final_report.pdf

[44] EERE, 2009. Available at: https://www1.eere.energy.gov/buildings/publications/pdfs/commercial_initiative/toplighting_final_report.pdf

[45] California Energy Commission, 2003. Available at: http://h-m-g.com/downloads/Daylighting/A-5_Daylgt_Retail_2.3.7.pdf

[46] Solatube. Available at: https://static-assets-solatube.s3.amazonaws.com/s3fs-public/field/files/tech_resources/daylight-facts-figures-retail-sales.pdf

[47] Ciriminna, R., Meneguzzo, F., Albanese, L., & Pagliaro, M. (2017). Solar street lighting: a key technology en route to sustainability. Wiley Interdisciplinary Reviews: Energy and Environment, 6(2), e218.

[48] Costa, M. A., Costa, G. H., dos Santos, A. S., Schuch, L., & Pinheiro, J. R. (2009, September). A high efficiency autonomous street lighting system based on solar energy and LEDs. In *2009 Brazilian Power Electronics Conference* (pp. 265-273). IEEE.

1.3.3 Lighting: LED Motion Sensor Light

The transition from incandescent light bulbs to Light Emitting Diodes (LEDs) is potentially the most feasible solution to reducing energy use with respect to the baseline in new buildings or as a retrofit. LEDs can generate more than 75% energy savings in comparison to incandescent lighting in the case of residential and Energy Star LEDs.[49] In many cases, they can be installed in the same fixtures used to light the store and as incandescent or fluorescent lights. It was found, from a retrofit done at Meijer, that transitioning to LEDs resulted in a 7% reduction in energy and associated emissions (**Appendix B**). Adding a motion sensor to LEDs would increase the overall efficiency of the system and reduce energy and emissions even further. A smart LED lighting system resulted in 55% power reduction in a study where dimming capabilities were added to a commercial LED panel and it also accounted for user preferences.[50] This solution is not viable in every area of the store, as certain areas such as stairways or restrooms, must remain lit at all times to meet safety standards.[51] Meijer could apply LED motion sensor lights to the salesfloor area. To address the concern, the LED motion sensor lights could be staggered with dimmed LED lights. This way customers would always have a lit horizon and the areas would become brighter when they entered them saving on energy use and emissions when there is no one in the area as opposed to having them lit at 100% brightness for 24 hours a day, 7 days a week. Kroger aims to introduce energy-efficient fixtures like LED motion sensor lights[22], and Simons has a state-of-the-art LED lighting control program.[52]

1.4 Refrigeration

1.4.1 Refrigeration: Case Refrigeration

Case refrigeration is another element that is another common element in grocery stores as certain products must be kept at a low temperature. It is one of the most energy intensive systems in supermarkets, reportedly consuming 36% of the annual energy use of a Whole Foods Market store,[53] and approximately 50% of total electrical energy use for average supermarkets.[54] This presents an opportunity for improvement, particularly in areas like the open cases. Adding doors on the refrigeration cases allows for better control of the building's temperature and humidity as well as a more comfortable setting for customers without the cold air leaking into the aisles.[55] This adjustment also saves energy by controlling the case temperature more effectively and requiring less cooling in the cases as it only leaks into the store when the doors are opened to access product. The DOE has found that adding case doors reduces the load by 50-80% by reducing cold air losses. It is estimated that this results in savings of $5-10k for a typical

[49] DOE. LED Lighting. Accessed https://www.energy.gov/energysaver/save-electricity-and-fuel/lighting-choices-save-you-money/led-lighting
[50] Magno, M., Polonelli, T., Benini, L., & Popovici, E. (2014). A low cost, highly scalable wireless sensor network solution to achieve smart LED light control for green buildings. IEEE Sensors Journal, 15(5), 2963-2973.
[51] NCAT (2017). Overview of Commercial Lighting Code Provisions. https://www.ncat.org/energy_services/docs/CommercialLightingCodeProvisions2017.pdf
[52] Simons Sustainability Report (2018). Accessed https://simon-malls.cld.bz/Simon-Sustainability-Report-2018/22-23/
[53] Deru, M., Bonnema, E., Doebber, I., Hirsch, A., McIntyre, M., & Scheib, J. (2011). Thinking like a whole building: a Whole Foods Market new construction case study (No. NREL/TP-5500-50056). National Renewable Energy Lab.(NREL), Golden, CO (United States). Accessed https://www.nrel.gov/docs/fy11osti/50056.pdf
[54] Fricke, B., & Becker, B. (2010). Energy use of doored and open vertical refrigerated display cases. Accessed https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2153&context=iracc
[55] Turpin, J. (2019). Refrigeration Retrofits Offer "Cool" Savings for Supermarkets. ACHR news. Accessed https://www.achrnews.com/articles/140605-refrigeration-retrofits-offer-cool-savings-for-supermarkets

supermarket.[56] However, condensation of the cases may be an issue, and this may also block sightlines to product causing customers to have to open the cases more frequently. To address this concern, Meijer could consider installing equipment such as electric resistance anti-sweat door heaters, as implemented in a Whole Foods Market study conducted by NREL.[53] Other benefits from installing case doors include better lighting with LEDs,[49] and increased shopping time as customers may be more inclined to linger in warmer aisles.[55] Besides these case studies, Walmart has goals to use reduced water refrigeration,[41] and Kroger is installing refrigeration case controls, demand defrost and demand control ventilation to reduce energy consumption.[22]

1.4.2 Refrigeration: Low GWP Refrigerant Alternatives

The largest energy reduction will come through efficiency improvements to the system. Besides energy reduction, refrigerant leakage is a common problem in the industry. The more square footage of pipelines the system occupies, the greater the risk of leakage from the total or transition to refrigerants that meet thermodynamic requirements and have lower Global Warming Potentials (GWP) and Ozone Depletion Potentials (ODP) than current refrigerants (such as HCFCs).[57] With a lower GWP there is less MT of CO_2 GreenChill Program, which aims to reduce the industry's effect on climate change and the ozone layer by reducing refrigerant emissions.[58] Meijer and many of its competitors are part of this program and Meijer's leakage has been reduced to 8%.[59] Besides reducing leakage to lower the carbon footprint there is potential to decrease carbon intensity by transitioning to low GWP refrigerant alternatives as Meijer currently uses, low ODP but high GWP refrigerants.[60] This would be beneficial as the leaked refrigerants are less harmful to the environment.

Refrigerant leakage can create health concerns for customers,[61] which exemplifies the importance of considering the ASHRAE safety classification of the alternative refrigerants that is based off of their flammability and toxicity, environmental effects from decomposition, and acute or chronic health risks.[62] While the alternatives have higher risks of ignitability and toxicity, these risks are mitigated by safety standards or requirements, like a specific charge level or system size. Out of the four scenarios researched in this study **(Table IV**), the natural alternatives, carbon dioxide, ammonia and propane, are the best solution for carbon reduction. This is primarily because of the transition from GWP levels of differing magnitudes that is GWP of, 1000s – 100s to < 100 CO_2e. However, the natural alternative refrigerants have higher capital costs (CC), as they require a new system that is more complex which increases the O&M costs. Alternatively, the synthetic alternative R-448A can be used as a replacement with the current system, reducing CC and O&M costs. A benchmark calculation performed during the summer internship produced 64.5% emissions reduction for the *Store of Tomorrow* when R-404A was replaced with R-448A (Appendix B). This could be further

[56] Goetzler, W. (2013). Retrofitting Doors on Open Refrigerated Cases. Department of Energy: Energy Efficiency and Renewable Energy. Accessed https://www.energy.gov/sites/prod/files/2013/12/f5/commlbldgs18_goetzler_040413.pdf
[57] Kujak, S. (2017). Flammability and new refrigerant options. ASHRAE Journal, 59(5), 16-23. Accessed http://www.trane.tj/content/dam/Trane/Commercial/global/products-systems/education-training/industry-articles/ASHRAE052017_Kujak_Refrigerants.pdf
[58] EPA, GreenChill Partnership. Accessed from https://www.epa.gov/greenchill
[59] EPA, (2019, June). 2018 GreenChill Partner 26 Data Report. *PDF*.
[60] Meijer GreenChill report. (GWP values)
[61] EPA, Significant New Alternatives Policy Refrigerant Safety. Accessed from https://www.epa.gov/snap/refrigerant-safety
[62] Carrier Corporation (2015). Carrier Engineering Newsletter Vol 3, Issue 2, PDF. Accessed from https://dms.hvacpartners.com/docs/1001/Public/0E/ENG_NEWS_3_2.pdf

reduced to nearly zero if the *Store of Tomorrow* used natural refrigerants with very low GWPs (i.e. CO_2, NH_3 or propane). The upfront costs are not as significant of an issue with new stores but are very relevant when considering retrofits. A retrofit would require Meijer to replace the old system, generating installation and disposal costs, versus only changing out the refrigerant in the case of R-448A. It is expected that as technology improves costs will decrease for CO_2 and ammonia, and that they will become more viable options in the future with their significantly low GWPs. Examples of alternative refrigerant usage in the industry include Nestle, which uses a cascade refrigeration cycle with two natural refrigerants (ammonia isolated from the process areas and CO_2 in the production areas), Target, which has transitioned to natural refrigerants instead of refrigerants like R-404A, [21] and Kroger, which participates in the EPA's GreenChill program to reduce refrigerant leaks.[22]

Table IV. The 5 scenarios are a transition from R-404A and R-407A, common refrigerants with high GWP to natural refrigerants with low GWP.

Scenario	**Refrigerants**
Baseline	R-404A and R-407A
Alternatives	
Scenario 1	Propane (R-290)
Scenario 2	A cascade system that uses both CO_2 and NH_3
Scenario 3	CO_2 (R-744)
Scenario 4	NH_3 (R-717)
Scenario 5	R-448A, a synthetic refrigerant.

2. Water and Plumbing

Commercial buildings consume significant amounts of water, using an estimated 10.2 billion gallons of water per day in 2005, according to the Center for Sustainable Systems.[63] Domestic or restroom water represented the largest end use category in commercial buildings, indicating the importance of considering improvement strategies for water and plumbing. This section will consider dual flush toilets, low flow fixtures, all-in-one toilets, and smart irrigation systems as potential strategies to implement in the *Store of Tomorrow.*

Water and Plumbing Strategies Scoring Sheet

Supercenter

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirements	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Water & Plumbing	All-in-one toilet								
	Low flow fixtures								
	Dual Flush Toilets								
	Smart Irrigation								

Market Format

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirements	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Water & Plumbing	All-in-one toilet								
	Low flow fixtures								
	Dual Flush Toilets								
	Smart Irrigation								

2.1 Interior

2.1.1 Interior: Dual Flush Toilets

Dual flush toilets could generate water savings in Meijer store restrooms, which typically have 11 toilets and three urinals. Commercial toilets, also referred to as flushometer-valve toilets, are typically installed in institutional or industrial restrooms such as in businesses, schools, office buildings, or other highly trafficked settings.[64] Under the 1992 Energy Policy Act, the standard maximum flow rate per flush was set to 1.6gpf (gallons per flush), reducing the flow from the baseline standard of 3-5 gpf.[65] Due to the lag in adoption time and estimated lifetime of plumbing appliances, the EPA estimates that many of the approximately 27 million flushometer-valve toilets installed in the United States operate with a higher flush volume than the federal standard of 1.6 gpf.[64] Installed prior to establishment of the Federal standard, many of these older, less efficient toilets are approaching retirement at the end of their useful life. This presents a significant opportunity to replace them with efficient toilet models. Toilets designated

[63] Commercial Buildings Factsheet (2019, August). In *Center for Sustainable Systems* . Retrieved from http://css.umich.edu/factsheets/commercial-buildings-factsheet

[64] Commercial Toilets (2018, August 7). In US Environmental Protection Agency. Retrieved from https://www.epa.gov/watersense/commercial-toilets

[65] Water Efficiency Management Guide Bathroom Suite (2017). In EPA Watersense. Retrieved from https://www.epa.gov/sites/production/files/2017-12/documents/ws-commercialbuildings-waterscore-bathroom-resource-guide.pdf

with the EPA WaterSense High Efficiency Toilet (HET) certification, for example, use no more than 1.28 gpf which offers a 20% savings over the 1.6 gpf Federal Standard, but still ensures a minimum flow rate of 1 gpf.[66]

Dual flush toilets generate water savings. Dual Flush Toilets offer a slightly different approach to water conservation. Dual flush toilets offer two separate flushing options for liquid and solid waste. The liquid waste flush uses 1.1gpf rate, while the solid waste option may use a full flush of 1.6 gpf.[66] Studies demonstrate that dual flush toilets can save 20% or more water compared to 1.6 gpf single flush toilet models, and that total flush volume averages out to 1.28gpf, the same as the low flow standard. This dual flush toilet model could also address some of Meijer's concerns about plumbing blockages from low flow models, as the default dual flush flow volume (1.6gpf for solid waste) is higher than the current flow from the Meijer prototype model (1.28gpf low flow).

Figure 2. The WES 111 UPPERCUT Expsed. Manual Water Closet Flushometer uses a distinct greer handle to nudge the user towards sustainable flush choices.

Efficiency savings from dual flush toilets are contingent upon user education and appropriate operation. Consumer education is the most critical element of dual flush toilet efficiency. This technology will only generate water savings if the users properly utilize the efficiency settings. If consumers operate the toilet as a standard flush toilet regardless of the liquid or solid nature of waste, the toilet will use a full flush each time, which will not generate any savings.[66] Installing signage in bathroom stalls or designing dual flush toilets with distinct green handles, such as existing models like the pictured Sloan Uppercut brand (**Figure 2**), can help remind users to make conscious and appropriate flush choices. Dual flush toilets are both efficient and educational. Highlighting savings from these toilets could inspire customers to implement residential models in their homes, reducing their environmental impact downstream.

Dual flush toilets require effective drain line maintenance to prevent blockages.[67]Case studies show that dual flush toilets are feasible in highly trafficked areas such as the Portland International Airport which supports over 35,000 travelers each day. Replacing the 3.5gpf baseline toilets with dual flush efficient toilets made a significant impact considering the airport supports 400 toilets that are flushed 200 times per day. This change generated savings of 177,000 gallons per day.[68]

Records indicate that dual flush toilets are becoming increasingly prevalent on University campuses (examples include the Dana Samuel Trask Building at the University of Michigan, Byerly Hall at Harvard University),[69] indicating that this technology is suitable for highly-trafficked restrooms. Organizations like the Alliance

[66] Response to Issues Raised During Public Comment on April 2006 Draft Specifications for WaterSense® Labeling of Tank-Type High-Efficiency Toilets (2006, November 15). In EPA WaterSense. Retrieved from https://www.epa.gov/sites/production/files/2017-02/documents/ws-background-toilets-comment-response.pdf

[67] High Efficiency Toilets (2020). In Minnesota Sustainable Housing Initiative . Retrieved from http://www.mnshi.umn.edu/kb/scale/toilets.html

[68]Dual-Flush Valves Curb Airport Water Usage (2009, February 9). In Facilities Net. Retrieved from https://www.facilitiesnet.com/plumbingrestrooms/casestudy/Dual-Flush-Valves-Curb-Airport-Water-Usage--19558

[69] [a]Byerly Hall Case Study (2009). In Radcliffe Institute for Advanced Study Harvard University. Retrieved from https://green.harvard.edu/sites/green.harvard.edu/files/migrated_story_files/radcliffe_byerly_hall_case_study.pdf

for Water Efficiency aim to support transitions to more efficient water systems providing tools and expertise to AWE members that assist with this complex transition.[70]

2.1.2 Interior: All-in-One Toilets

All-in-one-toilets combine the sink and toilet into one feature. These fixtures capture and store greywater from handwashing that is used to flush waste after use. The all-in-one toilet could advance customer understanding of grey water recycling and generate attention as a novel technology. It scores highly for size and space requirements, ease of implementation, education, and innovation. Meijer could consider implementing the all-in-one toilet in the Market Format store where it could contribute to the futuristic design criteria without compromising performance or customer experience. Another option would be to implement this as a specialty feature in a single occupancy restroom to compliment, rather than replace traditional bathroom features. Alternatively, Meijer could consider integrating all-in-one urinals which function similarly to the all-in-one toilet.

This technology first appeared in Japanese urinals in the 1950s, and has recently reemerged as a space saving, water-conscious feature in some densely populated urban areas.[71] Currently, all-in-one toilets are not common to the American grocery industry, but appear more frequently in European countries like Germany, Norway, Poland, Russia and Latvia.[71] After an initial review we anticipate that all-in-one toilets will have high capital costs relative to traditional toilet or urinal systems. The ”stand” urinal, pictured in **Figure 3** costs an estimated $590.[72] Home Depot offers a more affordable, retrofit sink topper for traditional toilets but we recommend further analysis to determine if the technology is suitable based on sustainability and customer experience standards before integrating it into retail locations.

Figure 3. The stand sink urinal was developed by Latvian designer Kaspars Jursons.

Figure 4. The Touch-Free Water and Space Saving Adjustable Toilet Tank Retrofit offers a more affordable alternative to the high-end all-in-one units, though further analysis is recommended to ensure durability, sustainability, and customer experience standards are met.

[70] Our 2030 Sustainable Water Vision (2019). In Alliance for Water Efficiency. Retrieved from https://www.allianceforwaterefficiency.org/our-impact

[71] Sikka, M. (2013, July 12). Everything Old Is New Again: The Toilet-Sink Edition. In *National Public Radio*. Retrieved from https://www.npr.org/sections/alltechconsidered/2013/07/12/201470855/everything-old-is-new-again-the-toilet-sink-edition

[72] Hu, E. (2013, May). The 'Sink-Urinal' Saves Water, Encourages Men To Wash Hands. In *National Public Radio*. Retrieved from https://www.npr.org/blogs/alltechconsidered/2013/07/09/200367795/the-sink-urinal-saves-water-encourages-men-to-wash-hands

2.1.3 Interior: Low flow fixtures

Low flow fixtures, such as urinals, showerheads, and faucets can reduce water flow by 20% to 30%.[73] This can generate positive sustainability impacts and financial savings through efficiency. Meijer has already incorporated low flow faucet fixtures in some locations. We recommend that Meijer continue this trend and expand this practice to all retail locations to maximize savings. This technology is compatible with existing infrastructure and is suitable for both market and Supercenter retail locations. This technology scores highly for size and space requirements, ease of implementation, and environmental impact reduction. This is a commonly implemented technology.

2.2 Exterior

2.2.1 Exterior: Smart Irrigation

On average, the United States consumes 9 billion gallons of water per day for outdoor applications, of which up to 50% is lost due to poor water management practices.[74] Examples of poor water management include overwatering, which can create runoff into nearby water systems, or watering at inefficient times such as during the day when plants lose more water through transpiration and irrigated water may evaporate before infiltrating the soil.[75] Smart irrigation systems use data from irrigation site sensors, weather forecasts, and plant databases to more efficiently meet the water needs of the landscape than a traditional timer system.[75]

There are two systems of smart irrigation technologies. The weather based system generates a watering schedule by taking into account the amount of precipitation a plot receives during a given period, historic weather trends, or onsite weather sensors.[75] Smart irrigation systems with soil sensors incorporate direct soil moisture measurements with plant specific water information to generate a watering schedule.[75] Soil moisture sensor systems function similarly to a traditional timer system but adjust by skipping or automatically initiating a watering cycle based on soil moisture readings.[75] In addition, most smart irrigation systems can regulate irrigation based on zones to provide more water to zones with greater water intake requirements, and many models rely on Wi-Fi or cellular controls to monitor and adjust settings or irrigation schedules remotely. Weather-based and cloud-based smart irrigation systems are best suited for Meijer landscaping areas and could be integrated into site design features like demonstration gardens. Watering based on the site-specific conditions and adjusting based on current weather patterns can improve efficiency by lowering water consumption and costs. Vendors claim smart irrigation systems can generate 30 to 50% savings in water use, based on controlled research studies.[76] Some smart watering technologies could be integrated into the Meijer garden centers to improve efficiency. Rather than watering manually with a hose, Meijer could consider transitioning to a mat watering system to directly water plants at the root zone to reduce evaporation losses.[77]

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[73] Tolson, M. (2011). ROI-Driven Products: Low-Flow Fixtures. In *Buildipedia*. Retrieved from http://buildipedia.com/aec-pros/construction-materials-and-methods/roi-driven-products-low-flow-fixtures

[74] What is Smart Irrigation? (2019). In HydroPoint. Retrieved from https://www.hydropoint.com/what-is-smart-irrigation/

[75] Top Smart Irrigation Sprinkler Controllers (2019). In Green Smart Home. Retrieved from https://www.postscapes.com/smart-irrigation-controllers/

[76] What is Smart Irrigation? (2019). In HydroPoint. Retrieved from https://www.hydropoint.com/what-is-smart-irrigation/

[77] *Water Pulse Capillary Irrigation* , waterpulse.com/

Meijer has already implemented smart irrigation systems into the landscape of some retail sites, and as a result potential savings may be slightly below the aforementioned figure. HydroPoint, a leading brand of smart irrigation technology, has already been adopted by competitor Walmart, as well as Coca-Cola, Hilton, Jack in the Box, the University of Arizona and the cities of Charleston, S.C., Houston and Santa Barbara.[78]

In some cases, growers have experimented with incorporating solar photovoltaics or solar-wind hybrid models to power smart irrigation pumps on small scale plots.[79] Applied to the Meijer *Store of Tomorrow* project, this may offer a potential use for energy generated by onsite demonstration solar panels or solar carports. Smart irrigation is particularly effective at reducing environmental impact and does not consume significant space in the store. Widely implemented across the industry, including at some Meijer locations, this strategy scores lower for innovation. Implementing this technology in garden centers or expanding to all irrigation systems could present a more robust application of this technology.

