ELSEVIER

THOMAS ABDALLAH

SUSTAINABLE MASS TRANSIT

CHALLENGES AND OPPORTUNITIES IN URBAN PUBLIC TRANSPORTATION

Sustainable Mass Transit

Sustainable Mass Transit

Challenges and Opportunities in Urban Public Transportation

Thomas Abdallah
Deputy Vice President and Chief Environmental Engineer,
MTA New York City Transit, and
Adjunct Professor,
Columbia University's Sustainability Management Graduate Program,
New York City, NY, United States

ELSEVIER

Elsevier
Radarweg 29, PO Box 211, 1000 AE Amsterdam, Netherlands
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States

Copyright © 2017 Elsevier Inc. All rights reserved.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices
Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

ISBN: 978-0-12-811299-1

For Information on all Elsevier publications
visit our website at https://www.elsevier.com/books-and-journals

ELSEVIER
Book Aid International
Working together to grow libraries in developing countries
www.elsevier.com • www.bookaid.org

Publisher: Jonathan Simpson
Acquisition Editor: Brian Romer
Editorial Project Manager: Andrae Akeh
Senior Production Project Manager: Priya Kumaraguruparan
Cover Designer: Matthew Limbert

Typeset by MPS Limited, Chennai, India

Dedication

I would like to dedicate this book to the thousands and thousands of people who I have been fortunate to be associated with throughout my entire professional career. It would be impossible to mention or even attempt to list all the important people that I have been associated with in my career, but I would like to thank all the men and women at MTA New York City Transit, and the entire MTA family who I have worked with these past 30 years.

The MTA has been very good to me and my family, and I must express my appreciation to everyone I have been associated with, including all my bosses, coworkers, consultants, contractors, and especially the people who work for me in the Environmental Engineering Division. I cherish each one of you who have dedicated yourselves to our mission to work hard, help protect the environment, and incorporate sustainable initiatives into our projects. I have enjoyed working with every person in our environmental family.

A special thank you to Joe Raskin, Steve Eget, and Kate Aglitsky for providing the fantastic photos of transit infrastructure and vehicles contained in the book. I would also like to thank my colleagues and all my students at Columbia University's Sustainability Management graduate program. It has been an honor and a privilege to work at such a prestigious institution, and help nurture the future sustainability champions of the world to help save the planet.

A very special thank you must go to my wife Ginger Abdallah, who has sacrificed so much for me, for so many years, which has allowed me to build my fantastic career. I must also thank her for all of time she has spent with our beautiful daughter Samantha. It has not always been an easy road for us, but Ginger has been loyal and dedicated to our little family, and I will always love and appreciate her for all her support since we have been married. I must also thank my sister-in-law Carol Castro, who is always there to help us when we need her.

I would also like to mention the love and support of my siblings and their families: my older sister Dr. Yvonne Zrake and her husband Anthony Zrake, and my nieces Christina Zrake and Andrea Zrake; my younger sister Kim Bianco, my nephew Phillip Bianco and his wife Joanne, and my niece Sara Bianco; and my brother Eli Abdallah, his wife Christina Harvey, and my niece Emma Abdallah. My sisters, my brother, and I had a wonderful upbringing by two extraordinary people. We were very fortunate to have loving parents who helped us all become successful adults.

It is impossible to express in words my gratitude to my mother, Rose Abdallah, who has and continues to dedicate her life to her children and grandchildren. Rose taught in the New York City public school system for over 25 years, and was and still is an influential figure in my ever-growing career. My mom always took a great interest in the education of her children. I am fortunate that as a professor and engineer I have been able to follow in both of my parent's footsteps.

Finally, I dedicate everything in loving memory of my father Eli T. Abdallah. My father was, and will always be, the best engineer I ever met, and as a dad there could not be anyone better. Eli dedicated his life to his family and I will always remember all the life lessons he provided to me growing up, and the career advice he provided as I moved up the ranks at the MTA. There will never be anyone more influential, and I know that looking down from above he is very proud of me, and I couldn't have been more fortunate to have him as my father.

Chapter 1

Sustainable Mass Transit

INTRODUCTION

Public mass transit systems including subway or elevated train lines, light rail systems, commuter rail, and bus service, rapidly move millions of people each day, and contribute less pollution per person than personal car usage in cities. In today's world, far too many people travel back and forth to work or school each day by getting into their car, igniting an internal combustion engine, and driving. This humble routine emits great amounts of pollution and greenhouse gases into the atmosphere.

Modern society has centered around the proliferation of the automobile, a great invention that typifies human ingenuity. The car has provided individual freedom for people to move both within cities and between them in extremely short amounts of time, for both work, school and recreational activities. However, emissions from the exhaust end of the engine have been polluting the air for decades, and increasing the amount of greenhouse gases in the atmosphere.

Gasoline and diesel are typical fuels that must be burned or combusted to make the car engine run. These fuels are extracted and produced from ancient plant fossils that are discovered far beneath the surface of the earth. Energy from fossil fuels, which has also helped to create the modern world we live in, is used for transportation, manufacturing, agriculture, the heating and cooling of buildings, and many industrial processes and activities.

Mass transit is inherently sustainable in its practice, and has opportunities to be more sustainable in its operation. Sustainability initiatives embedded within mass transit's infrastructure, facilities and vehicles help reduce electricity used by trains and ancillary transit structures, lessen the fuel usage of buses, and minimize environmental impacts.

SUSTAINABILITY AND ENERGY USE

Sustainability can be modestly described as not compromising the needs of future generations with the needs of the present. Consider the use of fossil fuels to cultivate energy needs. The scientific process to extract energy from coal, oil, or natural gas is perhaps the cornerstone of our contemporary civilization, and one of mankind's greatest scientific achievements. However, the

Sustainable Mass Transit. DOI: http://dx.doi.org/10.1016/B978-0-12-811299-1.00001-0
© 2017 Elsevier Inc. All rights reserved.

continuous combustion of fossil fuels for energy comes at a price that our future generations may have to pay for.

The many years of by-product air pollution have compromised the earth's atmosphere and ecosystem, which are essential to the well-being of the planet. Air pollution dirties the air people breathe, and threatens the everyday health of humans. Pollution, which gets into the atmosphere, does not just disappear. Essentially pollutants that are emitted in the air, linger in the atmosphere and return back down to earth when it rains, getting into our oceans, lakes, and freshwater, and damaging the ecosystem.

In addition to air pollution, the amount of carbon dioxide, the major greenhouse gas, which is produced with the combustion of fossil fuels, is causing the climate to exponentially change. While all of us here on earth need the greenhouse gas effect to survive, too much greenhouse gases in the atmosphere trap more heat radiating from earth, creating an imbalance which begins to warm the planet. This causes more extreme weather events, including sea-level rise, which has led to dangerous flooding conditions in coastal cities.

Fossil fuels are a finite resource, and searching for more sources of energy beneath the surface of the earth is still ongoing, although with much deliberations. It also takes a great amount of energy to extract great amounts of energy, causing more pollution in the process. Giant wells which are bored deep into the ground to find and ultimately extract fossil fuels, refineries which transform them into usable fuel, and the transportation required to get fuel where it is needed take a lot of energy and fuel usage as well. This all leads to a giant carbon footprint for the energy sector, and without stopping or slowing down the burning of fossil fuels for energy, we will continue to damage the planet for next generations to fix.

There have been improvements and technological advancements to reduce pollution as a result of the combustion of fossil fuels over the last century. Regulations on the amount of permissible emissions have forced the reduction of pollutants through the years, but levels of pollution that are allowed still exist. Sustainable initiatives in every sector are necessary to reduce emissions, save existing resources, and reduce the amount of carbon dioxide in the atmosphere. In the transportation sector, which includes cars, trucks, airplanes, trains, buses, ferries, etc., the overall use of the automobile is the largest contributor to the release of air pollution and greenhouse gases, including carbon dioxide.

Looking back to the earlier definition of sustainability as not compromising the needs of future generations with the needs of the present, the realization is that the present and continued use of fossil fuels to create energy causes harm to the environment and contributes to global warming. A major solution and opportunity for any city to become more sustainable is to enhance, extend, or implement mass transit.

MASS TRANSIT

Public transportation typically includes trains and buses that move individuals in large quantities back and forth to their desired destinations within cities. Subway trains traveling through underground tunnels, and trains running on elevated infrastructure, can move a huge number of people from destination to destination within large cities. When planning an urban environment, transportation is an essential component to be considered.

The subway train tunnel is the ideal mass transit infrastructure, in that it is below ground, it can travel unimpeded and very rapidly underground, and it does not take up valuable real estate or room above the surface. This leaves a city an opportunity to grow and develop a neighborhood in relationship to the mass transit system. In more recent decades, above ground light rail systems have been the mass transit system of choice for burgeoning cities to employ.

Light rail systems have grown in many small and large cities. Light rail is essentially the evolution of the electric streetcar system of the past. Light rail is prevalent all around the world, and has been recently increasing popularity in the United States. Almost every city includes a bus network. Bus rapid transit, which has also evolved in cities, provides an infrastructure solely dedicated for bus traffic only.

Each year millions of metric tons of carbon emissions are avoided and billions of gallons of gasoline are saved due to public transportation use in the United States. The most sustainable cities have mass transit networks and are less reliant on cars, which lead to reductions in pollution and greenhouse gas emittance. People who use mass transit as opposed to traveling in an automobile have a lower personal carbon footprint.

Mass transit does have its own substantial carbon footprint, pollution concerns, and significant environmental impacts. As a case in point, the predominant fuel for the use of buses is diesel, which is used in the fossil fuel burning internal combustion engine. The chief energy for trains is electricity. Electricity is similarly generated mostly by fossil fuel burning, especially the burning of coal, and the combustion emits bad air pollution and greenhouse gases.

While some electricity is produced by hydroelectric, solar, or wind power, which have little or no emissions, it is the burning of a fossil fuel predominantly that creates electricity. Reducing electrical consumption through sustainable initiatives decreases air pollution and greenhouse gas emittance. When electric train service in a city is plentiful and available, plus if it can become more energy efficient, it will make a city or region more sustainable.

Sustainability Elements

The mass transit industry over the past 20 years has had a revolution when it comes to being sustainable. A whole new discipline of sustainability has been established in the mass transit set of core values. Along with safety, integrity, reliance, resilience, customer service among others, sustainability has become as much a part of the fabric of the mass transit sector as any other core value. Sustainable elements are initiated to make the train and light rail systems more energy efficient.

Sustainable elements can be part of the infrastructure, including track, lighting, signal systems, substations, subway or train station environments, and the ancillary facilities, such as train car maintenance shops, train car storage facilities, and/or bus depots. Vehicles have also been made more energy efficient to save fuel or electricity. Buses that traditionally run on diesel fuel have seen a major upheaval when it comes to being more efficient and a whole lot cleaner.

Clean Buses

According to The American Public Transportation Association (APTA), almost half of all US public transportation buses as of January 1, 2015 were using alternative fuels, such as compressed natural gas, biodiesel, or hybrid technology, with hybrid buses comprising 16.7% of US transit buses. Hybrid buses have helped ignite the proliferation of the entire hybrid automotive industry.

Twenty years ago, there were a handful of hybrid buses used throughout the country, with very few public agencies participating in this relatively new technology. Today most bus fleets have at least some percentage of hybrid buses, and many have very large percentages including entire fleets of hybrid buses. At the beginning of their usage, they were studied intensely, and that information in that analysis became available to aid not only the bus industry, but also the entire automobile business in helping to study and continue to improve the performance of hybrids.

An important metric for the mass transit industry is miles traveled between failures, and studies were conducted to ascertain the overall effectiveness of hybrid buses in regard to maintenance routine and schedule. These studies included performance analysis in various environments, such as cold or hot climate. As a benefit of the government-infused funding of hybrid buses in the public transportation sector, today almost all bus manufacturers have hybrid options for almost all of their vehicles.

GROWING AND REVITALIZING A CITY

The subway system of New York City helped it grow into what is arguably the greatest city in the world and definitely the economic centerpiece of the universe. Many factors contributed to New York City's evolution, none more important than the below ground subway system, which carries millions of commuters every day, and has been called the lifeblood of the city. Mass transit can make a big difference in the growing or revitalization of a city.

Numerous large cities have excellent subway or rail systems and reap the benefits both sustainably and economically. New York City is a great example of a sustainable city because of its mass transit system. Almost half the population in New York City does not own or has access to a car. Energy consumption per person in New York City is one quarter the national average due largely to mass transit operations including subway and bus service.

In New York City, the birth of the subway system led to the proliferation of large office buildings centrally located in Manhattan, and a good majority of people taking public transportation from the outer boroughs. The tremendous amount of buildings including many skyscrapers in Manhattan, and numerous residences in the outer boroughs, means the heating and cooling of buildings and homes make up the largest percentage of pollution and greenhouse gas emissions in New York City.

Investing in mass transit is fundamentally good for the economy. A city with numerous mass transit options will attract people who want to reside in an urban environment and live near transit. By adding mass transit within a city, it can help grow its population, which in due course should translate to more money in their economy. Public transportation agencies play a critical role in any region or city in addition to providing mobility options, transit agencies employ many people, and contract with private vendors for engineering services, fuel and other materials and services.

Subway, Light Rail, or Bus Rapid Transit

To institute a new mass transit, infrastructure within a city or between regions is very complex, costly, and time consuming. Tunneling a new subway system is extremely expensive and takes considerable time, is intrinsically fraught with delay after delay, and has numerous potential environmental impacts in construction. However, for existing cities without the large funding required to implement mass transit by way of subway tunneling or building an elevated train line, considering either light rail or bus rapid transit built above the surface can be an attractive alternative.

Light rail, including trams or streetcars, is an increasingly popular transportation choice for cities to integrate reliable and convenient transit services. Predominantly, light rail is constructed side by side of the existing street network in their own dedicated infrastructure. Light rail systems have categorically begun to proliferate, and have reinvigorated the heart of many cities in the United States and around the world by bringing improved transportation options.

New light rail implementation can be intricate as it is usually designed and constructed on or adjacent to a current streetscape; however, it's complexity is dwarfed by the multifarious nature of building a new subway tunnel. Government funding today is going more toward new light rail than the more traditional heavy rail systems. A light rail, tram, or streetcar service can also connect existing bus services including bus rapid transit, to create, expand, or improve a mass transit network.