[78] Chen, I. (2011, July 4). Smart Irrigation: A Supercomputer Waters the Lawn. In Scientific American. Retrieved from: https://www.scientificamerican.com/article/smart-irrigation-a-superc/

[79] Garcia, A., Garcia, I., Poyato, E., Barrios, P., & Diaz, J. A. (2018, February 20). Coupling irrigation scheduling with solar energy production in a smart irrigation management system. Journal of Cleaner Production, 175, 670-682. doi:https://doi-org.proxy.lib.umich.edu/10.1016/j.jclepro.2017.12.093

3. Materials and Resources

Materials and resources analysis considers natural resource use and recycling in retail operations. Strategies for food waste management, potential impacts of a complete transition to reusable bags, alternatives to food packaging, digital receipt alternatives and construction waste diversion strategies represent opportunities to reduce Meijer's environmental footprint in the *Store of Tomorrow*.

Material and Resources Strategies Scoring Sheet

Supercenter

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirements	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Materials & Resources	Composting In Vessel Onsite								
	Composting Onsite								
	Composting with Pick Up Service								
	Anaerobic Digestion								
	Animal Feed								
	Reusable bags								
	Plastic bags and film with post-consumer recycled content								
	Reusable transport and display containers								
	Bulk food bins								
	Environmental footprint tracking								
	Digital receipt								
	Package waste backhauling and recycling								
	Community or commercial recycling program								
	Construction waste reuse and recycling								

Market Format

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirements	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Materials & Resources	Composting In Vessel Onsite								
	Composting Onsite								
	Composting with Pick Up Service								
	Anaerobic Digestion								
	Animal Feed								
	Reusable bags								
	Plastic bags and film with post-consumer recycled content								
	Reusable plastic containers								
	Bulk food bins								
	Environmental footprint tracking								
	Digital receipt								
	Package waste backhauled and recycled								
	Community or commercial recycling program								
	Construction waste reused and recycled								

3.1 Food Waste Management Strategies

Meijer calculates waste in six unique categories: landfill, recycling, organics recycling, incineration, hazardous waste, food bank donations. Under this system, Meijer categorizes composting within the larger category of organics recycling, which includes anaerobic digestion, composting, and animal feed disposal methods.

3.1.1 Food Waste Management: Composting (Onsite, In vessel)

Composting refers to the "biological decomposition of organic waste such as food or plant material by bacteria, fungi, worms and other organisms under controlled aerobic

conditions".[80] In this form of recycling, biodegradable materials are separated from trash and processed into nutrient-rich soil-like material.[81]

Composting diverts waste from landfill by returning nutrients to the soil, which reduces usable land devoted to landfill sites and reduces costs associated with waste processing. Compost, as an end product, improves soil quality and water holding capacity, and can reduce the need for applied fertilizers.[82] Composting programs can be implemented onsite, or offsite if food waste is transferred to a processing facility.

Michigan compost facilities with more than 200 cubic yards of material must be registered with the DEQ, and must meet specific design requirements.[83] For example, requirements specify they must be located 50 ft. from a property line, 200 ft. from a residence, 100ft. from a body of surface water, 800-2000 ft. from a well, 500 feet from a church or other house of worship, hospital, nursing home, licensed day care center, or school other than a home school, 4 feet above groundwater, and not in the 100 year floodplain.[84] A compost facility of this scale is not recommended as a feasible option for an urban *Store of Tomorrow* model. Requirements vary state by state. Mismanagement of composting systems can introduce additional risk including fire hazard as spontaneous combustion is possible if the material temperature exceeds 300°F.[84]

Restrictions regarding large scale composting operations suggest windrows or tunnel composting may not be feasible in either store model. Similar to many other commercial businesses, Meijer currently contracts with a 3rd party recycling firm that picks up food waste from 30 retail locations and transports it to an offsite facility for processing as animal feed or compost, based on the location. Meijer retail locations collect pre-packaged produce spoils and bakery items in 3-yard bins, but do not currently recycle packaged food, meat trimmings or seafood. Composting these items is possible in a well-controlled system but must be done correctly to prevent incidence of pests and odors.[85]

Alternatively, Meijer could integrate in-vessel composting systems, like the Ecoponics system. (**Figure 5**), which trap odors, reduce nutrient leaching, and appease pest concerns. With an in-vessel composting system Meijer could implement a type of composting container called a bioreactor to divert additional types of retail waste from landfill, such as meat and seafood. In this type of container composting system, food scraps are mixed with organic material such as wood chips or lawn clippings in a rotating drum.[86] Some upscale models have temperature control capacity, and pumps

[80] Composting (2006). In University of Florida Extension: Living Green Solutions. Retrieved from https://livinggreen.ifas.ufl.edu/waste/composting.html
[81] Supermarket Composting Handbook (2011). Retrieved from https://blog.ucsusa.org/wp-content/uploads/2011/07/smhandbk.pdf
[82] Impact (2019). In Compost Now. Retrieved from https://compostnow.org/impact/
[83] Coker, C. (2008). The Art of Mastering Compost Operations and Marketing. In US Environmental Protection Agency Archives. Retrieved from https://archive.epa.gov/pesticides/region4/rcra/mgtoolkit/web/pdf/masteringoperationsandmarketing.pdf
[84] Clawson, B. (2013, December 23). Compost piles will warm up and steam in the winter. In Michigan State University Extension . Retrieved from https://www.canr.msu.edu/news/compost_piles_will_warm_up_and_steam_in_the_winter
[85] Food Waste Composting: Institutional and Industrial Application (2017). In University of Georgia Extension. Retrieved from https://extension.uga.edu/publications/detail.html?number=B1189&title=Food%20Waste%20Composting:%20Institutional%20and%20Industrial%20Application
[86] Robertson, K. (n.d.). In-Vessel Composting. In Greenville County Soil and Water Conservation District. Retrieved from http://www.greenvillesoilandwater.com/composting/in-vessel-composting/

that integrate air into the system to support microorganism growth and expedite decomposition.[87]

In-vessel systems have their own set of limitations. Incorporating an in-vessel compost system onsite would impact the energy load of the store system, occupy usable space, and could pose higher upfront installation costs, which Meijer will need to consider prior to implementing this technology. For example, the CompTainer model manufactured by Green Mountain Technologies can process 40 to 50 cubic yards of waste and occupies 24'x8'6"x9'6" of space.[87]

Additionally, in-vessel composting systems can take 2-4 weeks to digest organic waste material, which could create some capacity or storage concerns in comparison to the contracted service, which picks up waste from retail locations on a weekly basis. Meijer should consider the volume of waste they aim to process with this technology to determine if retail locations require this amount of food waste management capacity.

Figure 5. The "Ecoponics" In-Vessel compost system processes food waste in a contained system to reduce odors and pest concerns.

Compost practices are well suited to the *Store of Tomorrow* as they systematically close the loop between food waste and food production, offering an opportunity to turn overripe perishables from the retail section into nutrients for an onsite garden**.** Site specific information will be needed to determine whether or not the retail site is suitable for onsite composting or if Meijer should instead pursue offsite compost models. Based on the scoring rubric, onsite composting offers potential benefits for consumer education and impact reduction, but offers potential challenges related to size and space requirements, and operational components like labor or odors, especially in the Market Format store model. Composting with an offsite pickup service has comparable impacts to composting onsite and is more feasible in terms of size and space requirements. Meijer may want to evaluate the cost of the pickup service compared to labor costs associated with turning and managing the compost pile. In addition, it is important to consider possible applications for the final compost product. If Meijer pursues an onsite demonstration garden in the *Store of Tomorrow* model, compost could provide essential nutrients as fertilizer. If onsite food production methods do not require compostable nutrients, or the compost generated exceeds onsite needs, Meijer could consider donating the compost to community gardens or local farms or packaging this product for sale in the garden center. The efficiency and related emissions of transporting compost will vary by geographic proximity to a composting service center, and zoning ordinances likely prohibit large scale composting operations in an urban setting.

[87] The Containerized Compost System (2018, July). In Green Mountain Technologies. Retrieved from http://compostingtechnology.com/wp-content/uploads/2018/07/CCS-Cut-Sheet-2018-July-.pdf

3.1.2 Food Waste Management: Anaerobic Digestion

Anaerobic digestion refers to a process by which microorganisms break down organic material without oxygen. The two most common types of anaerobic digesters are Mesophilic which function at target temperatures 95 F, 35 C, or Thermophilic 125 F, 50 C.[88] One byproduct of anaerobic digestion is biogas, which, with little to no processing can be combusted onsite to produce heat and electricity,[89] or reprocessed into natural gas and fuels.[90] Biogas is compatible with strategies being considered in the energy system such as combined heat and power systems.[92]

Historically, food waste from Meijer facilities in Lansing was processed with anaerobic digestion at Michigan State University.[91] In addition, Meijer previously integrated anaerobic digestion at two retail locations. The processes involves grinding the food waste, pumping it as a slurry into a storage tank and transporting it to an anaerobic digester. The scoring rubric identifies moderate size and space requirements depending on the capacity needed to process the waste as the most significant barrier to implementation. Based on the scoring rubric, anaerobic digestion presents significant benefits in the innovation, education, and environmental impact reduction categories.

Material composition of the waste can impact the effectiveness of the anaerobic digestion process, or lead to "instability", which presents a possible implementation challenge. Studies suggest tailoring the digestor conditions to meet the needs of the specific waste and nutrient portfolio or integrating trace nutrient or anti foam additives to stabilize the system[92].

Meijer could integrate this anaerobic digestion system into the *Store of Tomorrow* as a means to divert landfill waste and process meat trimmings, seafood, and other products not currently funneled into the organics recycling program. Meijer should carefully consider the waste portfolio that the anaerobic digester will process and adjust the system to manage the material accordingly. Meijer could also consider expanding contracted anaerobic digestion services which may alleviate some of the operational or financial burdens of integrating this system at retail locations.[92]

3.2 Construction waste reuse and recycling

During construction of a typical commercial building, each square foot of building area can generate 3.9 pounds of construction waste on average. By extension, a Market Format store of 40,000 ft^2 can generate 78 tons of waste and a Supercenter of 158,000 ft^2 can generate 308 tons of waste.[93] Instead of sending this waste to landfill or an incinerator, construction waste should be reused and recycled to improve sustainability.

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[88] What is Anaerobic Digestion? (2019). In American Biogas Council. Retrieved from https://americanbiogascouncil.org/resources/what-is-anaerobic-digestion/

[89] Fact Sheet - Biogas: Converting Waste to Energy (2017, October). In Environmental and Energy Study Institute. Retrieved from https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy

[90] What is Anaerobic Digestion? (2019). In American Biogas Council. Retrieved from https://americanbiogascouncil.org/resources/what-is-anaerobic-digestion/

[91] How Meijer Tackles Manufacturing and Composting Waste (n.d.). In Meijer Community. Retrieved from http://meijercommunity.com/sustainability/waste-reduction/how-meijer-tackles-manufacturing-and-composting-waste/

[92] Xu, F., Li, Y., Ge, X., Yang, L., & Li, Y. (2018, January). Anaerobic digestion of food waste – Challenges and opportunities. *Bioresource Technology*, *247*, 1047-1058. doi:https://doi.org/10.1016/j.biortech.2017.09.020

[93] Freymann, V., Tessicini, J., & Dion, M. (n.d.). Planning for Construction Waste Reduction. Retrieved from: http://www.modular.org/marketing/documents/USGBC_WhitePaper_PlanningConstructionWasteReduction.pdf

Construction waste refers to concrete, asphalt, wood, steel, drywall and plaster, brick and clay tiles, and asphalt shingles. The EPA estimated that in the US, 33.3 million tons of construction debris were generated in 2017, of which 62% was from concrete.[94]

To eliminate the construction waste generated by Meijer, minimizing of material usage should be the overarching principle of building design.[95] The forecast of waste generation should be included as part of the design requirements and a benchmark for evaluating the construction project. The Recycling and Reusing Hardscapes and Landscape Waste Cost Calculator developed by the EPA can be used to estimate the cost savings and environmental benefits in the context of reusing and recycling the lumber, asphalt, concrete and brick.[96] After reaching a consensus with contractors about the goal of zero waste, a comprehensive system for site waste management should be created. Explicit guidelines for efficient site sorting, an electronic platform and database for recording and analyzing the trace of waste, and regular design meetings for reporting the generation and destination of waste to Meijer‘s design team are essential components of this system.[97] Contractors with experience in construction waste management can facilitate the efficiency of jobsite sorting and increase the diversion rate. It’s important to keep the construction waste from becoming contaminated and fragmented, since waste that remains intact is more likely to be reused or recycled. Jobsite sorting might be infeasible for a Market Format store due to the availability of space, but it can be completed by a construction waste processing company instead.[98] Building areas that produce the most waste can be identified through monitoring the digital platform, which would enable the design team to quickly adjust the building materials and construction requirements. After the waste is backhauled to the companies for reuse and recycle, supervision is still needed to ensure the waste is actually diverted from landfill. To some extent, it can be viewed as an inspection of the waste management on the jobsite.

Directly reusing the materials is the simplest way to manage construction waste, but it is more difficult for new construction than a renovation project. When the project is finished, Meijer can sell or donate some of the remaining building materials to used building materials stores or relevant community organizations, including bricks, wood, windows and doors. One common way to reuse construction waste is to produce another material or product after transformation. For example, crushed concrete can be used as filler for asphalt concrete, sub-base materials for concrete and asphalt concrete aggregate, and soil stabilization materials.[99] Brick can be ground and used for filling

[94] EPA. (2019). Advancing Sustainable Materials Management: 2017 Fact Sheet. Retrieved from: https://www.epa.gov/sites/production/files/2019-11/documents/2017_facts_and_figures_fact_sheet_final.pdf
[95] Napier, T. (2016). Construction Waste Management. Retrieved from: https://www.wbdg.org/resources/construction-waste-management
[96] EPA. (n.d.). Retrieved from: https://archive.epa.gov/wastes/conserve/tools/greenscapes/web/pdf/reuse.pdf
[97] Wrap. (n.d.). Actions to Reduce Waste in Construction Projects and Minor Works. Retrieved from: http://www.wrap.org.uk/sites/files/wrap/W676%20Actions%20to%20reduce%20waste%20in%20construction%20projects%20and%20minor%20works_FINAL.pdf
[98] EPA. (2000). Building Savings - Strategies for Waste Reduction of Construction and Demolition Debris from Buildings. Retrieved from: https://nepis.epa.gov/Exe/ZyNET.exe/10000JVQ.txt?ZyActionD=ZyDocument&Client=EPA&Index=2000%20Thru%202005&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C00THRU05%5CTXT%5C00000000%5C10000JVQ.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&slide
[99] Waste Reduction Guidelines for Construction Industry. (n.d.). Retrieved from:

materials and hardcore. Wood can be chipped and reused as plank, beam and panel. Asphalt can be the source of asphalt aggregate and recycled asphalt. Glass waste can be reused as tile, glass fiber, tile and filling materials.[100] Metal scrap is melted to produce new steel. Crushed drywall can be used in cement. In addition, some recycling programs are working on the recovery of gypsum from drywall since gypsum accounts for 90% of the weight of drywall. In case of repair or renovation, Meijer should also consider keeping some of the remaining building materials which are highly customized and difficult to reshape especially in the Supercenter model which is spatially feasible.

Construction waste reuse and recycling are widely adopted by major retailers like Walmart, Whole Foods and Kroger. In 2018, Kroger launched a zero-waste initiative and tracked the construction waste generation and management of 271 projects. The renovation programs of 17 Walmart stores in Gainesville, Florida diverted 107,3 metric tonnes of construction waste from landfill to recycling in 2018.[101] The limited market and extra cost of construction waste recycling are major barriers to the goal of zero waste and make diversion of construction debris a challenge for *Store of Tomorrow*.

3.3 Packaging Management

3.3.1 Reusable Bags

Transitioning to reusable bags like the one in **Figure 6** offers an alternative to single-use plastic and paper grocery bags that are distributed to customers for free in Meijer store.[102] Defined by the Department of Resources Recycling and Recovery (CalRecycle) in California, a reusable bag is either a bag made from machine washable fabric that has handles or a durable plastic bag with handles which is designed to be at least 2.25 millimeters thick and reusable.[103] Every year, almost 1,500 plastic grocery bags are consumed by an average American family and about 100 billion plastic bags are disposed of across the country, which can take up to 1,000 years to degrade and lead to severe pollution.[104] One plastic bag is used for 12 minutes, yet impacts the life of at least 267 various species. More than 100,000 sea turtles and other marine animals suffocate to death annually, when they mistake the plastic bags as food.[105] Even in the Great Lakes, 9887 metric tonnes of plastic debris are estimated to enter the system every year.[106] To ease the burden of plastic waste and plastic pollution, reusable bags can replace single-use plastic and paper shopping bags in the *Store of Tomorrow*. Aiming for 100% replacement, the store will only provide reusable bags with fee at checkout and

https://www.wastereduction.gov.hk/sites/default/files/en/materials/workplace/Guide_construction.pdf

[100] Leigh, N. G., & Patterson, L. M. (2016). Construction & Demolition Debris Recycling for Environmental Protection and Economic Development. Retrieved from: https://louisville.edu/cepm/pdf-files/newpg7

[101] Walmart. (2019). 2019 Environmental, Social & Governance Report. Retrieved from: https://corporate.walmart.com/media-library/document/2019-environmental-social-governance-report/_proxyDocument?id=0000016a-9485-d766-abfb-fd8d84300000

[102] *Meijer Grocery Tote Bag Blue.* (n.d.). Meijer. Retrieved January 2, 2020 from: https://www.meijer.com/shop/en/paper-plastic-products/food-storage-bags/meijer-grocery-tote-bag-blue-1-ct/p/70882005257

[103] State California. (2018). Definitions: At-Store Recycling Program. Retrieved from: https://www.calrecycle.ca.gov/Plastics/AtStore/Definitions/#ReusableBag

[104] NRDC. (2008). NRDC Lauds Passage of New York City Council Legislation Requiring Groceries, Retailers to Provide Plastic Bag Recycling for Consumers. Retrieved from: https://www.nrdc.org/media/2008/080109

[105] SPREP. (2008). Factsheet-Plastic Bags. Retrieved from: https://www.sprep.org/attachments/Publications/FactSheet/plasticbags.pdf

[106] Hoffman, M. J., & Hittinger. E. (2017). Inventory and transport of plastic debris in the Laurentian Great Lakes. Retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S0025326X1630981X

[Fig4] Retrieved from: https://www.meijer.com/shop/en/paper-plastic-products/food-storage-bags/meijer-grocery-tote-bag-blue/p/70882005257

encourage the customers to bring their own bags. Requirements for durability and recycled content should be considered.

Figure 6. Meijer's Reusable Bags[102]

Opportunities to reduce the environmental impacts of Meijer and customers form the key driver to transition to reusable bags. Based on the Life Cycle Assessment of common grocery bags in the US performed by Kimmel (2014), reusable low-density polyethylene (LDPE) bags outperform single-use plastic and paper bags in various categories of environmental impacts, such as global warming potential (GWP), cumulative energy demand and terrestrial acidification when they are reused for more than 14.6 times and the secondary uses of plastic and paper bags are excluded. The GWP of reusable LDPE bags is about half that of plastic bags and 10 times less than paper bags, while the GWP of reusable non-woven polypropylene (NWPP) is similar to that of single-use plastic bags.[107] Meijer should inform customers of the potential environmental effects, and minimum time of reuse to achieve sustainability with reusable bags. The information could be displayed in signage or printed on the bags along with attractive designs. For both the market and Supercenter store models, adoption of reusable bags wouldn't affect the shopping experience and requires minimal modification, consuming the space typically dedicated to single-use plastic bags at checkout and in the warehouse. Economically, reusable bags can generate additional profit for Meijer.[108]

California was the first state to institute a state-wide ban on single-use plastic bags at large-scale retail stores in 2014, followed by Hawaii, New York, Vermont and four other states.[109] [110] In Michigan, although Senate Bill 853 has effectively put a hold on banning plastic bags since 2016, House Bill 4500 has been proposed in April 2019 to ban the Bill 853 and give the local municipalities the opportunity to regulate the use of plastic bags.[111] Since 2008, Whole Foods has stopped providing single-use plastic bags at stores. Instead, reusable bags and paper bags with recycled content are offered for sale.[112] In December 2018, Trader Joe's announced that single-use plastic grocery bags would no longer be offered at all stores nationwide, and instead provided paper and

[107] Kimmel, R. M. (2014). Life Cycle Assessment of Grocery Bags in Common Use in the United States. Retrieved from: https://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=1006&context=cudp_environment
[108] Waste Management. (n.d.). Bags by the Numbers. Retrieved from: http://www.wmnorthwest.com/guidelines/plasticvspaper.htm
[109] Plastics Task Force and Gov. Endorse Statewide Bag Ban. (2019, February). EcoRI News. Retrieved from: https://www.ecori.org/government/2019/2/15/plastic-task-force-and-governor-endorse-bag-ban
[110] NSCL. (2019). State Plastic and Paper Bag Legislation. Retrieved from: https://www.ncsl.org/research/environment-and-natural-resources/plastic-bag-legislation.aspx
[111] Michigan Legislature. (n.d.) House Bill 4500 (2019). Retrieved January 04, 2020 from http://www.legislature.mi.gov/(S(tlquhvjtt5n2os55wjckyuxh))/mileg.aspx?page=GetObject&objectname=2019-HB-4500
[112] Whole Foods Market. (2019). Whole Foods Market to Further Reduce Plastics Across all Stores. Retrieved from:https://media.wholefoodsmarket.com/news/whole-foods-market-to-further-reduce-plastics-across-all-stores

reusable bags.[113] Walmart has begun to sell reusable plastic bags since April 2019 with a recommendation of 125 times of use, but single-use plastic bags are still handed out for free.[114] Meijer is also taking action to eliminate single-use plastic bags. The Woodward Corner Market, which opened in January 2020 only provides reusable LDPE bags at store. Meijer should consider printing the minimum number of times the bag should be used for shopping trips to outperform the single use equivalent on reusable bags to encourage sustainable behavior.[115] Phasing out the disposable bags is not only a strategy for the *Store of Tomorrow*, but would address potential future state legislation to ban the single-use plastic bags and Meijer should be leading the way towards a more sustainable future.

3.3.2 Plastic Bags and Film with Post-Consumer Recycled Content

Plastic bags and plastic film are very commonly used for food packaging. Customers can easily find the plastic produce bags placed on hangers to bag fruits and vegetables. Relying on circular economy, new bags and film can be manufactured using recycled plastic rather than virgin resin. Plastic bags and film with post-consumer recycled content would be a wise choice for the store, and not impact the user shopping practices. Plastic produce bags with 100% post-industrial recycled resin is shown in **Figure 7**.
Systems for recycling plastic and technologies for producing packaging materials with post-consumer content are well-developed in the United States. Utilizing recycled plastic can reduce the energy usage and conserve fossil fuels. Research by Siracusa, Dalla Rosa, Romani, Rocculi, & Tylewicz (2011) shows that multilayer polymer packaging film with 25% recycled content can reduce more than 15% GWPe compared with 0% recycled materials.[116] This study also emphasizes that thinning the thickness can improve the environmental performance of the film. Particularly, films of 65 μm thick would reduce the GWP by about 25%.

In addition, this strategy can collaborate with Meijer's recycling program of packaging materials at store locations to function as a closed loop system. The post-consumer plastic bags and films collected through recycling bins, as well as the packaging waste created by store operations can be the sources of recycled plastic. In partnership with Petoskey Plastics, Walmart is able to convert over 200 tons of post-consumer plastic to new plastic bags with 40%-70% recycled content every month. The bags are then used in Walmart stores and for sale.[117] In the case of closed loop recycling, less plastic waste is sent to the landfill and more space is saved.

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[113] Trader Joe's. (2018). Sustainability - Packaging Improvements. Retrieved from: https://www.traderjoes.com/announcement/packaging-improvements

[114] The Post and Courier. (2019). Walmart Switches to 'Reusable' Plastic Bags in Plastic-bag Banning Mount Pleasant. Retrieved from: https://www.postandcourier.com/business/walmart-switches-to-reusable-plastic-bags-in-plastic-bag-banning/article_84d719ae-65e0-11e9-879f-3b8d9867c71e.html

[115] Meijer. (2020).Woodward Corner Market Encourages Sustainable Practices: Eliminating Single Plastic Bags for Recyclable Options. Retrieved from: http://newsroom.meijer.com/2020-01-08-Woodward-Corner-Market-Encourages-Sustainable-Practices-Eliminating-Single-Use-Plastic-Bags-for-Recyclable-Options

[116] Siracusa, V., Rosa, M. D., Romani, S., Rocculi, P., & Tylewicz, U. (2011). Life Cycle Assessment of Multilayer Polymer Film used on Food Packaging Field. Retrieved from: https://www.researchgate.net/publication/257742784_Life_Cycle_Assessment_of_multilayer_polymer_film_used_on_food_packaging_field

[117] Walmart. (n.d.). Sustainability - Eliminating Waste in Our Operations. Retrieved from: https://cdn.corporate.walmart.com/46/db/79511ff245e894c0771bd34aed82/10.WMT_GRR_Sustainability-Eliminating-Waste.pdf

Figure 7. Plastic Produce Bags Made of 100% Post Industrial Recycled Resin offers a more sustainable alternative to plastic. [118]

3.3.3 Reusable Transport and Display Containers

Cardboard boxes are often used to store and transport fruits and vegetables from farms to distribution centers and retailers. Cardboard is then baled and backhauled to distribution centers for recycling. In the *Store of Tomorrow*, a more sustainable solution is required, such as reusable plastic containers (RPCs). RPCs provide produce packaging from the beginning, and since RPCs are ready for display, the produce can be placed directly on shelves once delivered. When the RPCs are emptied, they are backhauled to distribution centers for sorting, and then to service centers for cleaning and sterilization. The supplier is responsible for the logistics of RPCs between growers, distribution centers, stores, and service centers.

A detailed comparative LCA for RPCs, display-ready corrugated fiber containers and non-display-ready corrugated fiber containers was conducted by Franklin Associates in 2016 for IFCO, the leading supplier of RPCs in the US. The report indicated input savings of 31% of energy consumption, 28% of GWP, 64% of water demand and 84% of solid waste when 1,000 tons of produce are delivered in RPCs instead of non-display-ready fiber containers in the base case. The potential savings resulted from a switch from display-ready fiber containers to RPCs are even 2% greater than a change from non-display-ready fiber containers to RPCs. However, fiber containers with more than 52.7% recycled content have a lower GWP than RPCs, indicating that RPCs might not be a good alternative if Meijer uses corrugated cardboard containers with high recycled content.[119] Also, transitioning to RPCs may require additional labor, since RPCs need to be sorted based on size before they are backhauled to centers. At the same time, more space is saved because RPCs can be readily folded and stacked.

Working with IFCO, Kroger shipped about 140 million RPCs in 2017 for fresh produce, which were estimated to replace 97,000 tons of waxed and corrugated boxes (**Figure 8**). [120] Continuing in 2018, Kroger used 160 million RPCs to reduce the need of cardboard and food waste.[121] Walmart adopts the reusable packing containers as well to

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[118] *Recycled Produce Bags*. (n.d.). BRENMAR. Retrieved February 10, 2020 from: https://www.brenmarco.com/product/pull-n-pak-recycled-produce-bag/

[119] Franklin Associates. (2017). Comparative Life Cycle Assessment of Reusable Plastic Containers and Display- and Non-display-ready Corregulated Containers used for Fresh Produce Applications. Retrieved from: https://cdn0.scrvt.com/f152d078e18222739495b38742ac2b85/cc5a5d129eb3c63b/829b9801e469/IFCO-RPC-Life-Cycle-Assessment_Feb2017_Executive-Summary.pdf

[120] Kroger. (2018). The Kroger Family of Companies 2018 Sustainability Report. Retrieved from: http://sustainability.kroger.com/Kroger_CSR2018.pdf

[121] Kroger. (2019). Kroger's 2019 Environmental, Social & Governmental (EST) Report. Retrieved from: http://sustainability.kroger.com/Kroger-2019-ESG-Report.pdf

Fig 6 Adapted from 'SiCar Farms Extends Use of IFCO Reusable Plastic Containers'. Retrieved from: https://www.waste360.com/contracts/sicar-farms-extends-use-ifco-reusable-plastic-containers

eliminate the use of cardboard boxes and shrink wrap. For example, Walmart's Asda stores in the UK used up to 1.25 million reusable packing containers in 2017.

Figure 8. IFCO's Reusable Plastic Containers[122]

3.3.4 Bulk Food Bins

Buying food in bulk can reduce packaging waste, especially when customers use their own containers. Different from free plastic bags with a zipper, under this strategy, shoppers would need to buy a reusable container offered by store if they forget to bring one. The tare weight of the container is recorded before use to account for differences in containers (size and materials).

Bulk food with a reusable container can help save energy and reduce the natural resources used to manufacture the disposal package for packaged food. Compared with the opaque packages, the products are more appealing through the aesthetic design of bulk food bins and combinations of color (**Figure 9**). Customers are able to control the amount of product they purchase and learn about sustainability through signage that describes the purpose and benefits of zero waste shopping. Some opponents argue that bulk food aisles would lead to less options of products and brands, particularly in the Market Format where the space is relatively limited.[123] Another concern is food safety since bulk food is unpacked and some bin designs allow users to directly access the foods (e.g., with scoops). This can be resolved with regular maintenance and a better design for food bins (e.g., use of gravity feed bins) to avoid contamination.

Kroger provides bulk food bins, but with free single-use plastic bags. Whole Foods offers many kinds of products in bulk like grains, herbs, spices and nuts, most of which are organically grown. Customers can use either a plastic bag or container provided by the store to bag the food.[124] The community-owned grocery store Landwinds Food Co-op located in Chanhassen, Minnetoka and Richfield provides glass jars, cloth produce bags, stainless steel food storage tins, and other reusable containers for bulk food.[125] Although Meijer is in favor of packaged bulk food to avoid the food safety and potential

[122] *SiCar Farms Extends Use of IFCO Reusable Plastic Containers*. (2019, September 19). Waste360. Retrieved from: https://www.waste360.com/contracts/sicar-farms-extends-use-ifco-reusable-plastic-containers

[123] Beitzen-Heineke, E. F., Balta-Ozkan N., & Reefke, H. (2016). The Prospects of Zero-packaging Grocery Stores to Improve the Social and Environmental Impacts of the Food Supply Chain. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0959652616315797#!

[124] Whole Foods Market. (n.d.). Bulk. Retrieved from: https://www.wholefoodsmarket.com/department/bulk

Fig 7 Adapted from 'Whole Foods Market//Greenway//Tigard, OR'. (2014). Retrieved from: http://naturallylindsay.com/2014/05/20/whole-foods-market-greenway-tigard-or/comment-page-1/

[125] Litterless: Zero Waste Grocery Guide: Minnesota. (n.d.). Retrieved from: https://www.litterless.com/bulk-food-guide/minnesota

economic losses, bulk food aisles still play an important role in advancing sustainability education and reducing customers' environmental impact.

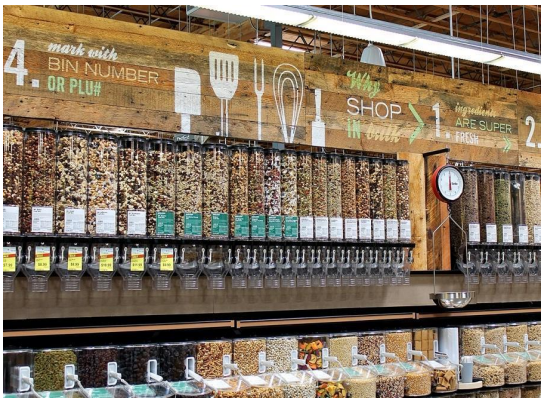

Figure 9. Bulk Food Bins [126]

3.3.5 Digital Receipt

Digital receipts are becoming a common replacement for conventional paper receipts. Instead of keeping the physical receipt, customers can receive and check their purchase receipt electronically via email or retail applications, which helps reduce paper waste for customers and costs for retailers. It is feasible for most customers to only receive an e-receipt because mobile phones and laptops are widely used by shoppers. However, customers should still have the option to print out a paper receipt at checkout.

In addition to reducing the energy and resources used to produce the conventional receipts, electrification can eliminate the pollution and damage due to the toxic chemicals Bisphenol A (BPA) and Bisphenol S (BPS) in receipt paper. BPS has similar impacts to BPA, including cancer, heart disease and diabetes and infertility.[127] A study on the thermal paper for receipts has found that 93% of the 207 samples collected from various business, grocery stores and retailers like Kroger and TJX contain BPA or BPS.[128] To avoid potential harm to health and environment, e-receipt is an ideal strategy.

Digital receipts have been adopted by major retailers in the US. Walmart provides e-Receipt on the Walmart Mobile App as well as a paper receipt at checkout if requested.[129] Kroger has partnered with Ibotta to electrify their receipts.[130] Kroger App users can also check their purchase history in addition to individual electronic receipts. Although there is no legislation for e-receipts so far, Assembly Bill 161 has been introduced in California in 2019, which would require stores to use digital receipts by default unless customers request a paper one. Assembly Bill 161 is the first bill relative to paperless receipts in the US.[131]

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[126] *Whole Foods Market//Greenway//Tigard, OR*. (2014, May 20). Naturally Lindsay. Retrieved from: http://naturallylindsay.com/2014/05/20/whole-foods-market-greenway-tigard-or/comment-page-1/

[127] Kablo. (n.d.) Top 5 Negative Side Effects of BPA and How to Avoid it. Retrieved from: https://shopkablo.com/blogs/the-reformist/dangerous-side-effects-of-bpa-plastic

[128] HealthStuff. (2018). Receipt Paper Study 2018. Retrieved from: https://www.ecocenter.org/healthy-stuff/reports/receipt-paper-study-2018

[129] Walmart. (n.d.). Walmart EReceipts. Retrieved from: https://help.walmart.com/app/answers/detail/a_id/900/~/walmart-ereceipts

[130] Kroger Krazy. (n.d.). Ibotta: Kroger is now Receipt-free! Connect your loyalty Card. Retrieved from: https://www.krogerkrazy.com/2019/01/ibotta-kroger-is-now-receipt-free-connect-your-loyalty-card/

[131] CNBC. (2019). California Bill Would Curb Use of Paper Receipt to Reduce Waste, Push Digital Alternative. Retrieved from: https://www.cnbc.com/2019/01/08/california-bill-would-curb-use-of-paper-receipts-push-digital-option.html

Meijer's Mobile App provides a digital receipt feature in addition to the printed one, (which is BPA free) at check out. This service can be enhanced by offering the option of no paper receipts in the *Store of Tomorrow* in order to eliminate the receipt paper consumption and the associated environmental contamination.

3.3.6 Environmental Footprint Tracking

An innovative application of Meijer's Mobile App would be to incorporate environmental footprint tracking for every purchase in store. Products could be categorized into different groups such as beef, milk and bread depending on the available life-cycle assessment (LCA) data. This strategy could be used in conjunction with digital receipts, where an environmental footprint for different products and purchases could be calculated and then reported to users. The tracking tool could also provide customized recommendations to improve users' carbon footprint. Advised by nutritionists and experts in the field of environmental footprints of food production, sustainable dietary guidelines aimed for Meijer's customers should be developed before the platform is launched. Based on customer food preferences, the system would select and recommend the food that has similar calories but much smaller carbon footprints.

From a customer's perspective, the footprint tracking could reveal their environmental impacts in real time. With the help of shopping recommendations, they would then be able to change their daily diet and make more sustainable choices without any external support, which could not only enhance the customers' education of sustainability, but also advance communication between customers and Meijer. The preciseness of results might raise an issue due to the lack of LCA data for specific brands and products. For instance, the differences of carbon footprint between imported and local grown vegetables might not be shown. From Meijer's perspective, operation of the footprint tracking tool could require software experts to upgrade the mobile app and manage the database of environmental performances for different products. The application would not require any modifications to the store and could result in increased customer preference toward low carbon intensity products, reducing carbon emissions along Meijer's supply chain.

In recent years, footprint tracking has been used to assess sustainability performance by different organizations. When a student in the University of Michigan uses the school printers, the app MPrint would record the usage of paper and report the accumulated carbon emissions to them.[132] Mastercard has funded the program of tracking the carbon footprint of every transaction with Doconomy and Bank of Aland and announced to offer his cardholders this service in December 2019.[133] Mastercard also works with the startup Enfuce in developing the My Carbon Action app for purchase-based carbon footprint tracking. In the field of grocery shopping, the project of tracking the climate impacts of food with the Evocco score is acknowledged by UNEP.[134] K Group in Finland has also created and introduced a carbon footprint calculator for purchases in its grocery stores in August 2019.[135]

[132] University of Michigan-Information and Technology Services. (n.d.). MPrint. Retrieved from: https://its.umich.edu/computing/printing/mprint
[133] RYMNTS. (2019). Mastercard, Doconomy to Enable Carbon Footprint Tracking of Purchase. Retrieved from: https://www.pymnts.com/mastercard/2019/mastercard-doconomy-to-enable-carbon-footprint-tracking-of-purchases/
[134] Evocco. (n.d.). Home. Retrieved from: https://www.evocco.com/
[135] KESKO. (2019). K Group is Creating a Carbon Footprint Calculator for Grocery Purchases. Retrieved from: https://kesko.fi/en/media/news-and-releases/news/2019/K-Group-is-creating-a-carbon-footprint-calculator-for-grocery-purchases/

3.3.7 Packaging Waste Backhauling and Recycling

Packaging is another waste material that poses collection and recycling challenges. According to a waste audit of 15 Meijer stores in July 2019, on average, cardboard ranked first with 14.53% and LDPE ranked second with 7.53% among package waste. Styrofoam accounted for 2.60%, wood accounted for 2.33% and strapping was responsible for 0.80%. The audit has also indicated the opportunities of higher diversion rates for cardboard, LDPE, food waste and other recyclables if the stores improve their segregation processes.[136]

The 2017 Fact Sheet published by the EPA has indicated that recycling of 44.2 million tons of paper and paperboard could save 148 million metric tons of CO_2 equivalent in 2017, which is equal to the impact of removing more than 31 million vehicles from the road for 1 year.[94] About 27.65 and 3.82 million metric tons of CO_2 equivalent can be reduced respectively if 8.33 million tons of metal and 2.96 million tons of plastics are recycled. Packaging waste recycling bears similar challenges to construction waste, including oversupply and low revenue. Despite this, grocery stores and retailers commonly collect, reuse and recycle cardboard, plastic bags and film, wood pallets, aluminum cans and plastic pill bottles. In 2018, Walmart recycled 430 million pounds of plastic film and rigid plastics in stores worldwide.[101] Kroger's 2019 ESG report also stated that about 52.2 million pounds of plastic and 1.5 billion pounds of corrugated cardboard were recycled in 2018.[121]

To enhance the effect of recycling, Meijer should collect as many types of packaging waste as possible, which might not be applicable to the Market Format store given space constraints. Confronting the problem of size requirement, Meijer could start with cardboard, LDPE, and wood, which are relatively cost-effective and adjust the categories based on the results from regular waste audits. A higher frequency of backhauling and a better design of collection bins could also help solve the problem of restricted space.