Bus rapid transit is a bus-based mass transit system, that has a specific street or highway infrastructure that removes the major source of bus delay, other traffic, with the aim to combine the volume and speed of light rail with the flexibility and lower cost of a bus system. A real benefit of bus rapid transit is that implementation can begin, in some cases, almost immediately if using existing lanes of traffic with some small modifications. For a more dedicated and appropriately equipped street infrastructure, it may take some time for planning, designing, and construction prior to complete bus rapid transit operation.

Subway, light rail, or bus rapid transit can help grow a city, and have revitalized large, medium, and small cities around the world, who have enhanced, extended, or implemented any or all of them. They take people out of their cars and into mass transit. In many instances, new implementation of light rail or bus rapid transit requires the displacement of existing streetscape, to provide the new dedicated lanes that are required to function, which incidentally also helps to take more individual cars of the road as well. Therefore, new implementation has a double effect in that it takes people out of their own cars and into mass transit, and it allows less cars on the road, reducing potential emissions.

Commuter Rail

In the second half of the last century, we saw the rise of the population in increasing numbers in the suburbs of large cities. People with dreams of raising a family outside the city, in a secluded house with a fence around the perimeter, living far enough to be away from the big city, but close enough to work and earn a good living in a thriving metropolis. When mass amounts of people living far enough away and spread out from a city drive into the city's central business district each day, in numerous automobiles, the result is usually substantial regional pollution.

These automobiles sit in stand still traffic on a daily basis polluting the air, and more often than not, in a single person vehicle. In addition, since suburban living necessitates the use of an automobile, a typical household of four people could include up to three or even four vehicles per house. Commuter or suburban rail systems were built to help try to mitigate the traffic that was caused by the mass migration of city dwellers into suburban towns outside city limits.

Commuter rail is typically "heavier" than normal rail options found within major city limits. They usually cover greater distances, run faster and above ground for the most part. It is usually an all seated affair with prices higher than your normal mass transit fare. They do not always have robust station environments, mostly they have just a platform for the station stops, and all likely include an adjacent parking lot for riders to park and ride into the major city where they work. The park and ride feature helps mitigate some long drives into the city.

The proliferation and growing of suburbs increased job opportunities in these regions outside major cities. This actually leads to a good number of city dwellers that find jobs and work in the suburbs, and reverse commute in the opposite direction to those who live in the suburbs and work in the city. Growing suburbs saw the increase in shopping malls, restaurants, small business, and other essential services that require labor, and either required people drive to their work destination in the suburbs or use the commuter rail if that option is available. Commuter rail can be electrified or rely on a diesel locomotive. Opportunely, some diesel locomotives are being phased out or converted to electric, and perhaps more will follow.

THE FOUR CATEGORIES OF COMMUTING

There are four major categories of commuting that people usually fall into. One category that commuters fall into is where the person always takes public transportation for a variety of reasons. These reasons could include any or all of the following: it is plentiful, available, and reliable; the person does not own or has access to a car; the person cannot afford to drive because of the expense (including gas, tolls, and parking); or there is little or no parking available which makes driving unattainable. Large cities with dense neighborhoods usually have a lot of their denizens fall into this category.

The second category includes people who have no choice but to drive back and forth to work, where there does not even exist a mass transit network to carry them to their work locations. Mass transit is just not available. This depicts the quintessential car centric city. Hopefully, civic leaders in areas such as these are considering some kind of mass transit in the future, at minimum these cities should encourage car sharing, vanpooling, or at minimum high occupancy or low emission vehicle priority lanes to reduce environmental impacts.

The third category is those commuters who could actually walk or take a bicycle to their work destinations. The people in this category are the most sustainable commuters and they usually choose to live, work, or go to school in the same immediate area. It is not typical to be able to walk or bike directly to work but it happens most often in very dense urban areas. Bicycles are making headway into the commuting routine with the proliferation of bike lanes and bike sharing programs in cities throughout the world. Millions of commuters around the world ride their bicycle directly to work, and/or to the train station or bus stop, and store their bike in well-equipped and secure bicycle storage areas.

The fourth and final category is one where each commuter actually has a choice, where mass transit exists, but the opportunity to drive does as well.

It is in this last category where a lot of effort must be made to entice people to leave their cars in their driveway and take a train, bus, or combination to get to work or school. Therefore, whenever something can convince a commuter to take mass transit on a regular basis, as opposed to driving their fossil fuel burning vehicle, it makes their city more sustainable.

CONVINCING PEOPLE TO TAKE MASS TRANSIT

In order to convince people to take mass transit when there is an available option to drive, the mass transit in cities has to be plentiful, reliable, comfortable, safe, and affordable. It becomes especially hard when driving is more convenient, particularly when the contemporary lifestyle is geared toward the car. Given the choice of getting into a car and driving to work, or waiting endlessly for a train or bus, many choose the car. One thing that can make mass transit more appealing is consistency, when trains or buses arrive exactly when scheduled. Within the past decade, the sense of reliability is increasing, including less frequent delays, outages, or complete breakdowns.

Numerous transit networks are now including departure and arrival times displayed at the train stations or bus stops. In addition, with the advent of global positioning and smart phones, commuters now have great accuracy of the arrival time of their train or bus. Transit agencies with advanced communication techniques are now able to broadcast via the Internet this information. Knowing where your next bus or train is and when it will arrive, provided through an app on your smart phone, has increased the popularity of mass transit. This type of reliability gives mass transit more customers and greater appeal.

Train travel is by far the preferred method of travel both within many European cities, and definitely between countries in Europe. It is in the blood of the European traveler to take the train, not so much in the United States. In Europe, one does not have to be convinced to take the train. In the United States, something must convince a person, that has train or bus options to take mass transit instead of using their car. A simplistic illustration of the European mentality toward train travel is that many European family vacations are through the use of train travel between visiting cities and countries. More often the American family vacations is typically to get in the car and drive somewhere.

AN INTERNATIONAL IDEOLOGY

“Mass Transit” and “Mass Transport” are both essentially the same term defining public transportation. It can be looked at as an American term versus a European or International term. In Europe and around the world, more often you hear the use of the term transport as opposed to transit. Mass transit is semantically united with the term ‘rapid transit’ in the United States, and is traditionally defined as the public transportation modes carrying voluminous amounts of people in subways, elevated trains, and bus service.

Transit systems worldwide have many similarities, and sharing knowledge is a hallmark in the public transportation business. A lot of sustainable initiatives have been copied from each other. Several sustainability initiatives incorporated by US transit agencies have borrowed liberally from international models. This is quite important as many legacy transit agencies have cultures that resist substantial change or even the suggestion of change. Many US transit agencies have copied numerous successful sustainability initiatives from around the world to affect change.

One major sustainability enterprise that several major US Transit Agencies have adopted from their international brethren is the utilization of an environmental management system to provide a foundation and a framework on managing environmental impacts and to continually improve environmental performance. Numerous international transit agencies have adopted the International Organization for Standardization Environmental Management System (ISO 14001 EMS) standard to guide the development, maintenance, and continuous improvement of their environmental performance.

The International Organization for Standardization develops and publishes international standards to provide real-world tools for tackling many global challenges, and the ISO 14001 EMS standard includes the demonstration of commitments to foster sustainability through operations, maintenance, design, and construction. A major requirement for adherence to the ISO 14001 EMS standard is to create an organization-wide environmental policy, that pledges to work to improve environmental performance, and how it will be accomplished.

It has been a hallmark of transit agencies to go beyond compliance in the past two decades. This is a totally voluntary standard under which a transit agency or a department or program within an agency can operate under. By adhering to the ISO 14001 EMS standard, an agency volunteers to make judgments and assessments of their own environmental performance in order to continually improve, and strives to go above and beyond to be more environmentally sustainable. Mass transit agencies in New York, Los Angeles, and Philadelphia are among the US agencies which have voluntarily committed parts of their agency, a department, or a facility, to adhere to the ISO 14001 EMS standard.

THE HUMAN ELEMENT

Certainly driving to work can at times be more comfortable than standing in a train packed with a lot of people. Increasing service, adding capacity, and getting or guaranteeing a seat on a train or bus is more appealing to any commuter. Overcrowding is a legitimate issue, and it makes people who have a choice of train or car think before deciding whether to drive or take mass transit. Plush comfortable seating is also attractive to most.

Safety concerns are also a fear for some when taking public transportation, especially those within inner cities, where crime is prevalent. Well-lit environments, convenient communications, and a constant police presence make commuters feel a sense of security, and this will make it much more likely for them to choose mass transit. The cost of taking a train or bus to work has to be affordable to the majority of commuters. It certainly costs to drive a car, with gasoline, maintenance, insurance, tolls, and parking fees. To balance the decision making process, low-cost mass transit can help sway those who have a decision to make when it comes to picking their mode of transportation to go back and forth to work or school.

Many people's small choices can make big change happen. In many circumstances, it comes down to an individual's choice or preference. Someone can choose to be more personally sustainable and contribute to emissions and greenhouse gas reduction, if they desire. Taking the train or bus in lieu of a car is a personal choice, which can lead to a more sustainable city. It may individually be a tiny fraction of the energy savings required to reverse climate change; however, if more and more people make this choice, the savings can add up and make a big difference.

A real advantage of including sustainable initiatives in mass transit is that in some instances the initiatives can be visible to the riding public. A lot of the infrastructure within a mass transit system is hidden, and not seen by the riding public. However, there is a great deal of public mass transit infrastructure where sustainable elements can be witnessed, especially in the station and terminal environments.

Large terminals, such as Grand Central Station in New York City or Union Station in Los Angeles, are often impressive historic structures, which include elaborate shops and unique public spaces or areas, in addition to waiting areas, token booth or ticket agent areas. Sustainable initiatives such as lighting or renewable energy can be highlighted in a public environment and seen by millions of people passing through. Information boards in addition to advertisements could also highlight sustainability initiatives to help inform and educate the public.

Marketing

The Internet and social media are great marketing tools for sustainability projects. Social media have afforded the opportunity to showcase and report on the progress of projects, especially those in the public domain. Social media have brought knowledge sharing to a whole new level. Successful projects could be role models for others to copy and even enhance upon. Word travels fast in the Internet era, and once sustainable projects are completed everyone in the industry knows about it, and if successful will be copied.

GREAT OPPORTUNITIES

The opportunities are endless when it comes to reducing carbon footprint in the mass transit industry, especially by means of sustainable initiatives. Transportation professionals within the mass transit industry can make decisions, formulate policies, and create programs devoted to sustainable operations. Agency presidents and superintendents of mass transit operations can pursue more sustainable strategies and outcomes.

There are numerous opportunities to make mass transit more sustainable, and millions of professionals can be involved to help influence big change. Working in the public transportation field provides many ways for technical professionals to enhance the quality of life for city dwellers as part of their everyday work life, and this generally instills sustainability as a core value. The mass transit industry has seen the professional decision makers, those with the authority to do so, direct their agencies to add or incorporate sustainable initiatives into their transit infrastructure, facilities, and vehicles.

Engineers, architects, and planners, and other transportation professionals who understand the need to curb emissions in order to combat climate change and reduce pollution, can add energy efficient elements and advanced technologies, and include them into new or rehabilitated transit infrastructure projects. Specifically, engineers of all disciplines including civil, electrical, mechanical, chemical, and environmental can design into capital construction projects advanced technologies that research scientists have developed that can ultimately reduce energy usage during operations.

Over the past two decades, the mass transit industry has been out at the forefront in sustainable or green engineering. Prospects are unlimited for transportation professionals to be part of sustainable initiatives, either in operations, maintenance, design, or construction. In regard to the challenge of reducing emissions, there are quality solutions and great opportunities in the hands of numerous professional people looking to make a big difference.

GOVERNMENT PARTICIPATION

About 50 years ago, the US Federal Government started to impart federal funding toward the construction and implementation of new subway systems in large cities. In addition to new systems, it also understood the role of existing transit in places like New York City, and began to fund what is commonly referred to as State of Good Repair funding for existing systems. Billions of dollars have been poured into older subway systems in New York City, Chicago, and Boston, to keep them running, while new systems were being implemented.

New technological advancements have been initiated and studied in the public transportation sector. These opportunities can help influence and impact the entire transportation industry, both public and private. Government can help fund these pilot initiatives and include them within the capital financing of the rehabilitation of existing transit systems, and within new systems to be built. Government funding helped transit agencies purchase hybrid buses. The government invested in hybrid buses in the public transportation sector and this helped to accelerate the learning curve on hybrids in order to improve viability. The government also supported appropriate studies on their overall performance including the study of the batteries used in the hybrids, the fuel economy, and maintenance of the vehicles.

Policy makers can suggest and lobby for more sustainable transit options for their constituents, and put forth capital funding for more and further reliable mass transit. Importantly, over the past 50 years of federal funding of mass transit projects, the bar began to rise in the competition between state transit agencies vying for precious federal dollars. Sustainability has become a deciding factor in the dissemination of money, and special grants targeting greenhouse gas reduction became available to transit agencies, whose projects could demonstrate the largest decreases in greenhouse gases after completion.

Federal Transit Administration

The Federal Transit Administration, under the US Department of Transportation, provides financial and technical assistance to public transit systems, including subway and elevated trains, light rail, commuter rail, buses, and ferries. The Federal Transit Administration partners with state and local transit agencies to design, construct, and improve public transportation systems, and manages roughly $12 billion annually in federal funds to support public transportation.

The Federal Transit Administration funds the building of new mass transit systems, the rehabilitation or expansion of existing mass transit systems, and the purchasing of train cars and buses for transit agencies. The past decade has seen the growth in funding of numerous light rail or electric streetcar projects. In addition to the main grant programs, targeted grant programs fund projects with significant environmental benefits. The Federal Transit Administration uses sustainability as part of the decision-making process when deciding what projects receive federal funding, and also helps to develop advanced technology research.