3.3.8 Recycling Campaigns and Programs

Conducting campaigns or programs targeting multiple stores or communities could not only motivate a wider range of waste recycling, but also engage employees and other citizens in Meijer's roadmap towards sustainability and enhance Meijer's image of responsibility. Meijer could hold campaigns between different stores that call for a greater reduction in waste generation and higher diversion rate. The participating stores should be similar in size, location and target market to ensure the potential of waste reduction is comparable. Programs around neighborhoods could motivate residents to recycle by collecting and bringing the waste from home to recycling bins in store. Both the supermarket and Market Format store can function as a drop-off site if the recyclables are picked up in time. The process should be supervised by the waste management team in store and the outcomes should be published online.

Recycling campaigns and programs are a good opportunity for educating employees and customers. Through a competition program, the store that performs most sustainable could be used as an example to inform company-wide waste management strategies. It might be difficult for the Market Format store to place a lot of recycling bins in store

[136] Meijer. (2019). Meijer 2019 Waste Audits.

locations for various kinds of waste due to limited space availability. Instead, bins could be set up for the waste that is the most common in that residential area.

In April 2018, the one-week Spring Cleanup Campaign was held in a Walgreens support office in Deerfield, Illinois, where over 37,000 pounds of paper and 3,400 pounds of electronic waste were collected.[137] Kroger's Fred Meyer stores also hosted an event to encourage recycling in their community, collaborating with the NBA's Portland Trail Blazers. In the end, more than 1,100 pounds of packaging waste was collected. Additionally, community recycling programs could be held in partnership with firms that accept post-consumer waste, like the Recycled Playground Challenge that Meijer sponsored with TerraCycle and Colgate in 2019, to encourage recycling of used oral care products and packaging. Meijer could consider additional projects like Trex the University & Community Recycling Program run by Trex, which requires participants to collect more than 500 pounds of plastic waste in 6 months. A composite bench with recycled content is then given as a reward, which could be donated to the community park as a motivation to adhere to Meijer's community values.[138]

[137] Walgreens Boots Alliance. (2019). Corporate Social Responsibility Report 2018. Retrieved from: https://www.walgreensbootsalliance.com/corporate-social-responsibility-report/
[138] Trex. (n.d.). Recycling Programs. Retrieved from: https://documents.trex.com/is/content/Trex/trex-community-recycling-challenge-information-sheetpdf.pdf

4. Sustainable Sites

Currently, the most significant environmental challenge that we face is climate change, which is caused by carbon dioxide and other greenhouse gas emissions. Air and water pollution, as well as urban heat island effects further impact our environment. To drive sustainability in the *Store of Tomorrow* prototype, sustainable sites are introduced as strategies to sequester carbon dioxide, reduce rainwater runoff, mitigate heat island effect, and green the storescape.

There are three components in Sustainable Site: Onsite agriculture, Stormwater management, and Ecological benefits. Onsite agriculture offers fresh vegetables and fruits planted at the store with precise agricultural practices. It demonstrates a new trend of farming, while providing transparency in the food production process. Stormwater management and ecological benefits are crucial compositions in the design of the storescape. Stormwater management focuses on harvesting rainwater, and managing the flashy flows onsite, while ecological benefits serve to mitigate environmental problems like carbon footprint and urban heat island effects.

Sustainable Sites Strategies Scoring Sheet

Supercenter

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirements	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmenta Impact Reduction (Customers)
Sustainable Sites	Onsite agriculture- Vertical Growing Hydroponics								
	Onsite agriculture- Demonstration Garden								
	Onsite agriculture- Freight Farm								
	Stormwater mgmt- Cistern								
	Stormwater mgmt- Bioswale								
	Stormwater mgmt- Rain Garden								
	Stormwater mgmt- Underground Detention								
	Stormwater mgmt- Detention Pond								
	Stormwater mgmt- Retention Pond								
	Stormwater mgmt- Permeable Paving								
	Ecological benefit- Native Plants								
	Ecological benefit- Wind Break								
	Ecological benefit- Pollinator Garden								
	Ecological benefit- Green Roof								
	Light color pavement								

Market Format

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirements	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Sustainable Sites	Onsite agriculture- Demonstration Garden								
	Onsite agriculture- Freight Farm								
	Onsite agriculture- Vertical Growing Hydroponics								
	Stormwater mgmt- Cistern								
	Stormwater mgmt- Bioswale								
	Stormwater mgmt- Rain Garden								
	Stormwater mgmt- Underground Detention								
	Stormwater mgmt- Detention Pond								
	Stormwater mgmt- Retention Pond								
	Stormwater mgmt- Permeable Paving								
	Ecological benefit- Native Plants								
	Ecological benefit- Wind Break								
	Ecological benefit- Pollinator Garden								
	Ecological benefit- Green Roof								
	Light color pavement								

4.1 Onsite Agriculture

4.1.1 Onsite Agriculture: Onsite Demonstration Garden

Implementing onsite food production techniques such as a traditional garden plot or raised bed planters could allow Meijer to provide fresh, local food to customers and would also provide opportunities for sustainable food system education. Depending on the store model, Meijer could consider a variety of onsite growing systems, some more conducive to the urban small-scale market model than others. Onsite food production strategies will vary based on Meijer goals, as some elements may be better suited for community education and some more productive for supplying retail produce. Meijer must also consider labor associated with hyperlocal food production, to determine if it is more efficient to hire contracted professionals to tend to their land, or to dedicate staff time to maintain crops.

4.1.2 Onsite Agriculture: Freight Farm

A Freight Farm container farm offers an innovative approach to farming onsite. The Freight Farm, pictured in **Figures 10** and **11**, is a closed container system that would allow Meijer to produce products like butter head lettuce, spinach, and herbs, year-round, in a climate-controlled greenhouse container. Freight Farms rely on grow lights and cloud-based smart hydroponic systems to grow produce in shipping containers. The Swedish technology launched in 2012 as a way to "democratize and decentralize" local food production.[139]

According to the manufacturer, Freight Farms have a maximum power load of 180kWh/day and can be powered by solar energy.[140] This may present a use opportunity for energy generated by compatible technologies like rooftop solar, solar carports, or other onsite generation technologies. Freight Farms can grow in climates with temperatures ranging from -40F to 120 F,[141] and consume less than 5 gallons of water per day.[142] There are currently more than six Freight Farm Systems operating in Michigan, including one at the University of Michigan campus farm, which will supply greens to campus dining halls and will be evaluated under a full life cycle analysis assessment.[143] It is important to consider the fuel type used to generate the electricity that powers the Freight Farm in order to evaluate its sustainability performance. If the electricity is generated from a carbon intensive source such as a coal fired power plant, the energy requirements of this system could make this the less sustainable option compared to traditional growing methods.[144] That being said, some of the transportation impacts of conventional sourcing would be offset, as onsite production can reduce the food miles traveled. Meijer should consider the trade-off between additional energy load

[139] First ICA Maxi Store in Sweden, One of 84 Grocery Locations, Launches Sale of Onsite-Grown Produce (2019, April 10). In Ciston PR Newswire. Retrieved from https://www.prnewswire.com/news-releases/first-ica-maxi-store-in-sweden-one-of-84-grocery-locations-launches-sale-of-onsite-grown-produce-300829894.html

[140] Frequently asked questions (n.d.). In Freight Farms. Retrieved from https://www.freightfarms.com/faq

[141] Greenery: The smartest hydroponic farm inside of a shipping container (2019). In Freight Farms. Retrieved from https://www.freightfarms.com/greenery#container-farm

[142] First ICA Maxi Store in Sweden, One of 84 Grocery Locations, Launches Sale of Onsite-Grown Produce (2019, April 10). In Ciston PR Newswire. Retrieved from https://www.prnewswire.com/news-releases/first-ica-maxi-store-in-sweden-one-of-84-grocery-locations-launches-sale-of-onsite-grown-produce-300829894.html

[143] Skiver, C. (2019, September 9). Freight Farm gives U-M fresh produce, sustainability data. In University Record. Retrieved from https://record.umich.edu/articles/freight-farm-gives-u-m-fresh-produce-sustainability-data/

[144] Breewood, H. (2019, January 18). Spotlight on urban, vertical and indoor agriculture. In *FCRN: Knowledge for Better Food Systems* . Retrieved from https://www.fcrn.org.uk/fcrn-blogs/spotlight-urban-vertical-and-indoor-agriculture

requirements and opportunities for innovative customer education when considering this strategy.

Freight Farm space requirements may create implementation challenges for Meijer at Market Format retail sites, depending on the conditions at each location. As with some of the other strategies, the contained nature of this technology will not inherently expose customers to the futuristic appeal and may need to be highlighted with signage or other marketing materials to fully demonstrate the system's sustainability impact.

Figure 10. From the external viewpoint, the Freight Farm growing system looks like a standard shipping container.

Figure 11. The Freight Farm growing container is equipped with grow lights and planting trays to grow produce year-round in a temperature controlled environment.

4.1.3 Onsite Agriculture: Vertical Growing Hydroponics

Vertical growing hydroponic systems offer an opportunity to grow produce inside the store providing an innovative production strategy that is visible to the consumer. Common to European grocery chains, a few competitors have experimented with this production model, as pictured in **Figure 12** and **Figure 13**.[145] Kroger recently contracted with a company called InFarm to pilot hydroponic farming systems in some retail locations.[146] InFarm remotely operates vertical growing systems using cloudbased technology to regulate growing systems. According to vendors, InFarm hydroponic systems use 95% less water and 75% less fertilizer than producing a comparable amount of product with conventional farming systems.[147] Though the system does require energy input, some of this impact may be offset by reduced need for produce transportation and packaging.[148] Lighting is the hydroponic system component that contributes the largest emission footprint, some of which can be offset depending on the energy source used to produce the electricity. Efficient, LED bulbs are typically used in hydroponic systems.[149]

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[145] Ettinger, J. (2018, October 22). Indoor Urban Farming Puts the 'Grow' in Grocery Store for a Berlin Supermarket. In Organic Authority. Retrieved from https://www.organicauthority.com/buzz-news/indoor-urban-farming-puts-the-grow-in-grocery-store-for-a-berlin-supermarket

[146] Vedantam, K. (2019, November 20). Growing produce inside the grocery store? Some QFCs try a new approach. In The Seattle Times. Retrieved from https://www.seattletimes.com/business/retail/supermarket-giant-tests-growing-hydroponic-produce-in-eastside-qfc-stores/

[147] Nosowitz, D. (2019, December 6). Produce Grown Right in Stores is the Newest Food Trend You Need to Try. In Better Homes and Gardens. Retrieved from https://www.bhg.com/news/in-store-farming/

[148] Products (2019). In InFarm. Retrieved from https://www.infarm.com/products

[149] Molin, E., & Martin, M. (2018, March). Assessing the energy and environmental performance of vertical hydroponic farming. *IVL Swedish Environmental Research Institute*, *29*. doi:https://www.ivl.se/download/18.2aa2697816097278807e72e/1522250395541/C299.pdf

Studies show that in hydroponic systems plants can be cultivated in higher density, decreasing the growing area required for production.[150] The contained nature of hydroponic systems, and the lack of soil in used for cultivation can reduce risk of exposure to insect pests and diseases and reduce water loss through evaporation.[150] Hydroponic systems can be especially beneficial in regions with low levels of light or seasonal temperature patterns that prevent year-round growing. Experts note that hydroponic systems are best utilized as a supplement to, not a replacement for traditional cultivation techniques.[151]

Implementing costly contract services could translate to price premiums for the customer, a potential challenge of implementing this strategy**.** In addition, a system where customers pick their own produce, there could be some concern for quality when customers are handling package free produce. Additionally, the system may generate more waste as the produce cannot be returned to the shelf once a customer harvests it. Meijer would not be able to utilize compost generated through food waste management under this system, and there is no organic certification scheme for hydroponic produce.

Figure 12. Hydroponic growing systems allow retailers to grow produce in the store.

Figure 13. Hydroponic systems could allow customers to harvest produce directly.

4.2 Stormwater Management

Green infrastructure uses soil, vegetation, and other elements to filter, treat, move and manage stormwater from the built environment.[152] In stormwater management systems, several strategies are used to slow down the flashy rainwater and reconstruct the natural infiltration and detention functions in an urban setting. Rainwater is kept onsite to reduce the risk of flooding in 50-yr or 100-yr storms. Green infrastructure removes pollutants from the rainwater removed to allow for the recycling and reuse of the water.

There are few principles used to determine the most appropriate stormwater management practices for a site theoretically. First, Meijer would need to determine the location of the site in the watershed. According to experts, there are three types of locations - upland, network, and the shoreline. In the **upland**, all rainwater is collected,

[150] Molin, E., & Martin, M. (2018, March). Assessing the energy and environmental performance of vertical hydroponic farming. *IVL Swedish Environmental Research Institute*, *29*. doi:https://www.ivl.se/download/18.2aa2697816097278807e72e/1522250395541/C299.pdf

[151] Gao, J., Lakhiar, I., Sayed, T. N., Chandio, F., & Buttar, N. (2018, May 30). Modern plant cultivation technologies in agriculture under controlled environment: a review on aeroponics. *Journal of Plant Interactions*. doi: https://doi.org/10.1080/17429145.2018.1472308

[152] What is Green Infrastructure? (2019, December). In US Environmental Protection Agency. Retrieved from https://www.epa.gov/green-infrastructure/what-green-infrastructure

infiltrated, and dispersed as runoff. The upland includes building roofs, parking lots, driveways, and vegetated areas of private yards and public lands.[153] The **network** contains locations that convey significant amounts of stormwater runoff, including constructed pipe systems, roadway surfaces, and roadside ditches, and streams.[153] The **shoreline** refers to areas that are next to water bodies, or subject to flooding from those waterbodies.[153]

Depending on the watershed location, different management practices are applied to control rainwater runoff. Some standard practices, such as detention basin and rainwater garden, can apply to most situations and locations. The main functions of these practices are to infiltrate, detain, and retain the rainwater. Infiltration helps to remove pollutants, including chemicals, silts, and plastics. Detention slows down flashy flows, which may cause temporary flooding and hold water onsite for up to 48 hours. Retention will hold water onsite for deposition and prevents overflows for an extended period.

The second principle of stormwater management is connected imperviousness effectively according to the functions and watershed locations. The stormwater is treated onsite according to the watershed locations (uplands, network or shoreline), instead of discharging to the civil sewer system that will be burdensome in large storms.

4.2.1 Cistern

A cistern is a rainwater barrel that is used to collect rainwater, especially in a dense area, which has minimal space requirements. A cistern can be placed either on the ground or underground, depending on need. A cistern can be used in all watershed locations, but this strategy works best in urban settings with appropriate management. Cisterns are often served as complementary components with other stormwater management strategies, such as bioswales and rainwater gardens. They can help to collect extra runoff. Cisterns typically offer the most inexpensive method of managing stormwater, by collecting rainwater from the roof. Cisterns reduce roof runoff and settle pollutants. In addition, underground cisterns can be hard to clean.

***Case Studies:* Ann Arbor Municipal Center, MI[154]**

The Municipal center in Ann Arbor used multiple stormwater management strategies to direct the rainwater. In the subbasin 2, the rainwater runs through the green roof, and is collected by the underground cisterns.

[153] Hill, Kristina.(2009). Urban Design and Urban Water Ecosystems. In L.A. Baker (ed.), The WaterEnvironment of Cities, Springer Science+Business Media, LLC 2009.Retrieved from: http://books.nap.edu/openbook.php?record_id=12465&page=129

[154] Ann Arbor Municipal Center. Landscape Performance. Retrieved from: https://www.landscapeperformance.org/case-study-briefs/ann-arbor-municipal-center

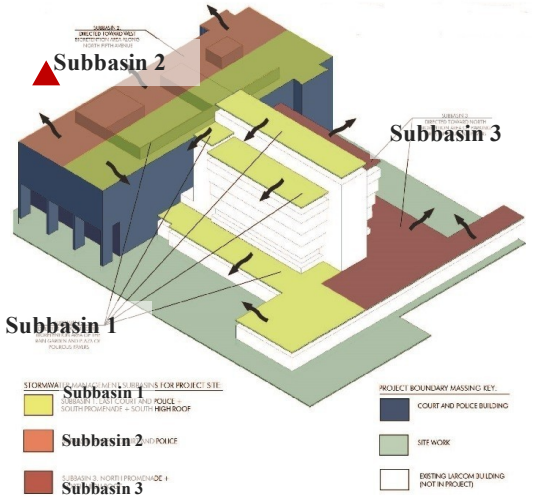

Figure 14. Isometrics view of stormwater management plan

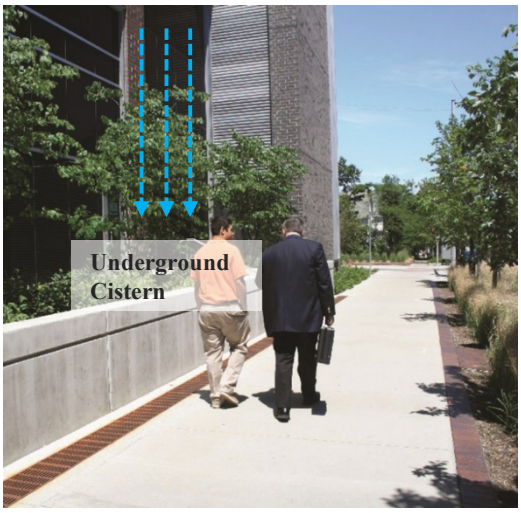

Figure 15. Underground Cistern

4.2.2 Bioswale

Bioswales are linear channels designed to concentrate and convey stormwater runoff while removing debris and pollutants (Wikipedia). Bioswales are usually vegetated with native plants to enhance the rainwater quality and allow the groundwater table to recharge. Functioning as an infiltration and detention channel, bioswales may be applied in both upland and network locations. It would not be appropriate at a shoreline site because the polluted runoff in the bioswale could easily discharge into water bodies during massive storms.

As open ditches, bioswales require less maintenance than underground pipe systems and through design, can be visually attractive. Additionally, bioswales can provide habitat for arthropods and pollinators. Due to specific spatial requirements, bioswales will work better in the Supercenter scenario. It can infiltrate stormwater and remove pollutants before allowing the water to enter the detention area.

4.2.3 Rain Garden

Rain Gardens are special types of gardens that collect and treat rainwater. Design specifications for rain gardens recommend that the garden is planted in a natural low spot with a safe overflow zone, and that the slope of the land draining to the rain garden does not exceed 12%.[155] Rain gardens are typically 3-6 inches deep, and range from 100 to 300 sq. ft in size. Experts recommend designing a rain garden roughly 20% the size of the land area that drains to it.[155]

Rain gardens are suitable for all watershed locations but should be carefully designed in locations near the shoreline. As a multifunctional garden, rain gardens not only filter and detain rainwater but can also act as a pollinator gardens that provides food to insects with specific plant selections. Size requirements for rain gardens vary depending on the

[155] Rain Gardens Stormwater Management (2008). In City of Ann Arbor. Retrieved from https://www.a2gov.org/departments/systems-planning/planning-areas/water-resources/Documents/systemsplanning_stormwater_raingardenguide_2008_05_05.pdf

volume of water storage required. Rain gardens can be installed in urban settings by dividing up the storage volume into several mini gardens or through incorporation into the planting strips on sidewalks that separate the vehicles and the pedestrians.