Public vehicle fleets piloting advanced technologies provides a perfect platform for demonstration and examination. The Federal Transit Administration research program supports the development and refinement of energy efficiency, alternative fuel vehicles, hybrid bus, and battery charging technologies research, with the intent to see energy and emissions benefits compared to regular diesel buses. New and now proven technologies that were previously demonstrated on transit buses have been adopted and used on other types of vehicles widening the impact of the public investment.

The mass transit industry in the United States has been committed to using environmentally sustainable technologies and practices. The largest transit agencies including New York, Los Angeles, San Francisco, Boston, Philadelphia, Atlanta, and Chicago have all been leaders in the past decade of sustainability initiatives. Other large cities including Portland, Seattle, and San Antonio and many other large- and medium-sized cities' transit agencies have also been big contributors to the recent sustainability movement in the mass transit industry.

CONCLUSION

Mass transit offers cities less pollution and greenhouse gas compared to individual car transportation, which prevails in cities or regions which do not have reliable, comfortable, or rapid mass transportation. The dominant use of the automobile in most cities, and the burning of fossil fuels has brought dirtier air, causing regional air pollution. Fossil fuel burning with the emittance of greenhouse gases contributes to global warming and extreme climate change.

If one of the foundation principles of sustainability is to not compromise the needs of future generations with the needs of the present, it is clear that the current continued use of fossil fuels for energy has a consequence that causes harm to the environment and contributes to global warming, impacting the future. This is something that needs to be reversed now, or our next generations will have to bear the burden, in order to sustain themselves and generations to come. Optimistically it is not too late to make this change, and convert to a more sustainable presence.

Mass Transit is a solution to this challenge!

Mass transit makes cities more sustainable each time a network adds service, and each time the service becomes more energy efficient. Train and bus commuting brings pollution levels down as well as carbon footprint, and sustainability initiatives help reduce or mitigate pollution and greenhouse gas emittance. Transit infrastructure, facilities, and vehicles can be made more sustainable. People can help cities become more sustainable by the choices they make.

There are many reasons that mass transit is one of the best and most effective sustainability solutions including: mass transit networks take people out of their cars and into less carbon footprint producing transportation modes; energy efficiency and advanced technologies can be engineered into mass transit capital projects; quality solutions and great opportunities are in the hands of numerous professional people looking to make a big difference; and there are abundant opportunities for government, in addition to funding more mass transit, to pilot sustainable initiative programs, which help accelerate the addition of sustainable initiatives and new advanced technologies into the main stream engineering field.

Mass transit is inherently sustainable in its practice, and has great opportunities to be more sustainable in its operation, henceforth Sustainable Mass Transit.

FURTHER READING

American Public Transportation Administration, www.apta.com.
Transportation Research Board, www.trb.org.
Federal Transit Administration, www.transit.dot.gov.
New York Metropolitan Transportation Authority, www.mta.org.
Los Angeles County Metropolitan Transportation Authority, www.metro.net.
International Organization for Standardization, www.iso.org.

Chapter 2

Infrastructure, Facilities and Vehicles

INTRODUCTION

Mass transit's infrastructure within a city is necessary to provide the movement of large volumes of people traveling on trains and buses, in the same travel corridor with great effectiveness, reliability, and most prominently rapidity. The most prodigious mass transit infrastructure is the subway and its accompanying stations and terminals. Mass transit infrastructure also includes elevated train structures built above the street surface, or train track right-of-ways at the surface. Buses move predominantly on city streets or highways, and in years that are more recent on their own dedicated infrastructure exclusive for bus only.

Subway tunnels are primarily made with tons of concrete, brick, wood and steel, and are equipped with electrical conduits and cables transmitting electricity, communication wires, signal systems, lighting, and the piping for water drainage. They also must contain the necessary rail track to allow subway trains to move from station to station. Necessary support structures in addition to the base infrastructure for subway tunnels, are substations, ventilation fan plants, emergency exits, and signal towers. The station environments, the public entry and exit points of the infrastructure, include many of the following; mezzanines, platforms, stairs, escalators, elevators, rest rooms, and concession areas such as newspaper stands.

Linked to the train network are ancillary facilities such as train storage yards and maintenance shops, which are major components of the entire train infrastructure. Elevated train structures are also made up of mainly steel, brick, wood and concrete, and require essentially the same transit accoutrements with the exception of subway ventilation equipment and the tunnel water pumping system. While many large cities have train infrastructure such as subway tunnels, elevated lines, heavy or light rail, numerous cities do not have any train service. Providentially, almost all cities, towns, or regions have a bus system.

Bus infrastructures built into the cityscape include bus stops, bus shelters, bus stations, or terminals, which are part of the overall bus network. Bus Rapid Transit improves the effectiveness of bus service by having its own

Sustainable Mass Transit. DOI: http://dx.doi.org/10.1016/B978-0-12-811299-1.00002-2
© 2017 Elsevier Inc. All rights reserved.

dedicated infrastructure. Buses also need places to be stored, serviced, and maintained, while not on the road. Bus Depots have parking spaces for the bus fleet, maintenance bays, and fueling infrastructure.

HISTORY

The history of mass transit started in the 1800s with people riding in carriages pulled by horses. The horse drawn carriage permitted many people to ride together through city street corridors, without any specific infrastructure except the street, and in some cases the unpaved dirt roads of an existing town. The only structures required were a facility to store the carriages, and of course a barn or shed to house and feed the horses. Pulling a carriage put a tremendous amount of strain on the horses too, and to help the horses move the carriage with more ease, the first formal mass transit infrastructure created, was by placing steel rails into the ground specifically for horse drawn carriages.

Rails were built into the ground and the carriage wheels were placed on the rail. The rail and wheel interface relieved the friction from the sometimes rocky or murky street bed, and maintained a more comfortable and smooth experience for passengers. It also enabled the horses to pull the carriage more easily with less energy required than without the rails, and also allowed multiple or separate cars to be chained together, extending the capacity of service. There were still significant environmental impacts of this initial mass transit operation, mostly coming from the use of the horse. The necessity to house, feed, and maintain the armada of horses required had impacts such as biological waste discharge, not only during the housing of the animals, but also within the city streets during operations.

The horses also required tremendous water requirements for drinking and cleaning, and the use of water was required to wash down city streets of horse manure, which clogged city sewers in addition to the pungent odor of horse excrement. Also the remains of the fallen horses became a major problem to consistently handle. These difficulties contributed to disease, widespread health issues, and ultimately led people to contemplate alternatives to be considered to eliminate the severe quality of life issues stemming from the horse drawn carriage system. One idea was to use cables to pull the cars instead of horses.

The cable car system was invented by placing the carriage on the street rails, and having the carriage or cable car pulled by long cables with the energy garnered from a steam-powered station. The cable car or trolley worked nicely and moved a lot of people, and many cities used cable cars for quite some time. The use of steam, by burning coal, was also being used in railroad locomotives all over the world and eventually steam locomotive trains were used on fixed rails, within cities.

Steam locomotives could move many more train cars operating over longer distances than cable cars, and they were significantly faster. The first elevated train structures used steam-powered locomotives. An extensive network of elevated train lines using steam locomotives was being put in service in many cities, however, steam generation had many difficulties, including engines that spilled ash and left cinders in its wake. While this enabled a mass amount of people to travel by train in bulk, the above surface intrusion and disruption led to the quest to place an entire electrified system in tunnels beneath the surface.

Engineering techniques in tunneling and electrification allowed construction of subterranean rail lines or subways with minimal disruption to the existing streetscape, and it permitted the rapid transit of numerous people beneath the congested streets. The first inner city subway tunnels, which were implemented and constructed under existing city streets, used an engineering tunneling method called cut and cover, which is basically a trench dug in the street, and decking used to cover the trench or the cut. This allowed street traffic to continue to flow, both during construction and then after the tunnel section was complete.

Operating trains on guideways with an exclusive right of way eliminated delays, and minimized the frequent collisions experienced by an overcrowded streetscape, providing faster and more reliable transportation. The separate exclusive right-of-way was an essential and important component to the growth of mass transit, and cities in general. Land use development was oriented around transit lines, mainly near stations. In actuality this circumstance allowed the swift ascension of the automobile, as well, since a lot of pedestrian and carriage traffic came off the street. Opportunely the arrival of bus service operating on the streets in mixed traffic began to grow.

Bus service, both public and private, was thrust into mass transportation services with the introduction and proliferation of the internal combustion engine. Buses offered operating flexibility for the short-term traveler and by mid-20th century became the largest carrier of pedestrians in the mass transit industry.

Considering the Climate

Climate always has been a consideration when building public infrastructure. Engineering requirements always consider the expected weather patterns where a project is located, for both above ground and below ground infrastructure. Many seminal civil engineering projects in modern urban history were influenced by big and disruptive weather events, including several initiatives that were spurred on and undertaken after the great blizzard of 1888 in New York City. The blizzard destroyed overhead electrical and utility lines, and paralyzed the above ground steam elevated train travel. This led authorities to seek beneath the surface alternatives. Thus began the following: burying numerous electrical cables below the street, the electrification of train service, and the location for that service to be constructed in a train tunnel. The impetus for mass transit was perhaps the first climate adaptation initiative in modern US history.

TRAIN INFRASTRUCTURE

The mass transit train infrastructure consists of subway tunnels, elevated railways or at grade-level surface rail. The elementary construction materials of most subway tunnels consists of concrete and steel, with steel framing and columns, concrete foundations and footings, and designed with the understanding of the natural soil conditions and water table. A subway tunnel in some cases may be built below the groundwater table, and therefore must have strong foundations and walls to counterattack water pressure from groundwater. Tunnels have to be equipped with a water pump and discharge system to remove any water infiltration. Tunnels can also be built in bedrock, which lessens the potential of water infiltration.

Tunnels also have to include ventilation and an emergency fan system, in case a fire or electrical smoke condition starts in the tunnel. Normal ventilation is provided mostly from the piston effect of trains pushing air through the tunnel and through street gratings or grills. High velocity ventilation systems need to be appropriately sized and spaced apart to maximize effectiveness. Tunnels also have to have emergency exits, manholes, communication hubs, and electrical distribution rooms.

Elevated train is a railway with the tracks above the street level mainly on a steel, concrete, or brick structure, and in most cases the tracks of elevated railways are adjacent to commercial establishments and residences, and can be seen and heard from street level. The elevated railway used in urban areas in many cases is needed when large number of street level crossings must to be bypassed. Above ground elevated railway must consider in its design the local climate, specifically hot and cold weather, concerning the expansion and contraction of steel rails.

Trains running at ground level have to be designed in reference to the potential flooding based on the base elevation at the location of the rail line. As an example, a train traveling in a low-lying area or toward the beach or coastal area may traverse on land close to sea level. Based on traditional rainfall and flooding, the track bed would have to be built on higher ground to avoid potential flood conditions that could affect the electric train operation.

The decision to build below the ground, on the ground, or above the ground has to be made with the existing landscape and the local climate as huge considerations. Soil conditions, nearby navigable water for potential bridges, and other factors such as economics and social benefits must be considered in deciding which infrastructure is best to implement. Symbiosis with other existing transit, including airports, and proximately to recreational activities, such as ballparks, stadiums and beaches also play a part. Urban planners always consider the best transit infrastructure in planning or revitalizing exiting urban settings.

Track

In the tunnel, at grade or on an elevated structure, the track bed includes a set or sets of two parallel rows of steel, which make up the rail that is used as the fixed guideway used by trains. The steel rails are supported by cross pieces called ties at consistent intervals, which spreads the pressure load forced by the train wheels into the ground or the foundation of the structure. Ties are traditionally made from wood. Ties often rest on ballast, which are very small pieces of broken-up rock that are packed together and hold the railway tracks in place. Ties have also been made of concrete and other materials, and ballast can be replaced with a concrete structure or other material holding the ties in place.

The running rails are maintained at a fixed distance apart called the gauge. The rails interface with the train wheels to help guide the vehicles of the train along the track. Each train car wheel also has a flange, an extended piece of the wheel, which sticks out from the inside edge all the way around. This helps to prevent the train from coming off the track or derailing, and helps guide the train around sharp curvature. One of the engineering challenges faced by running heavy trains on miles of steel track below, at grade, or above the surface of the ground includes the potential movement of the structure that could lead to ground-borne vibrations.

Electrification

Electric power is supplied to modern trains through a continuous conductor in two basic types; one type of train power is received by the train from a rail running alongside the track referred to as the third rail, and the other type is an overhead line or catenary wire suspended above the track. Trains get power from a third rail mounted at track level from contact with a train shoe, which stick out dangerously in many cases from beneath the train, and contacts the third rail. Pantographs on the roofs of the train contact the overhead or catenary contact wire to receive electricity, and both third rail and overhead wire systems use the running rails as the return conductor. Trains can be equipped with either a third rail shoe or pantograph, and some can be equipped with both for train infrastructure that requires energy from both sources.

Electric railways get energy from the electrical grid, typically generated by large electrical power generating facilities, transmitted to substations along the railway network, and then distributed to the trains via the third rail or catenary. Electric railways usually have their own electrical substations, transformers, and transmission lines, and mostly purchase power from an electric utility, which means they have no direct emissions, an important advantage in tunnels, and elevated train lines that traverse inner city neighborhoods. The safety concerns in dealing with high voltages from contact wires and third rails are potentially a life or death hazard to track workers, which means numerous precautions and safety training is required for anyone who works on the train tracks.

STATIONS AND TERMINALS

Stations and terminals are the focal points of a mass transit network. Strategically located within neighborhoods and cities, they are the first step into the typical mass transit journey. Stations are the places where people enter and exit the transit infrastructure to get on and off the train at their desired stop. The station or terminal is the first point of contact passengers have with the system so it has to have an efficient layout for ease of operation. The station environments must also provide the necessary route information.

Passengers entering the station must immediately be informed by way of signage of where they need to go to pay the fare, enter through a turnstile, and be directed toward the proper train. Stations are usually divided into unpaid and paid areas. Unpaid areas include zones where fares are secured at token booths, ticket offices, or automated fare machines. Station entrances and exits are designed to allow for the appropriate number of passengers passing through them under normal peak conditions. Entrances and exits in most cases are stairs, escalators, or elevators. Emergency exit requirements need to be included in case a mass exodus from the station is necessary.

Station sizes vary immensely with ridership and need to have appropriate lighting for pedestrian security. The most important area within a station arguably is the station platform. Platforms can include seating areas for passengers to wait for the next train; however, it is likely that passengers will be standing on a sometimes-crowded platform. In the case of an outdoor above ground station, weather protection is essential, such as large canopies and windscreens that line station platforms to protect customers from inclement weather conditions.

Concession areas such as newspaper stands, coffee shops, and fast-food places can be found in the larger stations or terminals, and may include rest rooms and larger waiting areas for passengers. Terminals are in many cases the starting or end point of the transit infrastructure, and include additional requirements above that of the normal station. Terminals are sometimes the size of medium-sized buildings, made up of traditional building materials, and may have unique architectural finishes. In some cases a complete heating, ventilation, and air conditioning system is required.

Terminals may include crew quarters for the many transit workers necessary to run a railroad, and these crew quarters include locker rooms, showers, toilets, and equipment or tool rooms. Terminal stops are often used to clean trains between runs when trains are waiting to depart, therefore refuse areas are necessary to help store collected trash prior to removal and disposal of passenger waste. In many instances transit agency offices including agency presidents and or line superintendent's offices are located at terminals. Offices for the numerous transit agency divisions are often strategically located within terminals, including maintenance, electrical power, lighting, signals, communications, engineering, security, and safety.

SIGNAL AND COMMUNICATIONS

The signal system of a mass transit infrastructure is the indispensable component necessary to move millions of people safely and expeditiously through the infrastructure. Signaling is used to keep rapidly moving trains from colliding with each other. The movement of trains is controlled so that they do not occupy the same section of track at the same time. Units of track are divided into sections known as blocks, and only one train is permitted in each block at a time. This principle forms the basis of train signal systems.

The blocks start and end with signals, usually green, yellow, and red lights, and the lengths of blocks are designed to allow trains to operate as often as necessary. A new train is not permitted to enter a block until a signal, usually the green light, indicates that the train may proceed. A lengthy buffer section, usually at least the distance required to stop the train, provides the necessary safety net to avoid collisions. In determining the length of the blocks, consideration of train speed and volume of trains through the system are important.

In order to determine whether a block section of line is occupied the rails at the end of each section are electrically isolated from the next section. The signal system knows when a section is unoccupied, and when a new train enters an unoccupied section, the signal system alerts the signal lights to turn red. If any part of the train remains in the section, the red lights stay on, and this red light information, indicating stop, is relayed down the track. The red light signal tells the train conductor not to enter the next block. Conductors should stop, and never intentionally go through a red light unless commanded by the signal tower. If a train inadvertently goes through a red light, it triggers a safety relay, which will automatically stop the train.

Many modern signal systems are computerized and allow trains to run automatically. A typical transit system includes a master signal tower, which is where operators can detect and see where each train in the system is located. It is not always an above ground tower, and the signal tower is in most cases the communication hub that is in contact with the motorman or conductor on the train, although some systems have both a signal tower and separate communication hubs or rail control rooms.

Communications are traditionally through dedicated telephone and radio transmission lines built into the infrastructure, as well as additional wireless transmission to communicate with the transit workers through phones and radios. Communication is pivotal in the subway tunnel, and for communicating information to passengers using a public address system when a train is stuck or not moving. While some commuters may not believe it, operators always are working nonstop to move stuck trains as quickly and safely as possible.

LINE EQUIPMENT

The major line equipment infrastructure of subway tunnels are substations, ventilation fan plants, pumping stations, and lighting. Substations receive electricity from the electrical power grid and provide the necessary voltage through circuit breaker houses, transformers, and rectifiers to the third rail or catenary electrical lines. Depending on the size of the line, substations must be strategically spaced to maximize efficiency, and reduce voltage loss or drops.

Ventilation fan plants are essential to any subway tunnel in case a fire or electrical smoke condition starts in the tunnel. Ventilation fan plants often include large fans, in many cases multiple fans to exhaust or supply air in the tunnel. The fan chambers, which house the fans, can be below the ground or above, with large and sometimes lengthy air ducts connecting the tunnel to the fan chamber, and the chamber to the vent to the outside. These emergency fans have high velocity to supply or exhaust subway tunnel air. Many fan plants in subway tunnels are adjacent to the underground tunnel structures.

Subway tunnels must be equipped with a water pump and line discharge system to remove any water infiltration, from either groundwater, rainwater or flooding that gets into the tunnel. Water that gets into the subway tunnel is directed to drainage areas and then into a pumping station. The pumping station collects the water and gradually pumps it into the nearest sewer system. Tunnels are designed as practical to be waterproof; however, it is inevitable that groundwater gets into the system. The constant pressure from groundwater can make its way into the tunnel through very small openings, seems or erosions in the tunnel infrastructure. Some new techniques include allowing the water to come into the system and constantly pump it out, which requires complex pumps and piping be designed into the infrastructure.

Tunnel lighting is an essential safety element to the core subway infrastructure. Banks of light fixtures line subterranean tunnels providing the necessary lumens of light so the subway motorman can see the track bed in front. Electricity is also provided from an electrical distribution room located within the tunnel to energize the lighting system. Tunnel light fixtures traditionally housed incandescent, mercury vapor, or fluorescent lights in the bank of tunnel lights. Other lights in the system include those used for emergency exits, and of course signal lights.

FACILITIES

Ancillary facilities include train storage yards, maintenance shops, car washer facilities, material storage, crew quarters, and overhaul shops for motors, wheels, or specialty equipment such as air conditioning units or batteries. The ancillary facilities that complement a subway or elevated train line system requires tremendous square footage and a lot of real estate, specifically storage yards where train cars are stored during off peak or overnight. In addition, for trains to enter or exit storage yards, the yards have to be equipped with a connector track, this can sometimes by quite a distance from the mainline infrastructure, which adds to the total square footage of required infrastructure.

Train storage yards entail tremendous real estate, are largely located in industrial areas of cities, and have specific design requirements to ensure the safekeeping of very expensive train cars. Yards also have to include numerous electrified tracks for trains to be placed in, and tracks are required to help trains move around the yard. Storage yards must have drainage systems to handle rain events, barriers to protect against flooding, and security to protect against vandalism. Both heavy and light rail train cars require similar facilities, and have similar maintenance requirements and processes.

LIGHT RAIL SYSTEMS

Light rail systems usually operate with one, two, or short multiple passenger cars, on fixed rails built into a dedicated right-of-way that is most often separated from adjacent car traffic. Some light rail systems can also operate in rights-of-ways above or below the surface, and are typically powered from an overhead electric line via pantograph, although some use third rail electrification. The infrastructure investment of a light rail system in most cases is much less than for a heavy rail system. Light rail has evolved along with the times, with the aid of new technology, and there are two general versions of light rail, the traditional type and the more modern variation.

The traditional light rail type is where a single passenger car, a tram or electric streetcar runs on tracks, which are built into the street, so the tram or streetcar can share space with road traffic. They normally have frequent stops, with the sidewalk as the basic platform for passengers to enter and exit, similar to a city bus. Many of these trams or streetcars operate on the existing city streets sharing the roadway with cars and buses, some have exclusive right-of-ways that are closed to regular car traffic, and some frequently share roadway with only buses operating in a common corridor, and possibly the same exclusive infrastructure. All of these multiple roadway situations are common around the world.

The modern light rail type, which could include multiple cars in the chain in some cases up to four, is where the trains have their own dedicated right-of-way, tunnel or elevated structure, and are separated from road traffic, with built-up platforms forming the station environment. They require electrification, infrastructure, facilities, and vehicles, much like traditional heavy rail. The many light rail systems that exist today have various and mixed features and travel on the street, go underground, or travel on an elevated structure.

Light rail systems that are proliferating currently around the world are really just smaller versions of the inner city, heavy rail systems, found in larger cities. The engineering techniques, electrification, and line planning is similar to heavy rail; only in scale do they differ. In many cities around the world, modern light rail and tram both exist and are mixed with the city streetscape. The unofficial demarcation between light rail and tram is that a tram is most often a singular passenger car resembling the old electric streetcar, traveling on city streets sharing the road with mixed traffic, where light rail tends to have dedicated lanes or dedicated infrastructure. The materials used for light rail is the same for heavy rail, as are the electrical necessities to move the train cars.

TRAIN CARS

The train cars used in a modern light rail system have numerous similarities to heavy rail train cars, in design and function. The most important similarity is that in the majority of cases the track gauge is the same, the standard gauge. This means that heavy and light rail systems could run on the same track, and in many cases this happens. Light rail train cars must in many cases be somewhat thinner, because they must navigate city streets with sharper turns than a heavy rail train car would need to steer through. Train cars for both heavy and light rail have similar maintenance requirements. It is important to note that in several cases commuter, heavy and light rail train service from different agencies, both public and private, share the same existing tracks and infrastructure, and this can help networks connect with each other.

The modern subway train car is equipped to travel in either direction, operate as the lead car or as an add-on to a chain, normally 8–10 cars for heavy rail and 1–4 for light rail systems. Some systems still require a lead locomotive to pull passenger cars. One of the breakthrough engineering accomplishments in mass transit system operations is the ability for all the trains in a chain to operate their own motor or motors in tandem, as opposed to just getting power from the locomotive equipped lead car, which essentially pulls the other train cars along the right of way.

In most systems all train cars in the chain receive power from the third rail or overhead catenary, ensuring that the energy is evenly distributed.

Trains can accelerate much faster with this method. Train cars are equipped with a third rail shoe, an overhead pantograph or both to receive electrical power to accelerate the train. The cars contain passenger seats, doors that can open on either side, lighting, air ventilation for human comfort, and signage. While each car includes seating, standing room space with poles, overhead handrails and straps are usually made available for heavy and light rail train cars, however, commuter rail usually contains just seats and not much room to stand.

The newest 21st century trains are more reliable and easier to maintain than previous models, with equipment positioned for easy access for inspections and repairs, and diagnostic equipment to help identify failing or defective mechanisms. On-board equipment includes electronic strip maps, automated announcements, door closing lights, and intercoms. Newer trains have traditionally become lighter through the years, and now many include folding seats for more standing areas during rush hour.

Heavy Rail Versus Light Rail

There are distinct differences between light and heavy rail, however, more often than not it can be simply defined by the length of the train car chain, where light rail has 1−2 cars generally, and heavy rail usually has a larger chain. Heavy rail requires the power to accelerate quickly to the maximum speed permissible, and then decelerate to the stop. Light rail makes shorter stops in smaller areas, with decidedly less initial speed, and most often carry less people. While heavy rail is prominent in large older mega cities, light rail is more likely to be an up and coming cities prime mass transit mode, transporting millions of people back and forth to work, school, or recreation. Light rail is taking the lead in newly installed mass transit systems.

BUS SERVICE

At the turn of the 20th century the invention of the motor car with the fuel burning internal combustion engine led to the creation of large passenger vehicles or buses that were designed to carry multiple passengers. Private bus service started in several cities and towns all over the world with public transportation bus networks soon to follow. The term bus comes from omnibus, a term first used in Paris, France referring to their horse drawn carriage network of the 19th century.

There are two categories of buses in the mass transit family; city and express or suburban. City buses operate within inner cities, at times very slowly in regular street traffic, with two curbside entrances, one in the front and one toward the back. The seats have short backs. The city bus is designed not only for seated passengers but to accommodate standing passengers as well, since for the most part the distance and time traveled is short. The city buses make constant stops with passengers entering in the front, and hopefully exiting only from the backside exit when disembarking.

Express or suburban buses that require longer distances to travel have higher and more comfortable seats, and a single curbside front entrance. The express bus picks up passengers in preferably one location or several short pick-ups, and then travels the bulk of the commute, which is usually a relatively longer distance away, and then at the last stop, everyone exits. Therefore no side exit is necessary for the express bus. For buses with additional capacity to the standard bus, several alternate models exist, including articulated and double decker buses.

Articulated buses have an additional section of bus added. This extends seating and standing capacity, and articulated buses are designed to have the similar turning radius of a conventional bus. An accordion shaped middle, with a hinge and circular floor panel, enables the longer length bus to maneuver safely in turning the vehicle. Double decker buses, with two levels of passenger seating, are primarily found in Europe but there are many throughout the world. Articulated and double decker buses can be either city, express, or suburban.

BUS DEPOTS

Buses need to be stored, maintained, washed, and above all fueled. The depot is the home of the bus when it is not on the road working. Depots are large facilities, with immense areas for parking, and giant spaces for maintenance activities. A certain percentage of bays are demarcated for maintenance only, usually equipped with tailpipe exhaust removal systems to ensure exhaust is removed when running the engine of the vehicle and inspecting the engine during maintenance operations.

Bus depots also contain areas devoted to fueling, and filing up buses with fluids such as lubricants, transmission fluids, antifreeze, etc. Underground tanks are buried beneath the depot floor and typically store diesel fuel. The underground fuel tanks, complete with secondary containment to detect and prevent leaks, are normally filled by large fuel delivery trucks on a regimented basis. Fueling stations in bus depots are equipped with pumping and dispensing equipment. Fueling takes place usually after the bus has completed its run, so when the bus is ready to leave for its next run it has a full tank.

Bus wash facilities are contained within bus depots and look similar in nature to normal car washer facilities seen in cities. They of course require water, detergent, and drainage. Clean buses are more attractive to paying customers, but also for safety and maintenance reasons buses are washed often on a daily basis. City streets can sometimes deposit soot and grime on the bus, and constant removal not only keeps buses clean, but also removes and prevents the clogging of dirt within the bus engine, transmission, and other internal systems.

Depots in cities are usually quite huge, in some cases the size of an entire city block with large rooftops. These rooftops in many cases are used for additional parking of buses. Depots are characteristically massive because they require large turning radii for buses to maneuver within the building ultimately to get the bus safely to its parking spot. Bus depots hopefully are strategically located to minimize the distance between the depot and the start of the bus run.

BUS RAPID TRANSIT

Bus rapid transit aims to move people as conveniently, efficiently, and of course rapidly as a rail system. Bus infrastructure is normally the public city streets and highways. Buses can be severely delayed by existing traffic and overcapacity issues. A dedicated bus infrastructure, fundamentally a road or street only a bus is allowed in, can move people much faster when compared to normal bus service, which goes very short distances between stops. Bus shelters at bus stops provide weather protection for waiting passengers.