Rain gardens require regular maintenance, especially in the early establishing period, to ensure plant survival. Additionally, care should be taken during the planning and construction phases to prevent standing water from accumulating.

Example structure of the rain garden[156]

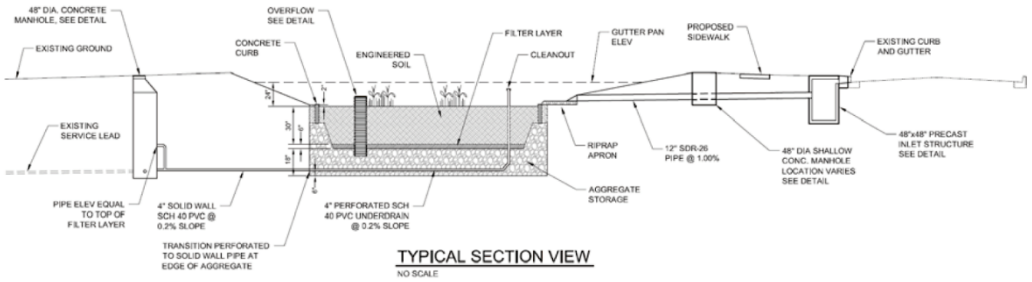

Figure 16. Section View of Bioretention Garden

From this illustration, we can see that the rain garden, or bioretention garden, is divided up into two parts. The stormwater storage is mostly underground, which alleviates concerns about open water. Meanwhile, the surface part can be designed with flexibly according to the client need. It can become a conventional rain garden by adding multiple plant species. It can also become a pollinator garden with careful species selection, such as Black-eyed Susan, that can provide food to pollinators.

Case Study: P street corridor, Phase 1, NE[157]

In this case, the rain gardens are combined with the planting strip (the planting are on the sidewalks) in an urban area. The carefully sized rain gardens can still function as space for slowing down and infiltrating stormwater even inside the city center.

Figure 17. Bird's-eye view of the series of rain gardens that build on the planting strip

[156] Joan iverson Nassauer and Yuanqiu Feng (August 2018). Different contexts, different designs: For green stormwater infrastructure. New-GI Technical Report No. 1. Neighborhood, Environment and Water Research Collaborations for green infrastructure. University of Michigan. Page 30.

[157] P street Corridor, Phase 1. Landscape Performance. Retrieved from: https://www.landscapeperformance.org/case-study-briefs/p-street

4.2.4 Detention Pond

Detention ponds are basins that receive and hold runoff for release at a predetermined rate, reducing the peak runoff delivered to storm sewers and streams (BMP Factsheets).[158] Detention ponds are usually vegetated with a relatively steeper slope to allow rainwater to enter the system and infiltrate. Underground detention pond systems can be hidden from the surface and can work in an urban setting. Detention ponds are suitable for installation in upland or network sites.

Detention ponds can be used as open space during the drought season and can reduce the burden on the civil sewer system by holding excessive stormwater. In addition, detention ponds can be aesthetically appealing if designed strategically.

Conventional detention ponds present a few potential challenges. Often, detention ponds can hold open water for up to 48 hours, which may be perceived as unsafe. In addition, detention ponds have specific spatial requirements, which may be better suited for a Supercenter setting. Lastly, detention ponds require regular maintenance, especially in the early establishment period.

Detention ponds can be designed differently from the standard style. The stormwater can be stored mostly underground, which allows the surface to become multifunctional spaces. The pond not only holds stormwater during storm events but can also be used as recreational areas for customers and nearby communities. Usually, the detention ponds, to save spaces in commercial areas, will have steep slopes that allow them to store more water. Such steep slopes, along with some kind of open water, may be considered as dangerous and uninviting. Either increasing the amount of plants inside the pond or turning the pond into an accessible landscape can make it more attractive to customers. The plants are able to cover the open water and minimize the height difference visually. A slightly sloped turf area with underground detention area can also reduce the danger of the ponds. Floating platforms or small trails can be added above the pond to provide access for customers if needed. Educational elements such as printed signage can also be placed inside the detention ponds to provide illustration and instruction of how the pond is functioning.

Case study: Advocate Lutheran General Hospital Patient Tower, IL[159]

Inside the hospital, the conventional detention pond is transferred into a spiral garden that can serve as a detention basin during storm events, and also serve as a recreational space.

[158] Detention Ponds. Best Management Practices Fact Sheet. Dauphin County. Retrieved from: http://www.dauphincd.org/swm/BMPfactsheets/Detention%20Basin%20fact%20sheet.pdf

[159] Advocate Lutheran General Hospital Patient Tower. Landscape Performance. Retrieved from: https://www.landscapeperformance.org/case-study-briefs/advocate-lutheran-general-hospital

Figure 18. Bird's-eye view of the detention garden

Figure 19. Inside of the detention garden

4.2.5 Retention Pond

Retention ponds are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events (NWRW).[160] Retention ponds are suitable for installation in upland or network sites.

Retention ponds are advantageous in that they can be designed as artificial water bodies that add visual appeal to landscaping. They can also store excessive stormwater permanently to avoid overflow.

Retention ponds also have a few drawbacks. They have sizable spatial requirements and are suitable only in big-box Supercenter stores. Additionally, retention ponds require regular maintenance with over-flow control, though at a relatively low level.

4.2.6 Permeable Pavement

Permeable pavement is designed to infiltrate and detain rainwater underground. Permeable pavement can improve the water holding capacity and infiltration rates of parking lots, paths and sidewalks. The water management capacity of this technology depends on the porosity and depth of the pavement. For example, if the pervious concrete has 15% effective porosity, then experts suggest every 1 inch (25 mm) of pavement depth can hold 0.15 inches (4 mm) of rain.[161] Permeable pavement can be applied to land with a maximum slope of 7%, however infiltration is most efficient on level ground.[12] Designers should also consider the soil type of the land where the permeable pavement will be installed, as this can impact infiltration rates and the depth of the subbase.[136]

Permeable pavement can be applied to all watershed locations but should be established carefully in the shoreline zone. Porous pavements prevent rainwater from running off the surface into adjacent land areas, and instead, create a system where it can infiltrate and recharge into the groundwater table.

For peak performance, permeable parking requires significant maintenance including regular vacuuming to clean dirt that can clog the pavements and disable the penetrability of rainwater. Through careful grading design, the size of permeable paving can be a constraint to a manageable level**.**

[160] Individual NWRM-Retention ponds. Natural Water Retention Service.European Commission. Retrieved from: http://nwrm.eu/sites/default/files/nwrm_ressources/u11_-_retention_ponds.pdf

[161] Pervious Pavement Design Hydrological Design Considerations (2011). In Pervious Pavement. Retrieved from https://www.perviouspavement.org/design/hydrological.html

4.3 Ecological Design

Besides stormwater management, the application of plants and the choices of pavement material and color can contribute to the sustainability of the site. This section discusses the importance of native plants as major food providers to the local ecosystem, and the usage of plants to improve building insulation. Meanwhile, the choice of pavement, especially pavement color, can also help to mitigate several urban ecological challenges.

4.3.1 Native Plants

Globalization has led to an increase in the introduction of non-native plants due to their adaptability and exotic appearance. Non-native plants can become invasive plants if no competitors are present in the area. In addition, non-native plants can negatively affect the visitation and reproductive success of focal native plants, when these two plant species have phenotypically similar flowers.[162]

We recommend using native plants in landscape design, to provide food for pollinators, and reduce the need for chemical pest control.[163] Maintenance requirements for native plants are relatively low once they are established. In addition, plants offer ecological benefits by sequestering carbon dioxide and holding water in their roots which can prevent erosion (See **Appendix C**). Research suggests that in an urban setting, the influence of non-native plants is not as significant as native plants, if the non-native plants do not outcompete the native plants (Harrison & Winfree, 2015). Therefore, Meijer should carefully select necessary non-native plants in the Market Format store when meeting aesthetic needs.

4.3.2 Wind-break

A wind-break is usually composed of mature evergreens as the main blockage with shrubs and smaller trees in filling the outer gaps.

Wind-breaks have several advantages. Research has shown that wind breaks, in addition to blocking harsh winds, also regulate the temperature and act as a habitat for wildlife.[164] Strategically placed wind-breaks within the store periphery can help regulate building temperatures, resulting in energy savings.

On the other hand, wind-breaks have large spatial requirements. They also block the view of the store from the street. For these reasons, wind-breaks are best suited for Supercenter stores.

4.3.3 Pollinator Garden

Pollinator gardens are critical sources of urban biodiversity in the urban ecosystem. Pollinator gardens provide food for pollinators, such as butterflies, bees, and other kinds

[162] Morales, C. L., & Traveset, A. (2009). A meta-analysis of impacts of alien vs. native plants on pollinator visitation and reproductive success of co-flowering native plants. *Ecology Letters*, 12(7), 716–728. doi: 10.1111/j.1461-0248.2009.01319.x
[163] Isaacs, R., Tuell, J., Fiedler, A., Gardiner, M., & Landis, D. (2009). Maximizing Arthropod-Mediated Ecosystem Services in Agricultural Landscapes: The Role of Native Plants. *Frontiers in Ecology and the Environment*, 7(4), 196-203. Retrieved January 10, 2020, from www.jstor.org/stable/25595116
[164] How to plant a wind break.: South Coast Register ; Nowra, N.S.W. [Nowra, N.S.W]22 May 2019: 15.Retrieved from: https://search-proquest-com.proxy.lib.umich.edu/docview/2228173170?pq-origsite=summon

of insects, to complete urban trophic levels and food chains. According to a recent study, humans prefer plants with early blossom and long flower duration, so those plants are commonly used in urban areas.[165] Therefore, plants should be carefully selected to ensure that they meet the lifecycle needs of beneficial pollinators.

Spatial requirements for pollinator gardens are variable and are well suited to both the Supercenter and Market Format stores. In the Market Format, pollinator gardens can be planted in flower beds, with limited soil and space.
Pollinator gardens require moderate maintenance. More management is required in the early establishment period, before the pollinator gardens become self-sustaining. Aesthetically, pollinator gardens are appealing to customers, and can include a variety of blossoms.

Pollinator gardens require careful planning to keep distant from the shoppers, which avoid disturbance from the shoppers while preventing children from touching the dangerous pollinators, such as bumblebees.

4.3.4 Green Roof/Green Walls

A green roof is defined as a roof covered with vegetation or a growing medium. Green roofs are becoming more prevalent as a component of urban greenery that reduces greenhouse gas emissions, mitigates pollution and the urban heat island effect, and provides habitat for small mammals and arthropods.[166]

Table 1
Classification of green roofs according to type of usage, construction factors and maintenance requirements [1].

	Extensive green roof	Semi intensive green roof	Intensive green roof
Maintenance	Low	Periodically	High
Irrigation	No	Periodically	Regularly
Plant communities	Moss-Sedum-Herbs and Grasses	Grass- Herbs and Shrubs	Lawn or Perennials, Shrubs and Trees
Cost	Low	Middle	High
Weight	60–150 kg/m^2	120–200 kg/m^2	180–500 kg/m^2
Use	Ecological protection layer	Designed green roof	Park like garden
System build- up height	60–200 mm	120–250 mm	150–400 mm underground garages ≥ 1000 mm

Figure 20. Types of Green Roof

Aesthetically, green roofs cover the traditional bare roof with plants that can attract attention from customers. Green roofs can also be designed to serve as an open space for recreation activities.

Despite providing the environmental and aesthetic benefits, the construction and maintenance burdens for the green roof can be significant. A green roof usually consists of several layers, including a plant layer, soil layer, drainage layer, insulation layer, and

[165] Harrison, Tina, and Rachael Winfree. "Urban Drivers of Plant-Pollinator Interactions." *Functional Ecology*, vol. 29, no. 7, 2015, pp. 882., doi:10.1111/1365-2435.12486.)
[166] Besir, Ahmet B., and Erdem Cuce. "Green Roofs and Facades: A Comprehensive Review." *Renewable and Sustainable Reviews*, vol. 82, pp.915-939., doi:10.1016/j.rser.2017.09.106

structured layer, which can add an enormous amount of additional weight to the existing building.[167] Therefore, a green roof would not be suitable for a retrofit site.

Green roofs consume space that is traditionally used for refrigeration and other appliances, and the survival rate of plants on green roofs is generally lower than that of on the ground due to the limited soil and nutrition.

It is possible that the green roof would not be visible to customers without signage or other promotional efforts. Green roofs offer an opportunity to educate the customer about sustainability by demonstrating ecological benefits and green infrastructure but are not as obvious to the consumer as technologies implemented on the ground or in the customers regular line of sight.

Green walls, an extension of green roofs, cover the growing structure of the exterior wall with vegetation. There are two kinds of green roofs, the green facade and the living wall. Here, green facade, both direct facade or indirect facade, is preferred due to its manageable nature. The plants are installed on the ground. The plants can either directly climb on the building facade or support by structures that allow them form the green wall.[167]

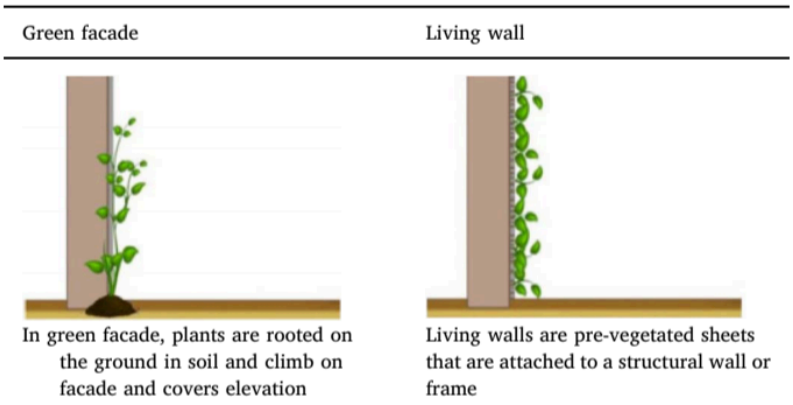

Figure 21. Types of Green Wall

Green roofs and green walls can improve building insulation by blocking heat in summer and cold in winter, which may contribute to energy saving and energy efficiency.[167] The annual saving of the green roofs and green walls can reach $215/year,[167] depending on regional and climatic conditions. A green wall can be an alternative to solve some shortcomings of the green roof. The spatial requirement for the green wall is smaller than that of the green roof. Green walls do not need an extra soil or drainage layer to grow, which reduces the weight that is added to the building. Since the plants grow on an exterior wall, the green wall will not occupy designated spaces for appliances such as HVAC rooftop units..

Meijer could implement a green roof hyperlocal food production system in the *Store of Tomorrow* to utilize rooftop square footage to produce crops. Several grocery stores have implemented this strategy, including Canadian retailer IGA Extra Famille Duchemin location in Brooklyn, which also incorporated a rooftop greenhouse (Figure

[167] Besir, Ahmet B., and Erdem Cuce. "Green Roofs and Facades: A Comprehensive Review." Renewable and Sustainable Reviews, vol. 82, pp.915-939., doi:10.1016/j.rser.2017.09.106

14).[168] To incorporate a rooftop greenhouse, retail stores may consider contracting with a company like BrightFarms in Brooklyn, that "design, build, finance and operate hydroponic greenhouse farms" specifically for supermarket rooftops.[169]

Figure 22. Pictured above, the Brooklyn WholeFoods location features a rooftop garden greenhouse.

4.3.5 Light Colored Pavement

When the sunlight hits the opaque surface, some energy will be absorbed in the surface, while others will be reflected. The amount of reflected energy is measured by Albedo. Usually, surface with low Albedo will worsen the Urban Heat Island Effect.[170] Light colored pavement with a relatively high Albedo is commonly used to combat the urban heat island effect. Dark colored pavement can absorb heat and trap it in the medium, while light colored pavement reflects more heat to the air. Therefore, increasing the amount of high Albedo surfaces will help to mitigate the issue of global warming potential through radiative forcing.[171]

Light colored pavement can be applied to buildings, roofs, asphalt paving for parking, and the light-colored pavement in front of the store. The commonly used concrete and asphalt, as paving materials, can be modified with cool-color pigments to increase the Albedo.[171]

The maintenance requirement of light-colored pavement is moderate, although they need to be cleaned and repainted periodically to remove dirt.

[168] Hoory, L. (2017, September). Epic 25,000 Square Foot Garden Opens on Rooftop of Montreal Supermarket. Garden Collage. Retrieved from https://gardencollage.com/change/sustainability/epic-25000-square-foot-garden-opens-rooftop-montreal-supermarket/

[169] Gunther, M. (2011, June). Turning a Rooftop Garden into a Supermarket's Supply Chain. In GreenBiz. Retrieved from https://www.greenbiz.com/blog/2011/06/08/turning-rooftop-garden-supermarkets-supply-chain

[170] Akbari, H., & Rose, L. S. (2008). Urban Surfaces and Heat Island Mitigation Potentials. Journal of the Human-Environment System, 11(2), 85–101. doi: 10.1618/jhes.11.85

[171] Li, H. (2016). Thermal Interaction between Pavement and Building Surfaces. Chapter 2 Literature Review on Cool Pavement Research, 16-42. doi: 10.1016/b978-0-12-803476-7.00010-6

5. Design and Customer Experience

In this system, we are exploring strategies that serve to increase customer awareness of Meijer's sustainability actions and provide sustainable education through interaction with the store. Displays and advertisements will be provided both in digital formats and printable formats to ensure justice and accessibility.

Design and Customer Experience Strategies Scoring

Supercenter

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirements	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Customer Experience	Display- Printed Sinage								
	Display- Quarterly Boards								
	Display- Digital Display								
	Display- Product Displays								
	Customer Awareness- Weekly Promotion/Ads								
	Customer Awareness- EV charging								
	Customer Awareness- Solar Canopy Carports								

Market Format

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirements	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Customer Experience	Display- Printed Sinage								
	Display- Quarterly Boards								
	Display- Digital Display								
	Display- Product Displays								
	Customer Awareness- Weekly Promotion/Ads								
	Customer Awareness- EV charging								
	Customer Awareness- Solar Canopy Carports								

5.1 Display

5.1.1 Printed signage

Printed signage is an effective way to raise customer awareness of Meijer's sustainable practices. Printed signage can interact with landscape designs, such as pollinator gardens, rainwater gardens, retention ponds etc., to provide information and illustration of the benefits of these elements.

Designers should consider some important principles when crafting these signs, as listed below: [172]

1. Applying Brown's writing standards (2002), *the scientific signs should have 30-100 words* (two to seven sentences with no more than 15 words each sentence, while 8-word sentence has the highest readership of 92%). Here, the benchmark is 70 words per signage.
2. The average word length, of the benchmark, is around 5 characters per word.

[172] Wandersee, J., & Renee M. Clary. (2007). Learning on the Trail: A Content Analysis of a University Arboretum's Exemplary Interpretive, Science Signage System. *The American Biology Teacher*, 69(1), 16-23. Retrieved January 11, 2020, from www.jstor.org/stable/4452076)

3. According to Gilson' research, the line length would be less than or equal to 42 characters.
4. Use passive voice sentences less than 20% of the time because they provide ineffective and uninteresting prose.
5. Applying Tufte's theory of graphic design (2001), a multivariate, small multiple graphic design that various data types and texts are presented in a consistent layout. Each sign should have the same interpretability profile that allows easy reading and understanding.

In conclusion, the design of the signage should follow these standards:

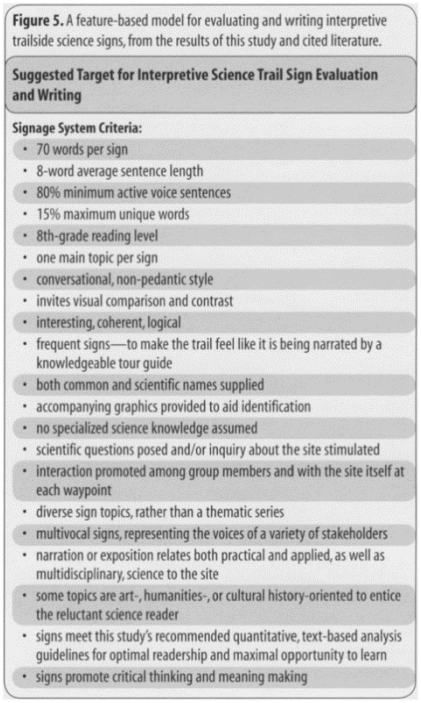

Figure 5. A feature-based model for evaluating and writing interpretive trailside science signs, from the results of this study and cited literature.

Suggested Target for Interpretive Science Trail Sign Evaluation and Writing
Signage System Criteria:
• 70 words per sign
• 8-word average sentence length
• 80% minimum active voice sentences
• 15% maximum unique words
• 8th-grade reading level
• one main topic per sign
• conversational, non-pedantic style
• invites visual comparison and contrast
• interesting, coherent, logical
• frequent signs—to make the trail feel like it is being narrated by a knowledgeable tour guide
• both common and scientific names supplied
• accompanying graphics provided to aid identification
• no specialized science knowledge assumed
• scientific questions posed and/or inquiry about the site stimulated
• interaction promoted among group members and with the site itself at each waypoint
• diverse sign topics, rather than a thematic series
• multivocal signs, representing the voices of a variety of stakeholders
• narration or exposition relates both practical and applied, as well as multidisciplinary, science to the site
• some topics are art-, humanities-, or cultural history-oriented to entice the reluctant science reader
• signs meet this study's recommended quantitative, text-based analysis guidelines for optimal readership and maximal opportunity to learn
• signs promote critical thinking and meaning making

Figure 23. A feature-based model for science signs

Printed signage has several advantages. First, it is a familiar way of delivering knowledge that is well accepted and very accessible to the customer. Signage can be placed to suit the needs of the site, and can be adjusted easily based on feedback, to maximize intended impact. Signage also requires minimal effort to maintain and can be easily cleaned or replaced as needed.

The key drawback with printed signs is that it lacks an interactive element. It is often a unidirectional communication tool where the shoppers cannot offer feedback or elicit responses from the signage.

The following are a few applications of printed signage that Meijer can adopt in the *Store of Tomorrow*:

Figure 24. Acrylic Signage

Figure 25. Signage that matches the history of the site

Figure 26. Bald Eagle Interactive Signage

Figure 27. HUB Green roof signage

5.1.2 Quarterly Boards or Posters

Quarterly Boards or Posters are similar to educational signage and could provide a printed medium to disseminate Meijer sustainability narratives and practices. Quarterly boards should be designed to attract the customer's attention at first glance when arriving at the store. Different from the educational signage, the board is designed to raise customers' awareness of Meijer's actions, while calling for downstream environmental impact reduction.

The board should consist of larger graphic elements than the educational signage, with minimal, but powerful sentences to best illustrate narratives. The design of the board should follow standard graphic design principles to achieve intended effects. The maintenance of the boards is relatively low, but the turnover rate would be high. We recommend that Meijer update the board to balance sustainability, education, and advertisement priorities.

5.1.3 Digital Display

In the digital age, customers would be more receptive to digital displays. Compared to conventional signage, digital displays have fewer limitations on the display content, and increase interactions between the customers and Meijer. Due to the typically larger size of digital screens, the display content can be more than that in printed signs. However, to retain the effectiveness of messaging, wordy sentences must be avoided. Digital displays allow the use of videos, multiple pictures, and scrolled layouts to convey more information and knowledge. The display contents can be updated regularly, according to media needs. Interactive elements, such as Q&A, sustainability quizzes, extended reading and related videos can also be added to better communicate with customers.

Digital displays are advantageous in that they are environmentally sustainable and energy efficient. They consume little power but can provide durable display mediums.[173] Using digital displays also saves resource intensive paper and ink.[173]

Outdoor digital signage is another trend used to improve outdoor education. The successful outdoor signage is incorporating the environment through the following principles: 1) the screens should be readable in different lighting conditions and weather (Digital signage magazine);[174] 2) place the digital displays at an accessible distance, which also merges into the environment; 3) use a higher color gamut as preferred by consumers; [175] 4) Consider various preferences for white point and gamma corrections;[175] and 5) Consider preferences for real world images rather than abstract images.[175]

Indoor digital signage can be flexible and placed at the top of the rack by using smaller screens. However, the font choice is important. The contents should be concise, and the sizes should be legible from a distance if placed at the top of the racks. Meanwhile, the height and angle of the screens should be carefully adjusted to increase legibility.

Pricing and maintenance represent the two primary shortcomings of digital displays. The display would require little regular maintenance, but the devices would ultimately need to be replaced or made to undergo lengthy repair if they were to become defective. Additionally, digital displays have a higher upfront installation cost than printed signage.

The following are a few applications of digital displays that Meijer can adopt in the *Store of Tomorrow*:

Figure 28. Digital Display with social media updates

Figure 29. Interactive digital display

Figure 30. Digital display for information

[173] DigitalSignageToday.com: Why digital displays are a perfect fit for higher education: Newstex Trade & Industry Blogs , Chatham: Newstex. Jul 28, 2016. Retrieved from: https://www.digitalsignagetoday.com/articles/why-digital-displays-are-a-perfect-fit-for-higher-education/

[174] Technology--like learning--never stops: digital signage for educational campuses. Digital Signage Magazine. Business Insight: Global. Retrieved from: https://bi.gale.com/global/article/GALE%7CA373476084?u=umuser&sid=summon

[175] Schumacher, Jennifer F. Hillis, James M. Shannon,Robert W. Van Derlofske,John F. Lamb, Dave J. Lathrop, Art A. Thielen, James A. Stankiewicz,Brian J . "Cultural Analysis of Digital Display Preference".Cultural Analysis of Digital Display Preference. *Journal of Vision*, August 2014, Vol.14, 1000. doi:https://doi.org/10.1167/14.10.1000

5.1.4 Product Displays

Product displays are a form of digital display that could be used to share sustainability information about products. The product displays allow customers to read and interact with the sustainable practices behind the products, including the supply chain, the packaging information, the primary production process, etc.

Product displays could be used to promote Meijer's sustainable practices and help customers reduce their household environmental impact. Product displays could also be placed strategically, such as next to crucial products that have high or low sustainability impacts. For example, Meijer can place product displays with detailed product information, including production process and supply chain, next to the organic products to help customers understand them.

Maintenance requirements are relatively high for the displays since they require many screens. Digital displays would work better in the Supercenter store because the store has more spaces to place the displays without crowding the space.

5.2 Customer Awareness

5.2.1 Weekly Promotions and Advertisements

Meijer has traditionally used weekly promotions to disseminate product information or special projects using both digital and printed mediums to ensure justice and accessibility. By introducing a similar program in the sustainability campaign, customers could receive a weekly update about Meijer sustainability practices. The promotions could be included as a special add-on to the current version with the goal of reducing the customer's environmental footprint.

It is possible that implementing this change could actually increase Meijer's environmental impact by introducing more printed materials. However, the printed material can be recycled easily, while the educational meaning that is conveyed by the hard copies can potentially reach more customers who have no attention on sustainability but constantly collecting discounts information. The current design of the ads or promotion should also be modified, and the fitted version still needs feedback from customers.

5.2.2 EV Charging

Electric vehicle charging stations for customers would be a very visible sustainability strategy for Meijer. EV charging could encourage downstream energy and emission savings and would have numerous benefits for Meijer.

EV charging stations would be very valuable to customers and Meijer employees. Lack of public charging stations is one of the primary issues with EV adoption and installing EV chargers on-site could greatly benefit adoption. EV chargers would provide Meijer with 'Green' credentials and could be a way to attract tech-savvy younger customers who care about the environment. Having EV chargers would also facilitate image recognition of Meijer among cognizant customers. There are significant rebates that Meijer could receive by installing chargers such as through Consumers Energy's PowerMIDrive rebate program.

On the other hand, an increase in electric load chargeable to Meijer due to EV charging could result in elevated electricity expenses.

Meijer should carefully weigh these pros and cons and model the economics before extensively investing in charging infrastructure on-site.

Several food retailers including Harris Teeter, Whole Foods and Fred Meyer are increasingly investing in on-site EV chargers. Meijer already has charging infrastructure in select stores, and we recommend that it would be wise to extend this strategy to include multiple stores.

5.2.3 Solar Canopy Carports

Solar Canopy carports provide an interactive and illustrative form of solar energy that would be valuable to Meijer's customers. Different from traditional solar panels that have to be placed on a flat surface, solar canopies can be designed to assemble the solar panels into decorative elements such as artificial tree formats. These solar trees can be designed to occupy space in the parking lot as a top layer that not only absorbs sunlight for electricity, but also provides shade for cars. This unique carport allows customers to visualize the process of renewable energy generation and would provide strong visual cues of a futuristic store.

The levelized cost solar canopy carport electricity is dependent on local solar resources and the relatively high construction cost of solar canopy trees. The futuristic style might have mixed results on shopper attraction. Some older customers may feel the carport is too progressive while younger customers may like to see such modifications. It needs ample space for installation, making it more suitable for the Supercenter store.

Figure 31. Solar Carports

Recommendations

From the technology review above certain strategies and technologies have been recommended based on their performance in the Market Format and Supercenter score sheet. The recommended technologies performed yellow or better in the score sheet indicating the potential of each for environmental impact reductions and/or educational merit to accomplish Meijer's sustainability goals and uphold the company's principles like their commitment to responsible growth. Each list of recommended technologies are separated into the Market Format and Supercenter store format and further divided into the 5 main systems outlined in the system diagram.

Table V. Summary of Recommended Strategies for Supercenter and Market Format

Strategy	Market Format	Supercenter
PPAs	x	x
Smart Appliances	x	x
Geothermal		x
LEDs	x	x
Low GWP Alternatives & Case Doors	x	x
Daylighting & Dimming	x	x
PPAs		x
Solar PV		x
Dual Flush Toilets	x	x
Low Flow Fixtures	x	x
Smart Irrigation		x
Container Composting		x
Composting with Onsite Pick Up	x	
Reusable Bags	x	x
Construction Waste Reuse & Recycling	x	x
Plastic Bags & Film with Post-consumer Recycled Content	x	x
Packaging Waste Backhauling & Recycling	x	x
Bioswale		x
Cistern	x	
Rain or Pollinator Garden	x	x
Hydroponic Growing System	x	
Green Roof	x	
Green Wall		x
Permeable Pavement		x
Detention Pond		x
Wind Break		x
Light Colored Pavement	x	x
Green Roof	x	

Freight Farm		x
Printed Signage		x
Digital Displays	x	
Weekly Promotions	x	x
Product Displays		x
EV Charging	x	x
Solar Canopy Carports		x

1. Market Format

This store model had to consider smaller space requirements than the Supercenter model as it is usually located in the center of cities like the Bridge Street Market in Grand Rapids, MI. This restricts Sustainable Site solutions like onsite agriculture or stormwater management. Besides square footage some Market Formats are located in multi-story leased spaces that makes certain technologies infeasible such as, rooftop solar or green roofs. However, it does have greater potential for innovation than the Supercenter model as it can be used to pilot technologies and has a more flexible design.

1.1 Energy

PPAs

PPAs would enable Meijer to incorporate renewable energy in its Market Format stores. By signing a renewable energy PPA, Meijer would be able to support the additionality of renewable energy capacity in the Midwest and elsewhere. Additionally, Meijer would be able to compete with other leading retailers such as Target and Walmart who have robust clean energy goals.

PPAs do not require any significant infrastructure changes and occupy no store space, making it ideal for market-format stores. PPAs have very high ease of implementation if virtual but would require energy management expertise if Meijer chooses a physical PPA where renewable energy directly feeds into the electric meter. PPAs score yellow in innovation and education given that PPA installations are now commonplace in retail and that there is no tangible educational element for Meijer's customers. PPAs score very well (green) in the environmental footprint category given that a significant portion of Meijer's operational footprint comes from electricity consumption.

Smart Appliances

Smart appliances performed well in the scoring sheet with no red categories. They have a moderate contribution to resource use and carbon emissions abatement. This is accomplished through increased automation and efficiency of the store systems. They enable Meijer better problem detecting capabilities, easier maintenance and optimal system operation. While it does not directly impact the customer's environmental footprint this strategy does offers moderate advances in customer sustainability education as it can inform them about smaller scale smart appliances that can be adopted in their own homes such as smart thermostats. Smart appliances do not have significant costs or require significantly more space than the current systems which increases their

feasibility. They have been implemented successfully in the industry by competitors such as Target and Kroger.

LEDs

LEDs are one of the most feasible strategies in terms of ease of implementation and size and space requirements. They require minimal space and little to not modification for installation and maintenance. In terms of environmental impact reduction, they provide a moderate contribution to carbon emissions abatement. This is due to a reduction of the energy required for Meijer's operational footprint. This is further improved when combined with dimming applications and daylighting strategies. LEDs moderately advance customer's sustainability education and is one of the easiest solutions for them to implement and it is best to replace inefficient incandescent light bulbs with LEDs as the payback period is very small. LEDs have been implemented in some stores, but it is recommended that they be a part of each new store and retrofitted in Meijer's existing fleet.

Daylighting & Dimming

Daylighting is an inexpensive and effective solution to reducing Meijer's operational footprint. Several retailers have daylighting and dimming installations which have reduced their energy requirements and hence their footprint. Daylighting also has proven effects on customer shopping, with research showing that exposure to natural light increases retail revenue by a statistically significant margin.

Daylighting, however, is tricky in market-format stores, especially if they are integrated into multi-story buildings. In such a case, glass walls are a potential solution. Daylighting has a high ease of implementation when planned for a new store. Daylighting also enhances customer shopping experience (green) and customer education (green) given that it is a demonstrable strategy. Daylighting is however not very innovative. It also has a moderate positive influence on Meijer's environmental footprint reduction.

Low GWP alternatives & Case Doors

Low GWP alternatives offer a very positive contribution to carbon emissions (green). They provide a large reduction in emissions which would advance Meijer's environmental impact reduction. This is achieved by having a much lower GWP, on the magnitude of hundreds, than the refrigerants currently being used, R-404a and R-407a. R-448a can directly replace R-404a since it can be used in the current system while R-290, R-717 and R-744 would require a new system to be installed. To further decrease carbon emissions Meijer can combine low GWP alternatives with the addition of case doors to their open medium temperature cases. Case doors would reduce the cooling load by having a more controlled environment as the system would not have the warmer air of the store infiltrating the cases. An added benefit is that customers may purchase more products as they would not be as cold and may stay in the aisles longer. From an education perspective, low GWP alternatives moderately enhance customer sustainability education. Whereas, adding case doors has the potential to significantly

enhance customer understanding of Meijer's sustainability practices as it is visual and can easily have signage attached to explain this strategy and low GWP refrigerants.

1.2 Water

Dual Flush Toilets

We recommend dual flush toilets for both the Market Format and Supercenter store formats. When operated correctly, dual flush toilets reduce water consumption by offering a low flow flush option for liquid waste. Dual flush toilets have been widely implemented in bathrooms that experience many flushes per day, and do not pose threats to plumbing infrastructure when integrated into a well-maintained plumbing system. Dual flush toilets would replace conventional toilets in guest restrooms and do not require additional modifications.

Low Flow Fixtures

Low flow fixtures, such as urinals, showerheads, and faucets can reduce water flow by 20% to 30%.[176] This can generate positive sustainability impacts and financial savings by improving efficiency. Meijer has already incorporated low flow faucet fixtures in some locations. We recommend that Meijer continue this trend and expand this practice to all retail locations to maximize savings. This strategy is suitable for both market and Supercenter locations.

1.3 Materials and Resources

Food Waste Recycling with On-Site Pick-Up

We recommend extending food waste recycling with on-site pickup services to the Market Format store to accommodate smaller sites and food waste management needs. The Market Format store is subject to restrictive zoning regulations that would make onsite composting less feasible. Additionally, the smaller store site or placement in a leased building would make installing a container system on site challenging. Food waste recycling with a contracted pick up service, similar to the baseline practices in some store locations would allow Meijer to sustainably process food waste without needing to make drastic adjustments to the site.

Reusable Bags and Phasing Out Single-Use Plastics

Replacing the single-use plastic bags by reusable bags is strongly recommended in the context of Market Format. Given the number of plastic bags consumed and disposed every year and the environment impacts, there is an upward trend to phasing out the single-use plastic bags, especially in the field of retailers. From the standpoint of both Meijer and customers, a switch from disposable plastic bags to reusable bags can significantly reduce the carbon footprint and bring environmental benefits. Since little modification is needed, this strategy is spatially feasible, but Meijer needs to consider the affordability of reusable bags for the low income households.[93]

Plastic Bags and Film with Post-Consumer Recycled Content

[176] Tolson, M. (2011). ROI-Driven Products: Low-Flow Fixtures. In *Buildipedia*. Retrieved from http://buildipedia.com/aec-pros/construction-materials-and-methods/roi-driven-products-low-flow-fixtures

This strategy is proposed to lower the need for virgin resin which consumes a large amount of energy and natural resources during the life cycle of a plastic produce bag or the plastic film.[99] Without sacrificing the customers' shopping experience, manufacturing the new product with post-consumer recycled content can decrease the use of fossil fuel, increase the diversion rate of plastic and therefore helps approach the goal of zero waste. Signages that demonstrate the diversion rate of waste can be leveraged to educate the customers in sustainable consumption.

Construction Waste Reuse and Recycling

The Market Format store should consider the necessity of reuse and recycling for the construction waste which is estimated to be 78 tons for a store of 40,000 ft^2.[177] There are different kinds of methods to utilize the construction debris like concrete, asphalt, wood, steel, and brick. Systematic management, efficient jobsite sorting and collection would help face the challenge of a small market and additional upfront cost. The capacity of waste storage and waste pickup rate are constricted because of the limited space.

Package Waste Backhauling and Recycling

During the operation of a Market Format store, this strategy is highly recommended for facilitating the diversion of packaging waste, typically including the LDPE, cardboard, wood, strapping and Styrofoam. Instead of diverting to the landfill or incineration, recycling the packaging waste greatly reduces the environmental impacts caused by plastic waste. Similar to the construction waste, package waste recycling confronts the challenge of a limited market and cost. It also requires an efficient system to manage and transport the waste, ensuring the space for continual sorting and storage. Combination with the strategy of plastic bags and film with post-consumer recycled content should be considered to help solve the economic problems.

1.4 Sustainable Sites:

Cistern

Cistern is a stormwater management strategy for collecting rainwater. It has minimal space requirements; therefore, it's usually installed in urban areas or high-density districts. Cistern can be either on the ground or hidden underground for aesthetic needs. Meijer can apply this strategy in the Market Format, as complementary to other stormwater management strategies, to reduce stormwater runoff and keep rainwater onsite. The rainwater that is stored inside the cistern can be reused in the grey infrastructures, which contribute to the water saving goal.

Rain or Pollinator Garden

In an urban area, a small-scale rain garden can be useful to infiltrate and detain stormwater. The rain garden can be incorporated with the planting strips (planters on sidewalks) or planters on the sidewalks. It can be connected to nearby civil green infrastructure and contribute to the city greenery system. The size of the rainwater garden is flexible and targets the needed region. With careful plant selection, the rain

[177] Freymann, V., Tessicini, J., & Dion, M. (n.d.). Planning for Construction Waste Reduction. Retrieved from: http://www.modular.org/marketing/documents/USGBC_WhitePaper_PlanningConstructionWasteReduction.pdf

garden can be modified to create a pollinator garden or demonstration garden that not only provides food to arthropods but also conveys educational messages of crop productions.

Light Colored Pavement

Light colored pavement is an efficient strategy of mitigating potential urban heat island effect and global warming. The cost of using light color pavement on roofs and paving are relatively low. To whitening the pavement color, Meijer can still use the conventional paving materials with small modifications, such as adding cool color pigments. However, in the Market Format, the application of the light color pavement can be restricted according to area code.

Green Roof

Installing a green roof will allow the increase of greening areas on building surfaces. The green roof can also improve the building envelope, which help to reduce energy usage and increase energy efficiency. The green roof is also a strong visual cue to customers that's attractive and exciting.

Hydroponics

Vertical growing hydroponic systems offer an opportunity to grow produce inside the store, providing an innovative production strategy that is visible to the consumer. Demonstrating the crop production process in the store, hydroponic systems can increase customer awareness of sustainable food issues, while also contributing to the futuristic Store design. Hydroponic systems may also generate water and fertilizer savings compared to traditional agriculture.