Bus rapid transit systems have fully dedicated right of way infrastructure that removes all delay to avoid traffic congestion. Some extensive bus rapid transit systems have station stops similar to subway and/or light rail station stops, in addition to their own dedicated lanes. A true bus rapid transit system includes bus priority at intersections, arguably the most essential element of the infrastructure.

Bus priority is the ability of the bus driver to hold green lights, and hold upcoming cross-traffic until the bus passes the intersection. Bus rapid transit allows buses to move freely with no delay from existing road traffic, and in some cases has a completely dedicated roadway at different grade than regular street traffic. Dedicated bus lanes on existing streets or avenues, is not considered bus rapid transit, in many ways but especially if the bus does not have intersection priority.

The genesis of bus rapid transit actually started with dedicated bus lanes introduced down major thoroughfares. The evolution of true bus rapid transit included the institution of off board fare collection, enclosed stations, platform-level boarding, and traffic signal control to give the bus priority at intersections. In the 40+ years of bus rapid transit, it has rapidly proliferated all over the world.

Any type bus can be used in a bus rapid transit operation, including articulated bus for additional capacity. Bus rapid transit makes travel faster, with rights of way that may be elevated, at grade, or in a tunnel. Many bus rapid transits include stations similar in scope and capacity to stations of subways, elevated train line, or light rail systems.

MATERIALS

The basic materials that make up the mass transit infrastructure are the traditional construction materials: concrete, steel, wood, brick, paint, glass, asphalt, ceramic tiles, adhesives, plastics, rubber, various steel alloys, copper for wiring, etc. All of these materials must be processed with great energy and require a lot of valuable natural resources. Tons of concrete and steel are utilized and they must be strong and durable to last a long time. In many cases concrete is strengthened with steel reinforcement bars or rebar, and working in tandem or alone concrete and steel make up the foundation of the mass transit infrastructure.

Bus infrastructure is made up of asphalt, tar, and concrete, and your typical roadbed material for streets or highways. Materials and components used for mass transit facilities and some stations or terminals are similar to typical building construction, including electrical wiring, conduit and outlets, communications, lighting, windows and skylights, plumbing, heating ventilation and air conditioning units, and characteristic roofing materials.

CONCLUSION

The history of mass transit and its infrastructure goes back almost 200 years. The very first mass transit infrastructure was the rail built into the streets to help horses carry people in carriages in large groups. Then the trolley car emerged, along with steam locomotives that were tried for mass transit. The large impacts of steam generation, specifically the soot from the coal-burning locomotive encouraged the electrification of trains, and thus the true beginning of mass transit infrastructure.

Electrification of the train system allowed the use of trains to travel in subterranean tunnels, not disturbing the above surface, and this helped to start and grow public transportation. Subways and elevated train systems which cities were built around, have their specific infrastructure, as well as light rail or tram systems, and are made with tons of concrete, brick, wood, cables, and steel.

Train infrastructure houses conduits carrying electricity, signals, communication systems, lighting, and water. Support structures such as substations, ventilation facilities, pumping facilities, line the transit infrastructure, and major components include station or terminal environments and the necessary track bed and rail system to propel trains that carry passengers from point to point within cities. Bus service usually runs on city streets, and Bus Rapid Transit includes its own dedicated infrastructure committed to buses only, so buses avoid being delayed by other traffic. Bus rapid transit can share roadway with tram or light rail service.

Ancillary facilities such as train storage yards, maintenance shops, and bus depots are an essential component of the mass transit infrastructure.

The ancillary facilities that accompany a subway or elevated train line system require tremendous square footage and a lot of space. Both heavy and light rail train systems have similar support facilities with comparable maintenance requirements, processes, and space requirements.

The vehicles involved with mass transit, train cars and buses have also evolved through the years from the small carriages to large multipassenger car, and continue to do so to this day. The train and buses today are modern, computerized, and include advancements in lighting, message boards, announcements, and automatic door opening and closing.

The evolution of mass transit in cities helped to grow cities. Mass transit can be a lifeline of any growing or revitalized city or neighborhood, in terms of development, quality of life, and economics. The history of mass transit centers on the development of its infrastructure, vehicles, and the use of energy, which is predominantly electricity for trains and fuel for buses. The mass transit infrastructure requires massive amounts of raw materials, labor, and energy to work.

Finding the precise and maximum effective energy matched with the right infrastructure, with the right mode or vehicle, was the cornerstone of the growth of mass transit. Energy is an essential requirement for the mass transit industry, and energy efficiency is at the epicenter of most of our modern sustainability challenges.

FURTHER READING

Urban Mass Transportation Planning by Alan Black 1995.

Defining an Alternative Future Birth of the Light Rail Movement in North America by Gregory L. Thompson Florida State University, <http://onlinepubs.trb.org/onlinepubs/circulars/ec058/03_01_Thompson.pdf>.

Recapturing Global Leadership in Bus Rapid Transit—A Survey of elect U.S. cities by Annie Weinstock, Walter Hook, Michael Repogle, and Ramon Cruz May 2011, <https://www.itdp.org/wp-content/uploads/2014/07/20110526ITDP_USBRT_Report-HR.pdf>.

The Blizzard of 1888; the Impact of this Devastating Storm on New York Transit by Christiano G.J., <http://www.nycsubway.org/wiki/The_Blizzard_of_1888;_the_Impact_of_this_Devastating_Storm_on_New_York_Transit>.

APTA—Glossary of Transit Terminology, <http://www.apta.com/resources/reportsandpublications/Documents/Transit_Glossary_1994.pdf>.

Chapter 3

Energy

INTRODUCTION

Energy is obligatory for mass transit. Public trains and buses all need a lot of energy to move millions of people each day as trains typically rely on electricity, and buses regularly use diesel fuel to work. Mass transit networks regularly use fossil fuel derived energy, which emits air pollution and creates a significant carbon foot print, thus adding additional greenhouse gases to the atmosphere, which accelerates global warming.

For over 100 years public trains have run on electricity, which is still predominantly produced by fossil fuel combustion. Electrical consumption begins with generation at a power plant, then transmission of electricity to a substation, which transmits electricity to transit's infrastructure. Buses are normally fueled at bus depots with fuel dispensing systems built into the facility. Electricity generation for trains and the internal combustion engine of a bus both rely on the combustion of fossil fuels to work. Renewable and clean energy generation reduces greenhouse gas emittance, saves finite resources, and helps lessen pollution.

The mass transit industry consumes considerable energy, and it is incumbent upon big energy users to conserve energy, become more efficient where possible, and continually consider the use of green energy. The more a transit agency opts to use or buy green energy it contributes to a healthier planet, and it fundamentally invests in the future growth of renewable energy.

FOSSIL FUELS

The first energy source to be used by human beings was fire, which provided light, warmth, and ability to cook food. To create fire initially the first people began by rubbing sticks together, using the heat generated by friction to set tree branches on fire. Years later oil extracted from animals, fishes, or plants were used as fuel for many applications. Still it was the discovery of fossil fuels that augmented the evolution of modern society.

Fossil fuels are the organic matter of ancient decomposed flora and fauna found deep under layers of the earth, and rose to prominence with the advancement of deep oil drilling technologies. Crude oil, coal, and natural gas are the major fossil fuels found beneath the earth surface. Petroleum

Sustainable Mass Transit. DOI: http://dx.doi.org/10.1016/B978-0-12-811299-1.00003-4
© 2017 Elsevier Inc. All rights reserved.

products are refined from crude oil. Refineries distill crude oil into fuel used for transportation, including gasoline, diesel, and jet fuel or kerosene.

Coal is a combustible sedimentary rock made of mostly carbon. Coal is plentiful in the world today, and took hundreds of millions of years to form. Coal was used early on in furnaces for heating buildings and hot water, and in many industrial processes such as casting iron into steel. Steam locomotives used coal as a fuel, and the coal powered steam engine was used to create an electric generator. Coal is mined from beneath the surface.

Natural gas is also extracted from beneath the earth surface, sometimes in deep underground bedrock, or in shallow swamplands. Natural gas may also be collected from landfills, sewage, or wastewater treatment plants. Natural gas has a low density and tends to rise to the surface of the earth through loose, shale type rock, and other materials. Natural gas is predominantly methane but it can also be in forms such as ethane, propane, butane, and pentane. The usage of fossil fuels has been a catalyst for the growth of contemporary civilization, and has helped advance and transform the world.

POWER GENERATING PLANTS

Electrical power generating plants typically produce electricity with the burning of various types of fossil fuels, such as coal, oil, or natural gas. The combustion or burning of fuel and the resulting heat and very high temperatures create a gas which is compressed, and used to turn blades within a turbine. In coal-fired plants steam is normally used to rotate the blades in the turbine, and the spinning turbine is connected to a rod in a generator that turns a large magnet. The spinning magnet creates a magnetic field that electrifies a wire, forcing electric flow and movement through the wire creating electricity.

In a natural gas turbine the gas is combusted and the resulting expanded gas is used to spin the generator rod. In a nuclear power plant uranium atoms are split, and the resulting heat is used to create steam. The energy produced is great, however, nuclear energy is a process that can result in devastation or destruction if something were to go wrong. The nuclear reaction creates so much heat; large amounts of cooling water must be used constantly to prevent meltdowns. In most cases the steam is cooled back into water in a cooling tower, and the water can then be reused. Renewable and clean electrical energy generating power plants including hydroelectric, solar, and wind, do not emit pollution or greenhouse gases upon generation of electricity.

ELECTRICITY FOR TRAIN SERVICE

Electricity used by trains starts in the generating power plant, and subsequent transmission through high-voltage lines that carry electrical current to the power grid. The power grid is the interconnected network of transmission lines and substations throughout the nation that transmits electricity. Mass transit substations receive electricity from the power grid, and supply electricity for the third rail or overhead catenary that provides the train with the required energy to run. In addition to traction power, the train car needs electricity for the opening and closing of doors, emergency brakes, lights, intercoms, speakers, message boards, signage, and the power for the ventilation system. Train storage yards can be powered from the substations because they normally use a third rail or an overhead catenary to move trains around the yard.

The mass transit substation normally converts and transforms voltage from alternating current to direct current for third rail traction power. Alternating current is used for the tunnel lighting, signal system, ventilation chambers, or water pump facilities of the subway infrastructure. Support structures, such as stations, terminals, and the ancillary facilities, maintenance shops, crew quarters, etc. are normally powered directly from the power grid using alternating current. Stations or terminals require electrical power for escalators and elevators, lighting, token booths or automatic ticket machines, communication rooms, signal towers, and possibly police or security facilities that are based at a station or terminal.

Rail maintenance shops use electricity that is required to be consumed for the benefit of train operations, including the power required to perform maintenance activities and run machines that overhaul motors and generators, fix or true wheels, and for train parts cleaning activities. Many maintenance shops also have special equipment, such as heavy duty cranes or pulleys, necessary to lift and maneuver extremely heavy train parts such as wheels, axils, and motors. There are numerous parts to a train with each piece part of the assembly. Parts may also be stored and retrieved using electrified lift and retrieval systems. Energy may be required for industrial elevators or special lifts, which may bring either personnel or parts from one level of the facility to the other.

For the employees who work at shops or depots, energy is required for ventilation, heat and cooling, to create ideal and safe working environments. Ancillary facilities throughout the mass transit infrastructure will require electricity, and may also require natural gas or oil for heating and hot water. In many transportation facilities, hot water is necessary for job functions, including cleaning operations. Electricity is the prime energy source for train operations, and it is primarily the combustion of fossil fuels that creates the majority of electricity from electrical power generating plants.

At the power generating plants the exhaust point releases gases that cause air pollution from what is considered a stationary source. Stationary sources are in fixed positions and mobile sources are those that are not in fixed locations, such as cars and buses, which exhaust similar air pollution and greenhouse gases, however, mobile sources spread out the emissions over an entire city or region.

DIESEL FUEL AND THE INTERNAL COMBUSTION ENGINE

Public transportation buses for almost 100 years have normally run on diesel fuel, and many buses now use compressed natural gas or other alternative fuels. Diesel fuel is refined from crude oil. When crude oil is processed at refineries, it is separated into several different kinds of fuels, including gasoline. Diesel fuel is heavier, has a higher boiling point, and has a higher energy density than gasoline. Diesel fuel works well with heavy vehicles such as buses, trucks, ships, construction vehicles, agricultural equipment, military vehicles such as tanks, and train locomotives in railroad or commuter rail. Many facilities including hospitals use diesel fuel for back-up generators.

The internal combustion engine relies on the exothermic chemical process of combustion. Similar to electricity producing power plants that use the combustion reaction to create great amounts of heat, the internal combustion engine process includes the burning of a fuel in a small cylinder called a combustion chamber. Fuel and air is let into the cylinder and ignited, which creates gases of high temperature and pressure. The expanding hot gases cause pistons, which are connected to a crankshaft, to move up and down. The crankshaft is able to create the rotational motion needed for the wheels of the vehicle to move in a linear motion. The combusted gas in the cylinders are continuously exhausted out through the tailpipe of the engine.

Internal combustion engines require a method for ignition within their chambers to initiate combustion. Compression ignition, which is used in the diesel engine, relies on pressure for ignition. Diesel engines take in air, and at peak compression of the air in the piston cylinder, a small quantity of diesel fuel is injected that permits the fuel to ignite instantly. Diesel engines and gasoline engines are both internal combustion engines that convert the potential energy of the fuel into the mechanical energy of the vehicle through a series of small combustions. Diesel engines do not have spark plugs, as it is the heat of the compressed air that ignites the fuel.

Diesel engines typically get better gas mileage than standard gasoline engines, as diesel has more carbon atoms than gasoline does, which contains more potential energy and greater power than regular gasoline engines. Compressed natural gas has been used as a replacement of diesel in buses. A major issue is that compressed natural gas fuel storage tanks require special and costly fueling infrastructure. Special care must be taken when fueling buses with gas under high pressure. Methane is also a greenhouse gas, so any unintentional leakage, contributes to global warming. Compared to diesel, natural gas burns much cleaner with less emissions of particulate matter than other petroleum fuels, although the compressed natural gas internal combustion engine produces similar pollution and greenhouse gas as diesel exhaust.