1.5 Customer Experience:

Digital Display

Digital display is an innovative and interactive educational component that can fit into urban context. Through digital displays, Meijer can instantly convey its sustainable practices and educate customers to reduce their personal environmental impacts. The content of the display can be changed or updates regularly according to Meijer's need. The maintenance requirement for the digital display is relatively low.

Weekly Promotions

Weekly promotion is another practical strategy for Meijer to increase its sustainable impacts in urban areas. Meijer could add a new page to current promotions and advertisements that either about their sustainable practices or environmental impact reduction education. Since the weekly ads and promotions can reach different customer groups, this strategy can help disseminate Meijer's practices to some targeted customers who pay less attention to sustainability.

2. Supercenter

The Supercenter has greater square footage and a larger site than the Market Format which makes technologies with larger space requirements more feasible. However, it can present challenges as some strategies have to be scaled up to accommodate the larger square footage and store operations. This model may not be as innovative in design as the Market Format as it is larger and has common design features and layout across the fleet.

2.1 Energy

Geothermal

Geothermal is highly recommended due to its potential for Meijer's environmental impact reduction. It has a very positive contribution to carbon emissions as it is much more efficient than conventional heating and cooling systems. Geothermal has also been shown to have good potential in Michigan through a study done for the state capital[178]. The higher efficiency will offset a large amount of emissions associated with the heating and cooling load that is one of the most energy intensive processes as it operates year-round. Since it would offset a large amount of emissions by increasing transparency Meijer can significantly enhance customer understanding of their sustainability practices and principles. This could be done by combining Geothermal with digital display and printed signage strategies.

Smart Appliances

Similar to the recommendations for the Market Format store, smart appliances can help Meijer optimize their operations by increasing automation in their machinery and appliances. They can also be used for preventative maintenance to avoid major issues from machine failure which saves time and money from reparations and downtime. They offer moderate resource use and carbon emissions abatement. This strategy can also moderately influence customer's environmental footprint if they decide to implement variations of it in their own home.

LEDs

This strategy is recommended for the same reasons listed above in the Market Format. LEDs still offer moderate carbon emissions that, due to increased size and load requirements, are greater than the Market Format. This strategy also has potential to be adopted by customers.

Low GWP Alternatives & Case Doors

Case doors combined with low GWP alternatives offer greater reduction in carbon emissions for the Supercenter than the Market Format due to the difference in scale. See the Market Format for the reasons behind recommendation. This strategy operates the same but will need to be scaled up to meet increased cooling load of the Supercenter's refrigeration system.

[178] Michigan State Capitol Commision (2017, Oct.). Capitol Infrastructure Upgrade Report. Accessed http://capitol.michigan.gov/Content/Files/Capitol/MSCC-Report-October-Issue.pdf

Daylighting & Dimming

Similar to the recommendations for the Market Format store, Supercenter stores, daylighting is further well-suited for large Supercenter stores. Dimmable skylights and glass walls can be strategically planned around the store during the design phase to ensure maximum energy savings and customer experience enhancement.

PPAs Shift Away From RECs

PPA is a salient strategy for the same reasons as outlined in the Market Format store section. Furthermore, in Supercenter stores, PPAs could be used to augment on-site power generation to optimize costs while retaining the benefits of renewable energy consumption. Additionally, embracing PPAs would enable Meijer to compete with other large retailers who have moved away from purchasing RECs and are signing PPAs extensively.

Solar PV

On-site solar energy generation would be a very visible strategy on the part of Meijer which would contribute to renewable energy additionality and have a positive impact (green) on Meijer's environmental footprint. On-site generation scores yellow in the space requirement and ease of implementation categories given their moderate space requirements and the need for expert installation and roof support (if required). On-site PV scores a yellow in innovation given that there are several commercial installations across the US. On-site solar energy agrees very well with the 'Store of Tomorrow' theme and adds positively to the aesthetic appeal (green). It is also a good source for customer education especially when coupled with a performance dashboard where customers can understand the contribution of solar energy and the associated emission abatement. Overall on-site solar would clearly establish Meijer's commitment to the environment, help engage and educate customers and equip Meijer to be a competitive retailer.

2.2 Water & Plumbing

Dual Flush Toilets

We recommend dual flush toilets for both the market and Supercenter store formats. When operated correctly, dual flush toilets reduce water consumption by offering a low flow flush option for liquid waste. Dual flush toilets have been widely implemented in bathrooms that experience many flushes per day, and do not pose any threats to plumbing infrastructure when integrated into a well-maintained plumbing system. Dual flush toilets would replace conventional toilets in guest restrooms and do not require additional modifications.

Low Flow Fixtures

Low flow fixtures, such as urinals, showerheads, and faucets can reduce water flow by 20% to 30%.[179] This can generate positive sustainability impacts and financial savings by improving efficiency. Meijer has already incorporated low flow faucet fixtures in some locations. We recommend that Meijer continue this trend and expand this practice

[179] Tolson, M. (2011). ROI-Driven Products: Low-Flow Fixtures. In *Buildipedia*. Retrieved from http://buildipedia.com/aec-pros/construction-materials-and-methods/roi-driven-products-low-flow-fixtures

to all retail locations to maximize savings. This strategy is suitable for both market and Supercenter locations.

Smart Irrigation

Smart irrigation should be integrated into landscaping elements and garden center watering where feasible. This strategy optimizes watering schedules using cloud based or data sensor technology and offers significant environmental impact reduction. This strategy is well suited for the Supercenter store format where Meijer has more control over the owned site, and where there is likely to be more greenery that needs to be watered both in landscaping elements or in a retail garden center.

2.3 Materials and Resources

Container Composting – In-Vessel System

We recommend Meijer consider container composting at the Supercenter location to process food waste onsite. This is feasible given size and space requirements, offers educational benefit and provides an opportunity to reduce Meijer's environmental impact. Depending on the capacity of the system, Meijer could consider accepting and processing food waste from the vendors (coffee shops, etc.) in the front of the store to efficiently utilize the technology to capacity. Meijer could integrate compost produced onsite into landscaping, the garden center, or donate to local community gardens.

Reusable Bags and Phasing Out Single-Use Plastic

This strategy is applicable to the Supercenter because it can help reduce Meijer's environmental footprint and at the same time, improve customers' social responsibility and sustainability knowledge. Space availability enables the store to provide all kinds of reusable bags with larger and different sizes and various patterns to meet the needs of purchase compared with the Market Format.

Plastic Bags and Film With Post-Consumer Recycled Content

Plastic bags and film with post-consumer recycled content are proposed in the supermarket based on the same reasons listed in the Market Format section. As the scale of consumption increases, the positive impacts of reduction in normal plastic bags and film accumulate faster than in the Market Format store over time.

Construction Waste Reuse and Recycling

Construction waste reuse and recycling should be implemented for the Supercenter store model. Assuming it's 158,000 ft^2 large, up to 308 tons of waste would be generated and sent to the landfill without second use and recycling. Limited market and extra cost are still problems, but the requirement of frequent pickup can be relaxed relatively thanks to the enough space for waste management.

Packaging Waste Backhauling and Recycling

The Supercenter is able to provide a larger space for the scaled-up packaging waste backhauling and recycling. Because of the same reasons explained in the Market Format section, this strategy is recommended for dealing with the package waste. Signs and

windows to show the process of waste sorting and collection backstage can make the recycling more visible and informative to the customers.

2.4 Sustainable Sites

Bioswale

Bioswale is a commonly used stormwater management strategy that slows runoff to increase infiltrate and slow down the runoff. It's an efficient practice, especially in suburban or rural areas with large empty spaces. Meijer can install bioswales in the isolation strip of store parking lots. On one hand, the parking lot can be graded to direct excessive stormwater runoff to the bioswale. On the other hand, a carefully designed bioswale can serve as an attractive landscape component that improves the Meijer storescape.

Rain Garden + Pollinator Garden (Bioretention Garden)

Rain gardens can be incorporated into the landscape design in the Supercenter. Rain Gardens help detain stormwater runoff, while infiltrating the runoff to remove soil particles and pollutants, especially from the first flushes of rainwater. With careful selection of plants, such as Black-eyed Susan, the rain garden can also serve as a pollinator garden that provides food to arthropods and birds.

Permeable Pavement

Permeable pavement allows stormwater to infiltrate into the ground, instead of over flowing to enter the sewage system. In the Supercenter, the permeable pavement can be installed in the parking lots to reduce stormwater runoff and reduce risk of flooding. Permeable pavement can be reduced to a manageable size with careful grading and a sloping design. It can also be placed next to a detention pond to help with stormwater infiltration before entering the pond.

Detention Pond

In store sites that experience significant amounts of stormwater runoff, a series of detention ponds can help Meijer to collect the rainwater and avoid overcharging. Detention ponds can combine with parking lot as an extra landscape component or located in the low point that is isolated from the store and parking lot. The size of the detention pond should be calculated according to the size of the site and the amount of estimated rainwater. Meanwhile, a detention pond can be divided into a series of smaller detention ponds that are connected onsite to maximize the space use efficiency. Educational and interactive elements, such as printed signage can be added to the detention ponds to turn it into a multifunctional space. Increasing the plantings in the pond can also reduce the problems, such as open water and steep slope, and make it more attractive to customers and nearby communities.

Wind Break

In harsh winter conditions, the green roof and green wall may not work as well as the wind breaks in mitigating the winds and improving the performance of the building

envelopes. By installing a necessary wind break, the winter winds and summer heat flows can be reduced to generate energy saving for heating and cooling.

Green Wall

In the Supercenter, Meijer could consider increasing green surfaces by adding green walls on the building, as a substitute to a green roof. A green facade would be most effective in the Supercenter stores. Like green roofs, green walls can improve the performance of building envelope, while still providing strong visual cues to customers. The installation and maintenance of the green facade is also manageable because the structure of the plants are visible and flexible.

Light colored pavement

Light colored pavement is an efficient strategy of mitigating potential Urban Heat Island effect and global warming. The cost of using light color pavement on roofs and paving are relatively low. To whitening the pavement color, Meijer can still use the conventional paving materials with small modifications, such as adding cool colored pigments.

Freight Farm

The Freight Farm, pictured in Figures 10 and 11, is a closed container system that would allow Meijer to produce products like butter head lettuce, spinach, and herbs, year-round, in a climate-controlled greenhouse container. Freight Farms rely on grow lights and cloud-based smart hydroponic systems to grow produce in shipping containers. We recommend Meijer integrate a Freight Farm or similar hydroponic container growing system in the Supercenter and highlight it with video feeds or signage to maximize education benefits. This technology presents an innovative opportunity to educate customers on concepts like food miles traveled, local sourcing, and non-traditional growing methods that can be used to supplement conventional agriculture on a smaller scale.

2.5 Customer Experience

Printed Signage

Printed signage is a traditional method of conveying educational components . In the Supercenter, printed signage can be placed outdoors, next to any of Meijer's sustainable practices. The printed signage should be concise and comprehensive, which would be suitable for reaching customers with relatively low educational background, such as pupils. The printed nature of the educational material also eliminates justice issues and would be available for all customers who visit the stores.

Weekly Promotions

Weekly promotion is another practical strategy for Meijer to increase its sustainable impacts in urban areas. Meijer could incorporate a new page to current promotions and advertisements about their sustainable practices or environmental impact reduction education. Since the weekly ads and promotions can reach different customer groups, this strategy can help disseminate Meijer's practices to some targeted customers who pay less attention to sustainability.

Product Displays

Product displays are another form of electronic display that captures detailed products. It can be placed next to organic products, such as organic berries, to show the supply chain and growing information that involve sustainable practices. The display would allow Meijer to highlight its efforts to increase product sustainability and provide interactive education to customers.

EV Charging

On-site EV charging infrastructure would allow Meijer to contribute to the downstream emissions of its customers (Scope 3 emissions). Providing on-site charging would help Meijer retain its environmentally conscious customers and also engage potential customers who value their environmental performance. Further, Meijer can avail of state and utility programs – such as Consumers Energy's PowerMIDrive – which provide tax benefits and rebates. Meijer can also indirectly influence the purchase of EVs as the shortage of public charging infrastructure is a major barrier to increased EV adoption.

On-site charging infrastructure can be easily incorporated in Supercenter stores which tend to have large parking lots, thereby scoring green in the space requirement and ease of implementation categories. EV charging infrastructure also scores green in innovation, education and customer experience. EV charging infrastructure would have minimal influence on Meijer's Scope 2 emissions but installing them would showcase Meijer's commitment to the environment and the community around its stores.

Solar Canopy Carports

The solar carport could be designed as solar trees in the parking lot as top layers that not only generate electricity from sunlight, but also provide shade for cars. This unique carport allows customers to increase the transparency of Meijer's sustainable practices and would provide strong visual cues of a futuristic store. The energy generated from the solar trees could potentially be used in the EV charging.

3 Additional Recommendations

In addition to adopting these technologies, we suggest the following:

- Emphasize educational components throughout both the Market Format and Supercenter sites to advance customer awareness and understanding of sustainability practices. This will contribute to larger scale change by encouraging customers to adopt green practices and technologies themselves and may make customers more receptive to innovative changes in the long term.
- Continue to cultivate sustainability values throughout the company. Further integration of sustainability into company culture will build support for innovation and help secure Meijer's position as a sustainability leader. Support from leadership is critical for advancing sustainability and pursuing the most efficient technologies. Events like employee symposiums, educational training sessions, all staff meetings and webinars offer potential opportunities to deepen sustainability understanding at all levels.

Conclusion

This study provides Meijer a range of strategies to contribute to achieving its sustainability goals and commitment to responsible growth. Through the technology review, our team created a portfolio of store design technologies categorized into Energy, Water, Waste, Sustainable Site and Customer Experience that can be used for retrofits and to draw from to create the *Store of Tomorrow*. Our recommendations comprise of a combination of strategies in wide use in the industry as well as innovative strategies that would enhance Meijer's outlook as a sustainability leader. This project provides a comprehensive coverage of strategies that Meijer can choose from, to support their sustainability goals.

Sustainable practices have been integrated and improved upon in multiple areas of the industry through increases in efficiency, management, system design, ecological benefits and transparency. By drawing from the technology review and the store prototype scored in this paper, Meijer can apply the strategies when developing new stores. Additionally, certain strategies can be applied as retrofits to their fleet furthering their commitment to responsible growth. In addition, Meijer's carbon footprint will decrease as Meijer becomes more sustainable.

By accomplishing these goals, Meijer continues to support the foundation laid down by Fred Meijer, and to demonstrate their commitment to their customers and the environment. This is emulated in a quote of Fred Meijer's, "I want to leave the world in a little better shape than when I entered it". Sustainability is an important concept for the present and the future as it offers more adaptable and renewable solutions to current practices and environmental problems. Through these opportunities Meijer can help influence others to adopt similar practices helping to improve the industry as a whole for future generations of customers and employees. In addition to Meijer's personal carbon emission abatement, these strategies if implemented carefully, would have substantial benefits for the community around Meijer's stores primarily through bettering the local environment, advancing food security and enhancing customer experience while shopping at Meijer.

We recognize that there are limitations to this study given the project time-frame. It is recommended that future studies focusing on more aspects be done to supplement this report. First, life cycle analysis could be performed for recommended strategies to further determine their carbon footprints and environmental impacts. In doing so, Meijer can fully evaluate the benefits of the strategy before implementation. Second, a financial analysis, potentially with carbon tax implications, could be done to determine the costs and benefits from a strictly monetary view and business perspective. This report focused primarily on the environmental performance of the strategies. Future studies should also consider Scope 3 components such as transportation, siting to ensure equitable access, supply chain, or stock and sourcing components. Lastly, there could be an analysis of future technologies as they become more viable through improvements in research and development or the emergence of new markets.

Illustrative Graphic for Supercenter (Outdoor)

Sustainable Sites

--Plant coverages are increased on sites to increase biodiversity and improve building envelope.

--Multiple stormwater management strategies are combined to infiltrate, detain and retain runoff.

Customer Experience

--Educational Component is incorporated with the onsite green infrastructure.

--The EV charger and solar carport help visualize the production and utilization of clean energy.

Illustrative Graphic for Supercenter (Indoor)

Energy

--Daylighting will allow potential electricity savings.

Sustainable Sites

--Freight farms demonstrate futuristic farming practices.

Customer Experience

--Product displays are digital signage with interactive components.

--Quarterly Boards provide strong visual cues for sustainability eduction.

Material and Resources

--Reusable display containers are used to reduce environmental impacts of packaging.

--Reusable bags encourage customers to reduce the use of plastics bags.

Illustrative Graphic for Market Format(Outdoor)

Sustainable Sites

--Plant coverages on sites are increased to enhance biodiversity and improve building envelope, such as green roof and green wall.

--Incorporated Rain Garden to the planting strips to treat runoff.

--Pollinator Gardens are installed to increase biodiversity.

Customer Experience

--The EV chargers are installed to encourage the use of clean energy.

Illustrative Graphic for Market Format (Indoor)

Energy

--Daylighting will allow potential electricity savings.

Customer Experience

--Digital display as vivid educational signage

Sustainable Sites

--Hydroponics provide living products to shoppers.

Material and Resources

--Onsite pick-up composting encourages composting behaviors of customers.

--Recycling Campaigns may increase customer's awareness on recycling and reusing.

Appendix

Appendix A Scoring Sheet Overview

Supercenter

System	Strategy	Criteria							
		Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirement	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Energy	On Site Renewable: Solar PV								
	PPA								
	RECs								
	Smart Appliances*								
	CHP								
	Geothermal								
	Building Envelope Improvement								
	HVAC (increased efficiency)								
	Daylighting*								
	Solar Streetlights								
	LED Motion sensor light*								
	Case Refrigeration								
	Low GWP refrigerants (alternatives)								
Water & Plumbing	All-in-one toilet								
	Low flow fixtures								
	Dual Flush Toilets								
	Smart Irrigation								
Materials & Resources	Composting In Vessel Onsite								
	Composting Onsite								
	Composting with Pick Up Service								
	Anaerobic Digestion								
	Animal Feed								
	Reusable bags								
	Plastic bags and film with post-consumer recycled content								
	Reusable transport and display containers								
	Bulk food bins								
	Environmental footprint tracking								
	Digital receipt								
	Package waste backhauling and recycling								
	Community or commercial recycling program								
	Construction waste reuse and recycling								
Sustainable Sites	Onsite agriculture- Vertical Growing Hydroponics								
	Onsite agriculture- Demonstration Garden								
	Onsite agriculture- Freight Farm								
	Stormwater mgmt- Cistern								
	Stormwater mgmt- Bioswale								
	Stormwater mgmt- Rain Garden								
	Stormwater mgmt- Underground Detention								
	Stormwater mgmt- Detention Pond								
	Stormwater mgmt- Retention Pond								
	Stormwater mgmt- Permeable Paving								
	Ecological benefit- Native Plants								
	Ecological benefit- Wind Break								
	Ecological benefit- Pollinator Garden								
	Ecological benefit- Green Roof								
	Light color pavement								
Customer Experience	Display- Printed Sinage								
	Display- Quarterly Boards								
	Display- Digital Display								
	Display- Product Displays								
	Customer Awareness- Weekly Promotion/Ads								
	Customer Awareness- EV charging								
	Customer Awareness- Solar Canopy Carports								

Market Format

System	Strategy	Feasibility		Education & Engagement				Environmental Footprint	
		Size and Space requirement	Ease of Implementation	Aesthetic Appeal	Innovation	Experience	Education	Meijer Environmental Impact Reduction	Downstream Environmental Impact Reduction (Customers)
Energy	On Site Renewable: Solar PV								
	PPAs and VPPAs								
	RECs								
	Smart Appliances								
	CHP								
	Geothermal								
	Building Envelope Improvement								
	HVAC (increased efficiency)								
	Daylighting								
	Solar Streetlights								
	LED Motion sensor light								
	Case Refrigeration								
	Low GWP refrigerants (alternatives)								
Water & Plumbing	All-in-one toilet								
	Low flow fixtures								
	Dual Flush Toilets								
	Smart Irrigation								
Materials & Resources	Composting In Vessel Onsite								
	Composting Onsite								
	Composting with Pick Up Service								
	Anaerobic Digestion								
	Animal Feed								
	Reusable bags								
	Plastic bags and film with post-consumer recycled content								
	Reusable plastic containers								
	Bulk food bins								
	Environmental footprint tracking								
	Digital receipt								
	Package waste backhauled and recycled								
	Community or commercial recycling program								
	Construction waste reused and recycled								
Sustainable Sites	Onsite agriculture- Demonstration Garden								
	Onsite agriculture- Freight Farm								
	Onsite agriculture- Vertical Growing Hydroponics								
	Stormwater mgmt- Cistern								
	Stormwater mgmt- Bioswale								
	Stormwater mgmt- Rain Garden								
	Stormwater mgmt- Underground Detention								
	Stormwater mgmt- Detention Pond								
	Stormwater mgmt- Retention Pond								
	Stormwater mgmt- Permeable Paving								
	Ecological benefit- Native Plants								
	Ecological benefit- Wind Break								
	Ecological benefit- Pollinator Garden								
	Ecological benefit- Green Roof								
	Light color pavement								
Customer Experience	Display- Printed Sinage								
	Display- Quarterly Boards								
	Display- Digital Display								
	Display- Product Displays								
	Customer Awareness- Weekly Promotion/Ads								
	Customer Awareness- EV charging								
	Customer Awareness- Solar Canopy Carports								

Appendix B Benchmark energy and emission savings of the prototype *Store of Tomorrow* model

Table 1 Emissions saved through the Store of the Future

System	Emissions saved (MT CO_2e)
HVAC	
EER 17	64.8
EER 13.6	30.5
EER 11.6	2.78
Lighting	
LED Retrofit	211
Refrigeration	
R-448A	227
Geothermal	
Heating	321
Cooling	131
Snowmelt	101
Total (with EER 17)	**1055.8**

HVAC

Summary: Energy and emissions savings associated with improvements in efficiency (EER) of the HVAC system for the Store of Tomorrow from the baseline. Energy and

emissions values were calculated for three scenarios and compared to the baseline usage using the PNNL RTU calculator.

Scenario	**Emissions saved (MT CO_2e)**
EER 17 (maximum)	64.8
EER 13.6	30.5
EER 11.6	2.78

Table 2 Comparison between scenarios of EER ratings and associated emissions savings

Calculations

Energy used per RTU and MAU (kWh) x conversion factor (1,272 lb. CO_2e/MWh) x conversion factor (MWh/1,000 kWh) = emissions per RTU and MAU (lb. CO_2e)

Emissions per RTU and MAU (lb. CO_2e) x conversion factor (2,204 MT CO2e/lb. CO_2e) = emissions per RTU and MAU (MT CO_2e)

Conversion Factors	**Units**	**Description**
1272.334447	lb. CO_2e/MWh	CO_2e adjusted per grid mix of electricity provided by Christina Britton
2204.62	lbs. CO_2e/MT CO_2e	Conversion Factor from google

Table 3 Conversion factors used in HVAC calculations

Lighting

Summary: Energy and associated emissions for the Store of Tomorrow savings averaged from yearly data of a LED retrofit store.

Calculations

Baseline energy usage (kWh) – post retrofit energy usage (kWh) = savings in energy usage (kWh)

(Savings in energy usage/baseline energy usage) x 100 = percent reduction of energy usage (%)

Savings in energy usage (kWh) x Conversion factor (MWh/1,000 kWh) x conversion factor (1,272 lb. CO_2e/MWh) x conversion factor (2,204 MT CO2e/lb. CO_2e) = emissions saved through LED retrofit (MT CO_2e)

Refrigeration

Summary: Emissions saved with the Store of Tomorrow by transitioning from R-404A to R-448A (an alternative refrigerant with a lower GWP).

Calculations

Current refrigerant charge level R-404A (2300 lbs./yr.) x leak rate (0.086%) = R-404A leaked refrigerant (lbs./yr.)

Leaked refrigerant (lbs./yr.) x refrigerant GWP (3,920 lbs. CO_2e/lbs. refrigerant) x conversion factor (2,204 MT CO2e/lb. CO_2e) = refrigerant R-404A emissions per store (MT CO_2e)

Repeat these two calculations for R-448A using a different GWP (1,390 lbs. CO_2e/lbs. refrigerant).

Refrigerant R-404A emissions per store (MT CO_2e) - Refrigerant R-448A emissions per store (MT CO_2e) = Refrigerant emissions saved per store (MT CO_2e)

[Refrigerant emissions saved per store (MT CO_2e)/ Refrigerant R-404A emissions per store (MT CO_2e)] x 100 = percent reduction of refrigerant emissions per store (%)

Geothermal

Summary: Energy and emissions for the Store of Tomorrow using a Geothermal Heat Pump to offset the prototype's heating & cooling load.

Calculations

Heating

Average non-heating NG usage (Therms/month) x conversion factor (12 months/yr.) = non-heating NG usage (Therms/yr.)

Average non-heating and heating usage (Therms/month) x conversion factor (12 months/yr.) = Total NG usage (Therms/yr.)

Total NG usage (Therms/yr.) - non-heating NG usage (Therms/yr.) = Heating load (Therms/yr.)

*Average non-heating NG usage was during the summer months (June-September) and Total NG usage was during the winter months (October-May)

Cooling

Average non-cooling electricity usage (kWh/month) x conversion factor (12 months/yr.) = non-cooling electricity usage (kWh/yr.)

Average non-cooling and cooling electricity usage (kWh/month) x conversion factor (12 months/yr.) = Total non-cooling and cooling electricity usage (kWh/yr.)

Total non-cooling and cooling electricity usage (kWh/yr.) - non-cooling electricity usage (kWh/yr.) = Cooling load (kWh/yr.)

**Average non-cooling electricity usage was during the winter months (October-May) and Total non-cooling and cooling electricity usage (kWh/yr.) was during the summer months (June-September)

Normalize to MMBtus

Heating load (Therms/yr.) x conversion factor (0.099976 MMBtus/Therms) = Heating load (MMBtus/yr.)

Cooling load (kWh/yr.) x conversion factor (0.003412 MMBtus/kWh) = Cooling load (MMBtus/yr.)

Emissions

Heating load (MMBtus/yr.) x conversion factor 1E6 (Btu/MMBtu) x conversion factor (0.0003 kWh/Btu) x conversion factor (0.001 MWh/kWh) x conversion factor (1,272 lb. CO_2e/MWh) x conversion factor (MT CO_2e/2,204 lb. CO_2e)

= Avg Emissions saved from diverting Heating and Cooling loads using Geothermal for stores opened in 2017 (MT CO_2e)

Snowmelt Applications

Total area to apply snowmelt (SQFT) x heat needed to melt snow (100 Btus/SQFT*hr.) x snowfall (3,449 hrs/yr.) x conversion factor (MMBtu/1E6 Btus) = Heat needed to provide snowmelt (MMBtus/yr.)

Heat needed to provide snowmelt (MMBtus/yr.) x conversion factor 1E6 (Btu/MMBtu) x conversion factor (0.0003 kWh/Btu) x conversion factor (0.001 MWh/kWh) x conversion factor (1,272 lb. CO_2e/MWh) x conversion factor (MT CO_2e/2,204 lb. CO_2e)

= Avg Emissions saved from diverting snowmelt loads using Geothermal MT CO_2e)

Appendix C. Carbon Sequestration and Water Interception of Selective Plants[180]

Table 1.2: Total Street Tree Atmospheric Carbon Reduction Per Year - All

Species	Average DBH (inches)	Land Use	Atmospheric Carbon Reduction Per Year (lbs)	# of Trees	Calculation	Total Atmospheric Carbon Reduction by Species Per Year (lbs)
Chinquapin Oak ***Quercus muehlenbergii***	1.40	Industrial or Large Commercial Business	7	10	7 x 10 =	70
Valley Forge Elm ***Ulmus Americana*** **'Valley Forge'**	4.93	Industrial or Large Commercial Business	92	30	92 x 30 =	2,760
Honey Locust ***Gleditsia triacanthos***	10.31	Industrial or Large Commercial Business	535	32	535 x 32 =	17,120
American Sycamore ***Platanus occidentalis***	3.58	Industrial or Large Commercial Business	87	2	87 x 2 =	174
Norway Maple ***Acer platanoides***	14.64	Industrial or Large Commercial Business	754	1	754 x 1 =	754
Kentucky coffeetree ***Gymnocladus dioicus***	15.6	Industrial or Large Commercial Business	863	1	863 x 1 =	863
Swamp White Oak ***Quercus bicolor***	0.84	Industrial or Large Commercial Business	7	4	7 x 4 =	28
American Linden ***Tilia americana***	17.19	Industrial or Large Commercial Business	966	1	966 x 1 =	966
Red Maple ***Acer rubrum***	11.14	Industrial or Large Commercial Business	547	1	547 x 1 =	547
Live oak ***Quercus virginiana***	3.82	Industrial or Large Commercial Business	96	1	96 x 1 =	96
						Total Atmospheric Carbon Reduction On Site Per Year (lbs): 23,378

Table 1.5: Street Tree Stormwater Runoff Interception Per Year - Total

Species	Average DBH (inches)	Land Use	Stormwater Runoff Interception Per Year (gal)	# of Trees	Calculation	Total Stormwater Runoff Interception by Species Per Year (gal)
Chinquapin Oak ***Quercus muehlenbergii***	1.40	Industrial or Large Commercial Business	17	10	17 x 10 =	170
Valley Forge Elm ***Ulmus Americana*** **'Valley Forge'**	4.93	Industrial or Large Commercial Business	130	30	130 x 30 =	3,900
Honey Locust ***Gleditsia triacanthos***	10.31	Industrial or Large Commercial Business	829	32	829 x 32 =	26,528
American Sycamore ***Platanus occidentalis***	3.58	Industrial or Large Commercial Business	124	2	124 x 2 =	248
Norway Maple ***Acer platanoides***	14.64	Industrial or Large Commercial Business	1,354	1	1,354 x 1 =	1,354
Kentucky coffeetree ***Gymnocladus dioicus***	15.6	Industrial or Large Commercial Business	1,578	1	1,578 x 1 =	1,578
Swamp White Oak ***Quercus bicolor***	0.84	Industrial or Large Commercial Business	7	4	7 x 4 =	28
American Linden ***Tilia americana***	17.19	Industrial or Large Commercial Business	1,665	1	1,665 x 1 =	1,665
Red Maple ***Acer rubrum***	11.14	Industrial or Large Commercial Business	968	1	968 x 1 =	968
Live oak ***Quercus virginiana***	3.82	Industrial or Large Commercial Business	137	1	137 x 1 =	137
						Total Stormwater Runoff Interception On Site Per Year (gal): 36,576

[180] De Almeida, Catherine, Hannah LoPresto, and Brandon Zambrano. "P Street Corridor, Phase 1 Methods." Landscape Performance Series. Landscape Architecture Foundation, 2018. https://doi.org/10.31353/cs1341

Appendix D. Plants List for Stormwater Management[181]

Scientific Name	Common Name
Warning -Typos happened in conversion of Shaw & S	
Acer rubrum	Red maple
Acer saccharinum*	Silver maple
Acer saccharum	Sugar maple
AChillea millefoNum	Common yarrow
Acarus calamus'	Sweet flag
Agastache foeniculum'	Giant hyssop
Alisma trivale*	Water plantain
Allium stellatum*	Prairie wild onion
Alnus incana'	Speckled alder
Amelanchier laevis	Allegheny serviceberry
Amorpha fruiticosa'	Indigo bush
Andropogen gerardi!,	Big bluestem
Anemone canadensis'	Canada anemone
Angelica atropurpurea'	Angelica
Antennaria negtecta	field pussytoes
Aquilegia canadensis	Red columbine
Arisaema triphvllum*	Jack -in-the-pulpit
Aronia metanocarpa*	Black chokeberry
Artemisia tudoviciana*	Prairie sage
Asarum canadense	Canadian wildginger
Asclepias incarnata	Marsh milkweed
Asclepias tuberose	Butterfly milkweed M-
Aster laevis	Smooth aster
Aster lanceotatus (simplex)	Paricle aster
Aster lucidulus	Swamp aster
Aster macrophyllus*	Bigleaf aster
Aster novae-angliae	New England aster
Aster aolentanglensls var. oatentanglensis	Skyblue aster
Aster pifosus	Frost aster
Aster ptarmicoides	Prairie goldenrod
Aster puniceus	Red-stemmed aster
Aster umbellatus var. umbellatus	Parasol flat-top white aster
Athyrium filix-femina*	Lady fern
Betula nigra*	River birch
Bidens carrlua*	Beggarsticks
Boltonia asteroides*	Boltonia
Bouteloua curtipendula	Sideoats grama
Bromus ciliatus*	Fringed brome
Calamagrostis	Canada blue-joint grass
Caltha paultris*	Marsh marigold
Carex aqllatilis*	Water sedge
Carex atherades	Slough sedge

[181] Daniel Shaw and Rusty Schmidt (July 2003). Plants for Stormwater Design: Species Selection for the Upper Midwest. Minnesota Pollution Control Agency. p30-35.

Scientific Name	Common Name
Carex bebbil*	Bebb's sedge
Carex comosa*	Bottlebrush sedge
Carex crinita*	Caterpillar sedge
Carex emoryi	Emory's sedge
Carex hystericina"'	Porcupine sedge
Carex interior	Inland sedge
Carex lacustris*	Lake sedge
Carex languinosa*	Wooley sedge
Carex lasiocarpa*	Wooley needle sedge
Carex retrorsa*	Retrorse sedge
Carex scoparia .	Broom sedge
Carex sprengelii	Sprengel's sedge
Carex stipata"	Awl-fruited sedge
Carex stricta	Tussock sedge
Carex tenera	Quill sedge
Carex vulpinoidea*	Fox sedge
Celtis occidentalls	Hackberry
Cephalanthus occidentatis*	Buttonbush
Chelone glabra*	Turtlehead
Coreopsis palmate	Wedgeleaf coreopsis
Comus altemifolia	Alternate-leaf dogwood
Comus amomum*	Silky dogwood
Cornus racemose*	Gray dogwood
Comus sericea*	Red-osier dogwood
Corylus Americana	American hazelnut
Crataegus punctata	Dotted hawthorn
Desmodium canadense	Showy tick-trefoil
Diervilla lonicera	Northern bush honeysuckle
Eleocharis obtusa*	Blunt spikerush
Eleocharis palustris	Creeping spikerush
Elymus canadensis	Canada wild rye
Elymus virginicus*	Virginia wild rye
Epilobium allgustifolium*	Fireweed
Equisetum fluviaiile*	Horestail
Eryngium yuccifofium*	Rattlesnake master
Eupaiorium maculatum*	Joe Pyeweed
Eupatorium perfofiatum"	Boneset
Euthamia graminifolia	Grass-leaved goldenrod
Fragaria virginiana	Wi Id strawberry
Fraxinus nigra	Black ash
Fraxinlls pennslyvanica*	Green ash
Ga!ium boreale*	Northern bedstraw
Gentiana andrewsir	Bottle gentian
Geranium maculatum	Spotted geranium
Geum triflarum	Prairie smoke
Glyceria grandislt	Giant manna grass
Glyceria striata*	Fowl manna grass

Scientific Name	Common Name
Helenium autumnale	Sneezeweed
Helianthus grosserratus*	Sawtooth sunflower
Helianthus maximiliani	Maximilian sunflower
Heliopsis helianthoides	Oxeye
Hepatica acutiloba	Sharplobe hepatica
Heuchera richardsonir	Prairie alumroot
Hydrophyflum virginianum var. Virginianum	Virginia waterleaf
Ilex verticulata*	Winterberry
Impatiens capensis	Jewelweed
Iris versicolor	Blueflag iris
Juncus balticus*	Baltic rush
Juncus effusus*	Soft rush
Juncus tenuis	Path rush
Juncus torreyi*	Torrey rush
Juniperus communis	Common juniper
Larix laricina*	Tamarack
Leersia oryzoides*	Rice-cut grass
Liatris aspera	Rough blazingstar
Liatris ligulistylis	Meadow blazingstar
liatris pyncostachya*	Prairie b!azingstar
Lilium superbum*	Turk's-cap lily
Lobelia cardinalis*	Cardinal flower
Lobelia siphifitica*	Blue lobelia
Matteuccia struthiopteris*	Ostrich fern
Mertensia virginica	Virginia bluebells
Mjmulus ringens	Allegheny monkeyflower
Monarda fistulosa*	Wild bergamot
Onoclea sensibiiis*	Sensitive fern
Osmund a cinnamomea	Cinnamon fern
Osmund a claytonian8	Interrupted fern
Osmund a regaJis	Royal fern
Panicum virgaturn*	Switchgrass
Phalaris anmdinacea″	Rean canary grass
Phlox pilosa	Prairie phlox
Physocarpus opufifofius	Ninebark
Physostegia virginjana	Obedient plant
Poa palustris	Fowl bluegrass
Polygonum amphlbium*	Water smartweed
Pontederia cordata	Pickerelweed
Populus deltoifies	Eastern cottonwood
Populus tremuloides	Quaking aspen
Patentilla fruticosa	Shrubby cinquefoil
Patentilla palustris	Marsh cinquefoil
Prunus sera tina	Black cherry
Prunus virginiana	Chokecherry
Pteridium aquilinum*	Bracken fern

Scientific Name	Common Name
Pycanthemum virgjnianum~'	Mountain mint
Quercus alba	White oak
Quercus bicolor	Swamp white oak
Quercus macrocarpa	Bur oak
Quercus rubra	Northern red oak
Ratibida pinnata*	Yel low coneflower
Rudbeckia hirta	Blackeyed susan
Rudbeckia laciniata	Green-head coneflower
Rudbeckia subtomentosa*	Brown-eyed-Susan
Sagittaria latifoiia*	Broadleaved arrowhead
Salix bebbiana	Bebb's willow
Salix discolor*	Pussy willow
Salix exigua*	Sandbar willow
Salix fucida	Shining willow
Salix nigra	Black willow
Sambucus canadensis var canadensis	American elderberry
Sambucus racemosa*	Red-berried elder
Sanguinaria Canadensis	Bloodroot
Schizachyrium scoparium'"	Little bluestern
Scirpus acutus*	Hardstem bulrush
Scirpus atrovirensl	Green bulrush
Scirpus cyperinus*	Woolgrass
Scirpus fluviatilis*	River bulrush
Scirpus pungens*	Tree-square bulrush
Scirpus validus"	Soft-stem bulrush
Scuteilaria lateri"ora*	Mad-dog sKullcap
Sifphium laciniatrJm*	Compass plant
SiJphium perfofiawm*	Cup plant
Smilacina racemosa*	False Solomon Seal
Solidago f!exicauiis*	Zig-zag goldenrod
Soiidago gigantea	Giant goldenrod
Solidago riddellii*	Riddell's goldenrod
Solidago rigida*	Stiff goldenrod
Solidago speciosa	Showy goldenrod
Sorghastrum nutans*	Indian grass
Spargan;um eurycarpum*	Giant burreed
Spartina pectinata	Prairie cord grass
Spirae alba	Meadowsweet
Sporobolus heterolepis	Prairie dropseed
Symphoricarpos albus	Snowberry
Symplocarpus foetidus*	Skunk cabbage
Thalictrum dasycarpum	Tall meadowrue
Thalfetrum thalictroides	Rue anemone
Thelypteris palustris	Marsh fern
Thuia accidentalis	Northern white cedar

Scientific Name	Common Name
Tj{fa americana	American basswood
Tradesc3ntia ohiensfs •	Ohio spiderwort
Typha latitolia	Broad-leaved cattail
Typha x gJauca*	Hybrid cattail
Ulmus americana	American elm
Vaccinium angustifolium	Lowbush blueberry
Verbena hastata	Blue vervain
Veronia fasiculata*	Ironweed
Veronicastrum virginicum	Culver's root
Viburnum tentago	Nannyberry
Viburnum rafin8squianum*	Downy arrowwood
Viburnum trilobum	High bush cranberry
Viola sororia	Common blue violet
Zizla aurea	Golden alexanders