The Exhaust

The combustion process that converts diesel fuel into the energy necessary to power buses, exhausts toxic air pollution that dirties the atmosphere, and greenhouse gases that contribute to climate change. The combustion reaction occurs when the diesel fuel hydrocarbons react with oxygen to produce carbon dioxide and water. Unfortunately combustion is not always efficient and incomplete combustion produces, in addition to carbon dioxide and water, harmful pollutants and particulate matter or soot. Incomplete combustion leads to emittance of carbon monoxide, nitrogen oxides, sulfur oxides, volatile organic compounds, and helps create ground level ozone.

Fossil fuels typically burn incompletely releasing detrimental byproducts into the atmosphere, including evaporated or unburned fuel. Fossil fuel combustion is the largest source of air pollution. In order to meet emission standards the internal combustion engine is enhanced with the help of the catalytic converter, which is a ceramic structure coated with a metal catalyst utilized to enhance combustion, and reduce pollutants.

COMBUSTION AND THE GREENHOUSE GAS EFFECT

During the combustion of fossil fuels, which creates a great amount of heat whether in the internal combustion engine or at an electric power generating plant carbon dioxide and water vapor are the expected products of the combustion reaction, and unfortunately both of these projected products are greenhouse gases. The release of carbon dioxide, the main greenhouse gas, is the leading cause of global warming. Referring to Fig. 3.1, in 1750, the estimated beginning of the Industrial Revolution, total carbon dioxide in the

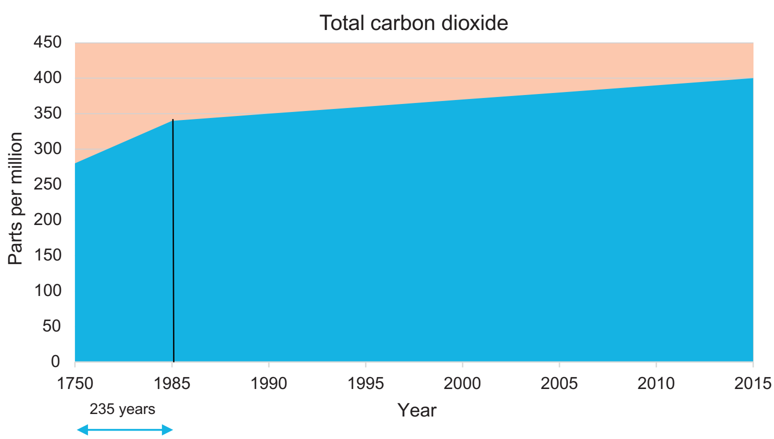

FIGURE 3.1 Total carbon dioxide.

atmosphere totaled approximately 278 parts per million, and by 2015 the level is a little over 397 parts per million. In 235 years the total level of carbon dioxide increased by about 60 parts per million, and in 35 years since 1985, the increase is also 60 parts per million.

The greenhouse effect is essential to all life on earth, however, too much greenhouse gases in the atmosphere creates too much heat, and continuously warms the air, land, and oceans. Of course humans and animals exhale carbon dioxide, and trees, plants, and vegetation all absorb carbon dioxide while releasing oxygen, which humans breathe. Therefore there is always a quantity of carbon dioxide in the atmosphere. However, a steady increase, and an overabundance has resulted in a risky increase in greenhouse gases.

The atmosphere acts like a real greenhouse. An authentic farmer's greenhouse allows sun to enter through a transparent material to keep plants warm, and then traps heat within to keep the inside of the greenhouse relatively warm, especially in winter. In reality when the rays of the sun penetrate the atmosphere, and brighten the earth, it also heats the surface that absorbs the rays and radiates heat back toward space in the form of heat waves. Greenhouse gases in the atmosphere absorb these waves, gaining heat themselves, and radiate more heat back toward earth.

The average earth surface temperature has increased almost 1°C or 1.6°F over the past century. The more greenhouse gases in the atmosphere the more heat is essentially regenerated, which makes the planet including oceans hotter. Global warming leads to rising sea levels due to ice melting and warmer air includes a higher moisture content due to evaporation of water bodies, which leads to more extreme and ferocious weather events. Greenhouse gas emissions arise mainly by burning fossil fuels.

There are several major greenhouse gases including carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, ozone, and water vapor. Carbon dioxide is the main greenhouse gas. The amount of carbon dioxide emitted during fossil fuel combustion can depend on the carbon content of the fuel. Coal has the highest level of carbon, than petroleum and natural gas. It is a scientific certainty that increasing greenhouse gas concentrations in the atmosphere warms the planet and the increase in greenhouse gas over the last two centuries is related to human activities.

As indicated in Fig. 3.2 US carbon dioxide emissions reached a peak around 2005 with over 6000 metric tons of carbon dioxide equivalents emitted. In the past decade carbon emissions have lowered based on less coal burning, albeit more natural gas usage, counterbalanced by added growth of renewable energy sources. In addition, the added spirit of conservation and energy efficiency in many sectors, including many initiatives piloted by mass transit agencies is helping to reduce carbon emissions in the United States.

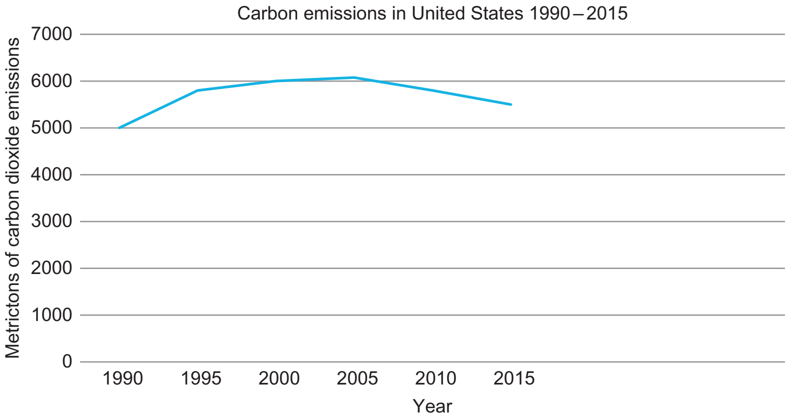

FIGURE 3.2 Carbon emissions in the United States 1990–2015.

FINANCIAL ASPECT OF ENERGY IN MASS TRANSIT

Operating a mass transit system, either a heavy or a light rail line or a bus service, either public or private, is similar to running any typical business with assets, budget, customer service, and labor. Assets in mass transit include the infrastructure, facilities, equipment, material, spare parts, and vehicles. Budgets are set by agency presidents or civic leaders. At the very core of mass transit is customer service. Labor includes both staff employees that work in all divisions and a management team of top professionals in leadership positions.

A mass transit agency must also operate their system efficiently, within budget, and avoid unanticipated expenditures and like any business, at the bottom line is the budget. A big part of the budget for a mass transit network is paying for energy. Therefore energy is a top issue that affects the entire operations, and is a discussion point during strategic planning and budgeting. It has to be estimated into final and future budgets, and energy consumption must be monitored and measured.

Hence in addition to conserving energy for the benefit of the environment, it also makes sense to conserve energy for the economic benefit. Electricity and fuel cost a lot of money, so the benefit of conservation extends to the economics of the agency. The balance of energy, environment, and economics is often subject to much debate. Timing is also a consideration. Many decisions in the energy world have to be made by looking at both the current and expected prices of energy, specifically fuel cost as oil prices traditionally fluctuate with many factors involved. Electricity usually has a more stable price structure.

Mass transit networks pay for electricity much the same way any business does, and many power distribution entities which supply electricity to transit systems get electricity from a variety of sources such as hydroelectric, biomass, or wind generating. Transit agencies can receive portions of the electricity they purchase from renewable generating sources. If the renewable resource generating electricity is available, most often for a premium, the agency can purchase renewable energy, such as hydro, solar, biomass, or wind.

RENEWABLE ENERGY

Renewable energy includes energy extracted from the sun, air, water, or the land. These include solar, wind, hydroelectric, and biomass, and when they are creating electricity, they normally do not directly emit pollution or greenhouse gases during generation with the exception of biomass electricity generation, which uses the combustion process. Therefore hydroelectric, solar, and wind are considered clean energy sources. Energy that is both renewable and clean are considered green energy.

Hydropower is currently the biggest renewable energy source for electricity generation in the United States. The process includes flowing water, usually from a waterfall or manmade dam, and the flowing water is used to spin a turbine connected to the generator. Wind power is produced by a wind turbine, which is moved by wind currents. Solar energy and photovoltaic systems convert sunlight into electricity. It does take energy to build and operate the equipment associated with renewable energy production. Materials for solar panels, wind turbines, and dams are transported, built, and assembled with the use of energy. In effect, even so called clean energy resources may have to use fossil fuel derived energy in its creation and delivery.

Renewable energy power plants also require massive amounts of space requirements. Solar and wind farms require great amounts of land compared to amount of land required to produce electricity from coal or natural gas. Waterfalls and dams required for hydroelectric energy production require massive infrastructure. After installation, and during the production of electricity, solar, hydroelectric, and wind farms do not emit any air pollution or greenhouse gases while producing electricity. Solar panels do not even have any moving mechanical parts.

Fossil fuels, however, plentiful are a finite or nonrenewable energy source. Nonrenewable resources do not multiply, grow, or become consistently available. Most of US electricity is still generated from power plants that uses fossil fuels, and in 2015 as indicated in Fig. 3.3, coal was used for about 33% of the electricity generated in the United States, and approximately 33% was fueled by natural gas. Therefore as of 2015, two thirds of electricity in the United States is produced by burning of fossil fuels, which of course releases great amounts of air pollution and carbon dioxide during the combustion process.

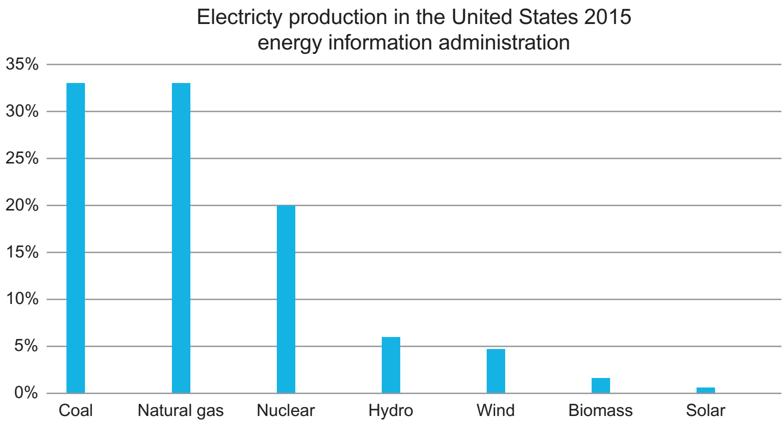

FIGURE 3.3 Electricity production in the United States 2015. *Energy Information Administration.*

In order to reduce pollution and greenhouse gas emittance, many states in the United States have mandated requirements of how much renewable energy is to be targeted for generation each year. Public electric utilities or power distribution authorities usually receive their electricity from a diverse mix of energy sources, and industries, businesses, and consumers can request green energy, with of course at premium prices. Wind power is the fastest growing renewable energy for electricity generation, however, hydroelectric is the most abundant in the United States as of 2015.

Hydroelectric

Hydroelectric power plants produce electricity by using fast and fierce flowing water to turn the propeller-like blades in a turbine, which then turns a magnetic shaft in a generator. Water is everywhere, in oceans, in rivers, and in lakes with rain and snow coming down from the sky, which replenishes our supply constantly in water bodies and reservoirs. Rainwater that infiltrates into the ground replenishes the underground water supply. Water is needed to survive on planet earth for drinking, plant growth, etc., and it is essential for the ecosystem and ecology.

Natural waterfalls have been utilized as an energy source for years. Manmade dams can be built to harness energy similar to natural falls. Dams are built on large powerful flowing rivers, preferably where there is a long drop in elevation, and the dam stores a lot of water behind it in a reservoir. An exit valve is built under the reservoir to allow water to flow through the dam, which first goes through a turbine that generates electricity, then the water flows back into the river. Water that has already flowed through the turbines can in some cases be pumped back into the reservoir to increase the capacity of the power plant.

Hydroelectric generating power plants operate efficiently and cleanly, as far as emissions are concerned, differing from coal burning or any other fossil fuel burning process that creates electricity. Environmental impacts include noise concerns from waterfalls and potential impacts on fishes and wildlife in the rivers where dams are built.

Solar Energy

Solar power relies on sunlight to create electricity. Solar or photovoltaic panels transform sunlight into an electric current with materials made out of semiconductors. Solar thermal processes use sunlight to heat water or other liquids, sometimes a synthetic oil, to transfer heat for heating or hot water. Solar power plants generate electricity from photovoltaic systems by combining individual solar panels in rows within solar farms, or from concentrated solar thermal plants, using solar thermal energy to make steam for a turbine to make electricity.

A photovoltaic cell converts light into electricity, when sunlight hits the panels it initiates a chemical reaction that excites electrons to move within the material, and an electric circuit captures the electron movement, and creates electricity. When sunlight hits the solar panels, it creates direct current electricity, which is converted into alternating current by an inverter, and the electricity travels through transformers for delivery onto the transmission lines, for local electric distribution.

Concentrated solar power plants use maneuverable systems with a strong lens or a mirror to follow the sun's rays and focus the sunlight into smaller areas to maximize and concentrate the beams of the sun to create steam from water. The steam is piped to a turbine generator to produce electricity. Solar energy can also be obtained by indirect transfer of heat using material that transfers heat from sunlight to a heat carrying medium such as air, water, or other liquids.

Wind

Wind turbines use the power of wind to create electricity. Wind power produces electricity without any emissions nor greenhouse gases during operation. Wind farms consist of many individual wind turbines that are connected to electric power transmission lines. Most wind turbines consist of three blades and sit atop a tubular tower, which in many cases are able to rotate into the face of the wind. Wind farms can be either onshore or offshore. Onshore wind farms require many turbines, usually between 80 and 300 feet tall and to be anywhere near competitive with fossil fuel burning electrical generation, requires much land and space. Many actual former real farm owners, lease land to companies to place wind turbines on their land.

Offshore wind farms include turbines placed in the ocean to capture the sea breezes, and produce more energy because generally there is stronger and more unobstructed wind to absorb. However, operation and maintenance costs are higher because of their location in the water. Construction of offshore wind farms is complicated and much costlier than onshore wind farms. There are not many large-scale offshore wind farms currently operating in the United States, however, there are many future projects planned along the US coasts. Wind power is growing in each of the 50 states with every state home to a wind farm, a wind project, or include facilities powered by wind energy.

Wind has been used by humans going back thousands of years with the use of sails for ships and windmills which were used for simple machinery work like granulating wheat and for pumping water. Windmills also were used for providing water for the steam engine. Wind turbines will generate noise and have small impacts on bird and bat populations. From an aesthetic point of view wind turbines can be seen in some instances as a blight on landscapes, however, aesthetic beauty is definitely in the eye of the beholder. A symbol of sustainability is sometimes depicted with a picture or silhouette of a wind turbine. The visual impact of the wind turbine can stir up feelings for the environment.

Biomass

As an energy source biomass can be burned to produce heat or steam to generate electricity or converted into biofuel such as methane gas, ethanol, or biodiesel. Biomass has been used for energy since people began burning tree branches to make fire. Biomass include trees, branches, plants, grass clippings, paper, and wood chips. In many cases the biomass material used for energy is the byproduct of an activity. For example, byproducts of forestry and farming that at one time were discarded as waste can now be used for energy in a process referred to as waste to energy.

The burning of wood releases air pollution similar, but not to the extent of fossil fuels, and also produces the greenhouse gas carbon dioxide. In many cases the crops used to make biofuel are specifically grown to convert to fuel. This is a great example of renewable energy because the crops are grown, harvested, converted into energy, then the crops are planted, and regrown again.

Agricultural crops can be fermented to produce ethanol, which can be an additive to gasoline. Biodiesel is produced from various types of plants, including switchgrass, corn, sugarcane, bamboo, and eucalyptus trees, as well as used products such as vegetable oils. Algae is being widely considered as a potential for biomass, as algae grows very fast. Research is ongoing for new approaches to improve algae as a source of biofuel.

US Electricity Generation and Clean Power Plan

In 2015 the United States generated about 4 trillion kilowatt-hours of electricity according to the United States Energy Information Administration. In the United States about 67% of the electricity generated was from fossil fuels with 33% coal, 33% natural gas, and 1% petroleum. The rest of the major energy sources include 20% Nuclear, 6% Hydropower, 4.7% Wind, 1.6% Biomass, and only 0.6% from Solar, accounting for almost 13% renewable resources in electrical production. It is projected that both natural gas and renewable electricity production will increase over the next decades, while coal will most likely decrease and nuclear hold steady.

From 1975 carbon emissions from coal burning power plants more than doubled in almost 30 years with an emissions peak in 2005. Since then coal producing power plants have seen a decrease, and that trend continues presently. However, as coal emissions decreased in the past decade, emissions from natural gas has increased. Natural gas does burn cleaner than diesel with much less particulate emissions. Renewables have also increased in the past decade as the US government attempted to move regulations to encourage more renewable and cleaner electrical energy production.

The Environmental Protection Agency's Clean Power Plan is a national directive that aims to move the United States toward clean and low polluting energy. The Clean Power Plan establishes state-by-state targets for carbon emissions reductions with the goal to reduce national electricity emissions by 32% below 2005 levels by 2030. The Clean Power Plan provides options to cut carbon emissions including investing in renewable energy, being more energy efficient, and moving further away from coal-fired power. States are free to establish their own plan and can use any method or combination to meet their goals. States can also join together for reducing their carbon emissions through joint projects and emissions trading programs.

For overall renewable energy consumption in the United States please refer Fig. 3.4. In 2015 hydropower accounted for 25% of renewable energy consumed with biomass wood 21%, biomass waste 5%, biofuels 22%, wind

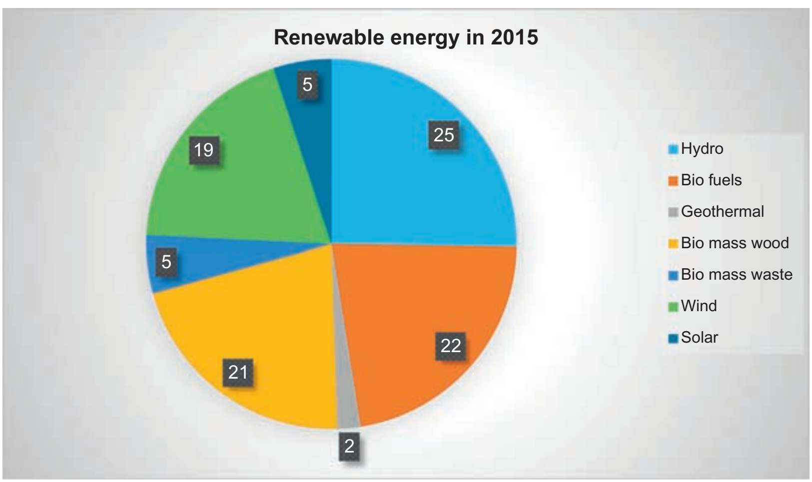

FIGURE 3.4 Renewable energy in 2015.

19%, solar 5%, and geothermal 2%. For renewable sources to advance and to keep growing it is imperative that investments continue to be made in renewable energy generating power plants. The Clean Power Plan is a movement toward renewables, because it mandates all states to lower their emissions, and encourages the use of renewable energy.

GREEN ENERGY FOR SALE

Mass transit uses an enormous amount of energy, that pollutes and emits greenhouse gases, so it is incumbent to look at renewable or green energy as an option. Public transportation agencies do not normally own their own power plants; however, it is possible to purchase renewable or green energy. Agencies can invest in solar, wind, biomass, or hydroelectric power by purchasing renewable energy certificates also known as RECs.

RECs represent energy that has been produced in an environmentally sustainable way and can be bought and sold. Many states have mandatory requirements of the level of renewable energy they must produce each year. Some states that cannot meet their goal can purchase green credits from other states to satisfy their state goals. In order to help achieve compliance with EPA's Clean Power Plan, as originally intended, individual states would set targets for entities within their state to buy renewable energy, depending on the level of electrical consumption. In some cases a train system is a city's largest electrical consumer.

Alternative Fuels

Buses have experimented with alternative fuels from renewable and cleaner sources. Alternative fuels such as ethanol, biodiesel, and hydrogen produces less pollution and greenhouse gases than petroleum products such as gasoline or diesel. Ethanol is derived from corn and other crops, biodiesel is derived from vegetable oils and animal fats, and hydrogen can be used in fuel cell vehicles which emit no harmful air pollutants, however, in some cases the hydrogen is extracted from natural gas or methane. This illustrates that some renewable energy commencement requires nonrenewable energy to help ignite the process.

CONCLUSION

Of all of the major aspects of mass transit the one with the most potential to significantly or adversely impact the natural environment is the use of energy. Electricity generation at a power plant and the internal combustion engine of a bus both rely on the combustion of a fossil fuel, which emits air pollution and greenhouse gases. In the atmosphere greenhouse gases absorb heat waves radiating from the earth and re-radiate more heat back toward earth keeping the earth warm. An overabundance of carbon dioxide and other greenhouse gases in the atmosphere, increases air, land, and ocean temperatures and this adds more moisture to the atmosphere and increases the sea levels.

State governments are setting carbon dioxide reduction targets along with steep goals to help stimulate further renewable energy production in individual states. In the past decade carbon emissions have decreased in the United States thanks to the decrease in coal producing electricity and the proliferation and growth of renewable energy, which has helped offset the additional emissions from the increased use of natural gas for electricity production. The relationship between mass transit and energy is intertwined and the more transit agencies opt to conserve and save energy, use or buy green energy, it fundamentally participates in the health of the planet.

The cost of electricity and fuel is a major expense to any mass transit agency, therefore, in order to help make the business case better for green energy investment, combining robust sustainability measures that provide energy consumption reduction can balance the additional cost of purchasing renewable energy credits. It is also incumbent upon mass transit entities that use a lot of energy, and compromise the environment, to invest in green energy that does not pollute. Power generating plants using hydroelectric power, solar energy, and wind power produce electricity without direct air emissions and greenhouse gas releases.

FURTHER READING

U.S. Energy Information Administration, <www.eia.gov>.

The EPA Clean Power Plan, <https://www.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants>.

Carbon Dioxide Emissions, <https://www3.epa.gov/climatechange/ghgemissions/gases/co2.html>.

NASA Earth Observatory, <http://earthobservatory.nasa.gov/Features/GlobalWarming/page2.php>.

Chapter 4

Environmental Impacts

INTRODUCTION

Environmental impacts are direct effects inflicted on either the natural or built environments, which can cause change leading to adverse consequences. Public train and bus service have distinct environmental impacts respective to their infrastructure, facilities, and vehicles. The most significant environmental impacts of mass transit stem from the use of energy, with the emittance of pollution and greenhouse gas for both train and bus operations, however, there are numerous additional potential environmental impacts associated with mass transit, that can damage or harm the environment.

Public train operations through subway tunnels or on large elevated structures create impacts such as loud noise generated by steel wheels on steel rails, and the vibrations of large elevated structures when trains pass over. Other major environmental impacts of subway infrastructure include water infiltration and discharge, and passenger waste and refuse disposal. Each day passenger waste, the public generated trash, needs to be collected, bundled, and disposed.

There are many challenging environmental issues related to historical construction materials and electrical equipment traditionally used for subway and elevated train infrastructure, and over time, infrastructure materials tend to deteriorate. Materials used that were later discovered to be harmful and were used in abundance in legacy transit systems throughout the world, include lead-based paint, asbestos, polychlorinated biphenyl (PCB) oil and mercury in great quantities for infrastructure and electrical equipment. These substances years later were found to be harmful to humans and hazardous to the environment, and uncontrolled releases can cause major contamination issues for the air, water, and land.

Buses, in addition to cars and trucks, add to the overall outdoor air pollution in cities. Bus depots have activities and significant indoor air quality impacts. The traditional use of underground storage tanks to store fuel has showed that over time there is a better than average chance that a tank has leaked, thereby contaminating soil and groundwater. Ancillary transit facilities have potential environmental impacts due to activities and maintenance. Mass transit infrastructure is traditionally very large and intrusive, leading to potential visual impacts on neighborhoods, and light pollution.

Sustainable Mass Transit. DOI: http://dx.doi.org/10.1016/B978-0-12-811299-1.00004-6
© 2017 Elsevier Inc. All rights reserved.

THE HISTORY OF IMPACTS ON THE ENVIRONMENT

The earth was not created with buildings, sewers, streets, subways, pipe lines, landfills, roads, dams, or any other man-made infrastructure commonly referred to as the built environment. From the beginning, as the land did not include any man-made structures yet, the hills of the land naturally contoured, and rivers flowed smoothly in the course that nature intended. Land had not been tampered with, so rain came down from the sky and naturally flowed into lakes, rivers, and streams, creating natural habitats and ecosystems.

Arguably, the first environmental impacts from human activities were most likely the smoke from fire, and the leftover ashes from the burning branches used to keep the fire lit. Smoke brought air pollution in the form of particles, dirtying the air, and the ashes needed to be put somewhere. Since the start of civilization, people who began living in permanent settlements have had to deal with the challenges of shelter, getting clean water, removing solid waste and disposing of sewage. As mankind evolved into the modern city lifestyle, large destructive impacts on the natural environment were the unfortunate byproduct of the immense residential, manufacturing, agricultural, energy, and transportation infrastructure built into the natural landscape.

For many centuries mankind has been building its infrastructure in the natural environment, and disturbing the balance of nature, with historic environmental destruction. Humans destroyed wetlands, and other valuable ecosystems to build cities, knocked down hills and filled in rivers, built ports in the coastal areas, essentially rearranging the natural landscape. Notably, some infrastructure was built to mimic the duties of the natural landscape; such as storm water sewers which needed to be implemented to remove rainwater that fell on the first communities.

The industrial revolution accelerated the evolution of modern society, but also created and left behind a trail of contaminated air, water, and land. The growth of cities saw the advent of extensive urban infrastructure, agriculture, industry, and manufacturing, resulting in air pollution, water pollution, and soil contamination from activities associated with essential services. In addition, some environmental impacts create a disturbance to humans or animals such as unwanted sound, or damage the existing built environment with potentially destructive vibrations.

NOISE AND VIBRATION

As trains move at a very rapid speed in subway tunnels, they run unimpeded from point to point in massive concrete and steel structures, that are built to withstand the pressure of soil and groundwater. The subway tunnel must be designed not to shake or rattle so that it does not disturb or damage above ground structures such as buildings, or sensitive receptors such as schools or hospitals. It is sometimes inevitable that some vibrations are felt above the surface, of course depending on how shallow is the tunnel.

Vibration concerns are a critically important civil engineering design component of subway service. The subway tunnel fundamentally may have only infinitesimal movement as heavy trains pass through, build up speed, and then come to a complete stop. The track rail layout which supports the moving trains must be built in such a manner that minimizes vibrations. The steel rails which are placed on numerous cross beams called ties, usually made from wood, distributes the load of the moving train evenly on the foundation of the subway tunnel floor to curtail vibrations.

The structure of the tunnel has to be built so strong, that any vibrations are miniscule. Vibrations can cause damage or cause destruction to above ground structures, and can move in any direction, side to side or up and down. Ground borne noise can also be generated as the train vibrations can be transmitted through certain types of conduits. Potential noise above ground can be generated by the vibrations under the ground if loose structures or conduits transmit vibration, which in turn creates a noise impact above ground.

Noise from trains is also a concern as in some cases unwanted sound can disturb the quality of life of everyday living. Sound is created by the train, specifically at the steel rail and steel wheel interface. Most train lines have miles and miles of track rail so trains can move from location to location. Rails do not come in mile long pieces; in fact, it is standard that rail is either 39 or 78 ft long, the usual size of a long truck. So pieces of rail must be lined up precisely so they match, and if the rail gap is off, even the slightest amount, as the train goes by, a clink or clank will be heard, causing in some cases loud noises as the train travels. In addition, curvature of the rails can cause a screech as trains travel on curved track. The wheels on the train remain straight, the rails however are curved, and upon going around curves, the friction between the wheel and the rail can cause severe noise around curves.

On elevated train lines noise and vibration are also of large concern. Of course the big difference between below ground and above ground transit infrastructure is people on the surface can both see and hear the trains as they travel at grade or on elevated infrastructure. Noise from elevated train lines usually are unimpeded, can be heard covering great distances, and can be of great concerns to neighbors where elevated lines travel adjacent to residential areas. The structures need to be quite strong to withstand the vibration of the rumbling train. A key to minimizing noise and vibration is good and consistent maintenance practices, to ensure the track and structures remain as designed to curtail noise and vibrations.

Noise Pollution

Noise pollution is the excessive sound level that can disturb human or animal life. In addition to transit infrastructure and vehicles, cars, trucks, airplanes, and construction activity all contribute to ambient noise levels in cities. Noise pollution can affect human health. Noise can induce hearing loss, contribute to cardiovascular effects, and can cause hypertension or high blood pressure, stress, tinnitus, or ringing in the ears, and mostly disturb people trying to sleep. Noise is basically unwanted sound. It can be subjective and effect people differently.

There are some environmental regulations in regard to noise. Noise laws vary from state to state, differ among cities, and not all cities even partake in a noise law. A noise ordinance may include general rules against making excessive noise that is considered a nuisance. Most noise ordinance set specific guidelines for the level of noise allowed at certain times of the day. For example, it is common for noise rules to prohibit construction before a certain time in the morning and not after certain times in the evening. The Environmental Protection Agency (EPA) pursuant to the Noise Control Act of 1972 and the Quiet Communities Act of 1978, is the national regulator of noise concerns in the United States.

WATER IMPACTS

Groundwater infiltration into a subway tunnel is inevitable, and a complete drainage system is required to remove and dispose of water that gets into the subway tunnel. Large drainage systems which direct water toward a pumping system must be designed and engineered into the subway infrastructure. During rain events, storm water can get into the subway infrastructure, through ventilation gratings, station entrances, or other openings in the tunnel. Water that gets into the system is directed to the pumping station and pumped into a nearby sewer. Pumping systems usually include a large catch basin which fills up and is connected to an adjacent sewer system. When the basin is full it starts to slowly pump water into the sewer.

With the concern of water getting into a subway tunnel the protection of the electrical equipment is of utmost concern, especially the live third rail where electricity flows constantly. If water is not drained properly and builds up especially in the track areas, electricity may need to be turned off to prevent the short circuiting of the system. Station or terminal environments are often washed daily to keep a clean and fresh appearance. Filthy stations do not appeal to anyone, while waiting on the subway platform. Drainage is also necessary for waste water removal due to cleaning and maintenance activities.

Another concern of storm water getting into the system, is that the runoff can carry pollutants, such as oils, dirt, and debris from the surface above into the subway environment. This can clog the drainage and pumping system rendering it unusable which could flood the tracks of the tunnel and stop service. Refuse in general if not managed properly can become an environmental concern. During rain events, if sewers become backed up, the potential for flooding exists, and water will find its way to its lowest level which in many instances in cities is the subway tunnel environment.

Storm Water Runoff

The built environment eclipsed the ability of the natural environment to absorb rainwater and let water naturally flow into rivers, lakes, streams, or oceans, or infiltrate into the ground. Cities in general have paved over or built upon the majority of available land minimizing the potential for natural ground infiltration, which can replenish groundwater supply. Storm water that hits the pavement and is not emitted into a sewer basin, can runoff into the nearest water body, an in many cases carry with it any debris or pollution that is in its path. Storm water running off impervious surfaces can pick up remnants of gasoline, motor oil, trash, and debris such as plastic bottles that do not make it into a garbage or recycling container.

CHALLENGING MATERIAL AND EQUIPMENT

There are many tons of material and electrical equipment as part of the traditional mass transit infrastructure. Over the past century materials, such as concrete and steel, piping, and electrical equipment including transformers and rectifiers, have been essential parts that make up the subway train tunnel and elevated train line infrastructure. These materials and equipment over time deteriorate which can lead to significant environmental impacts, because some additional components of materials and equipment can be problematic in less than favorable conditions.

In legacy transit infrastructure the foundation materials, concrete and steel, required protective coatings to prevent erosion and corrosion, and traditionally lead-based paint was used as both the initial paint and any over coat painting required. Electrical equipment including transformers, which in many cases included PCB oil, and electrical rectifiers for a brief period in the early to middle part of the last century utilized liquid mercury. Over the history of mass transit infrastructure asbestos insulation was used in piping, electrical material, and building material such as floor tile or roof shingles.

Lead-Based Paint

Mass transit infrastructure of concrete and steel contain surfaces traditionally coated with lead containing paint, specifically the steel members that make up the elevated train structures. Lead was intentionally added to industrial paint used to coat steel columns and girders to prevent moisture from causing corrosion. Lead is a hazardous material, and lead poisoning can cause damage to the nervous system, kidneys, and reproductive systems in adults. More prominently it is truly dangerous to small children in that it can severely stunt development. Lead was banned from household paints, toys, and furniture in the United States in 1977 to protect children.

Miles and miles of elevated train steel infrastructure crisscross cities, including bridges and overpasses, and the steel pieces of legacy infrastructure exposed to the weather were most likely painted with a lead-based paint. Over time with exposure to moisture, painted surfaces tend to dilapidate and begin to peel, and severe deterioration causes pieces of loose and flaking paint to fall off the structure and land on the ground or surface below. Steel surfaces often require touch up maintenance, or more often after several years a complete over coating, therefore at times it may be layers of painted surfaces containing lead coming off the structure.

The peeling off of paint chips emanating from mass transit infrastructure is a potential significant environmental impact. Free and uncontrolled paint chips can wind up in the street or ground below, in the storm sewer, as runoff contaminating the nearby waterbodies, or worse, paint chips could pollute playgrounds where children congregate. Urban infrastructure is plentiful with existing steel structures, including transit, highway, or other steel structures such as a water towers. In older or run down parts of cities a majority of structures have the appearance and evidence of loose and flaking paint on exposed steel members.

In addition to severe weather conditions that cause surface coatings to peel, the vibration of the structure as trains roll by can help expedite or exacerbate loose and flaking painted surface conditions. Also, when painted surfaces lose their protective coating, it can accelerate corrosion. Transit facilities such as older maintenance shops or depots also may have traditionally been painted with lead containing paint. Lead-based painted surfaces is a significant environmental aspect of mass transit infrastructure, especially potential adverse result of uncontrolled paint chips.

Polychlorinated Biphenyls

PCBs were most widely used as dielectric fluids in electrical equipment specifically electrical transformers, and commonly found in the insulating fluid for transformers, and capacitors in light ballasts. Other applications include use in paints, sealants, caulking, adhesives, electrical cables, and electronic components. Transformers are used in substations, or high a top electrical transmission lines, and are generally part of the electrical grid distribution system. PCBs are toxic and potentially carcinogenetic and production was banned by the United States in 1979.

Transformers that contain dielectric oil containing PCBs were traditionally located in substations and electrical distribution rooms in the mass transit infrastructure. Transformers could have in many cases up to five hundred gallons of oil, some containing PCBs in low percentages, and some with extreme amounts of PCBs. Spill prevention systems including secondary containment are required to prevent spills from entering drains. Some transformers also deteriorate with time, and leaks can occur posing a potentially severe environmental impact.

Mercury Arc Rectifiers

A mercury arc rectifier is a major electrical device used for converting high-voltage alternating current into direct current, utilizing a cathode made from mercury, in its natural form as a liquid. They were used often until replaced by semiconductor rectifiers in the 1970s. The rectifiers worked well except mercury vapors that leaked from their canisters were potentially harmful to workers who had to work in substations, as mercury could leak out in its natural form and expose workers to elemental mercury, which could lead to mercury poisoning.

Electrical equipment, and the associated wiring that provides the energy for trains to run is vital to the mass transit infrastructure. In addition to the dangerous levels of voltage continuously running through wires and conduits, some electrical equipment containing toxic and potentially harmful liquids, such as mercury, can be very problematic with the severity of potential environmental impacts associated.

Asbestos

Some electrical equipment, including insulation materials and circuit boards, going back over a century of mass transit infrastructure, were typically made of materials containing asbestos, which is a naturally occurring mineral that has many super strengths, most notably the resistance to fire and heat. It is also a nonconductor so it was widely used in the electricity generating and distribution industry starting in the 19th century. It was also widely used in buildings for insulation, including roof materials, floor materials, and piping. Asbestos was commonly used until the health hazards of being exposed became known, as it was discovered that inhalation of asbestos fibers can cause fatal illnesses including lung cancer, mesothelioma, and asbestosis.

The incredible multistrength of asbestos material was extensively utilized in the mass transit infrastructure. There was asbestos material used for pipe insulation, floor tile, roof material, shingles, electrical circuit boards and wiring, gaskets, seals, and all kinds of insulation. However, over time the condition of building and infrastructure material begins to dilapidate, especially in harsh physical environments, and in the case of material containing asbestos any disturbed or damaged part of the material may release deadly fibers into the air. Material containing asbestos poses a significant threat to both workers and the riding public if the condition of the material permits fibers to be released. Management of material containing asbestos is of utmost importance in maintaining safe infrastructure.

REFUSE REMOVAL AND DISPOSAL

The mass transit infrastructure is designed to accommodate as many people as it can fit. In fact, in many cases it is designed to the anticipated peak volume it will be required to handle during the morning and afternoon rush hours. With millions of people using the mass transit infrastructure, it also means that the inevitable amount of personnel trash generated by the riding public needs to be addressed. Trash bins that line station environments are hopefully the destination of personnel refuse from passengers.

Unfortunately, not all trash winds up in the designated bins. Debris not placed in designated cans or bins, ultimately wind upon the train track. This debris can build up over time and in some cases can cause electrical fires as it can make contact with electrical lines such as the third rail. While some transit systems ban eating and drinking on trains, most allow food and drink at least in the station or terminal environment. Newspapers, coffee cups, and remnants of breakfast are the biggest culprits of debris generated, most often during the morning rush hour.

If the debris contains leftover food, even if the amount is just crumbs, and is not properly disposed of and winds up in the tracks, the refuse can attract vermin such as mice or rats. Vermin population in many inner cities is prohibitive, and that most often extends into the subway environment. This may require the use of strong chemicals for rodent control, which can have harmful side effects if not appropriately used, or is exposed to workers or the riding public. The less trash that is uncontrolled the less issue with vermin.

A refuse removal and disposal system or plan of action needs to be designed into the subway operations. Many transit agencies have refuse trains that pick up garbage at subway stations, usually at the end of the day or middle of the night. Most often work trains, sometimes diesel locomotives pulling open platform train cars, pick up bins, and bring refuse to an area for pick up and disposal. These areas are most often built into the storage yard facilities, where trucks can pick up the refuse, and cart them to the nearest landfill, or appropriate waste disposal facility.

MAINTENANCE SHOP IMPACTS

Mass transit ancillary facilities have potential environmental impacts depending on the operation or maintenance requirements specific to the facility. Maintenance shops use solvents and cleaners to wash train vehicle parts, and may have the need to replace and replenish fluids required in equipment, such as electrolytes contained in batteries. Spill prevention, including containment curbs, is important to eliminate the potential of chemical liquids from entering the sewer system.

Ancillary facilities in mass transit also need to store a lot of material, parts, and chemicals. Raw material storage facilities require specific parameters be included such as emergency spill kits, fire extinguishers, etc. to ensure the safe handling and storage of chemical materials such as paints, solvents, cleaners, adhesives, etc. Chemical bulk storage units are usually large above ground tanks filled with specific chemicals requiring special storage requirements.

Mass transit facilities are usually large industrial buildings which require large emitting boilers and heaters, in many cases using natural gas or electricity for heat and hot water. Boilers combust fossil fuels to generate heat, and hot water heaters can use gas or electricity for hot water. Maintenance functions can also require the use of water, and in many cases hot water which requires energy consumption. Facilities also have potential noise emanating from both within the shop due to maintenance activities, and rooftop heating, ventilation, and air conditioning (HVAC) systems.

BUS OPERATION ENVIRONMENTAL IMPACTS

Buses travel the city streets and add to the ambient noise of any city or region. Traffic generates noise, and buses are a big part of traffic. Noise from buses can also be heard when backing up as most large vehicles are equipped with back-up alarms. Buses rarely back-up during their run, unless a unique situation arises, however in depots or depot parking lots, which could be outside, a bus may have to back-up to park, thus creating a potential neighborhood environmental impact when the sound of the back-up alarms are heard in an adjacent residential neighborhood.

Tailpipe exhaust from buses contributes to air pollution as buses make their way picking up pedestrians at bus stops and shelters. Most public buses use diesel fuel or compressed natural gas. As diesel fuel is combusted the exhaust adds more carbon monoxide, nitrogen oxides, sulfur dioxide, and particulate matter to the atmosphere. Compressed natural gas burns cleaner and emits less fine particles than diesel or gasoline during combustion. Air pollution from the tailpipe of internal combustion continues to be a major environmental impact, threatening the health of humans and animals.

Air Pollution

Major air pollutants include fine particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, ozone, methane, and volatile organic compounds. Fine particles are small particles that can penetrate deep into a person's lungs. Nitrogen oxides convert to nitrogen dioxide which irritate lungs, and it has a distinct and strong odor. Nitrogen oxides also react with volatile organic compounds to form ozone, which creates smog and contributes to respiratory illnesses. Sulfur is a constituent of coal and diesel fuel, and sulfur dioxide is a gas emitted during fossil fuel burning.

Carbon monoxide is a byproduct of incomplete combustion and is a colorless, odorless, and nonirritating but extremely harmful gas. Vehicular exhaust is a major source of carbon monoxide. It is also a product of burning wood. Volatile organic compounds in the atmosphere evolve into methane, and help create ground level ozone. Air pollution can form as solid particles, liquid droplets, or gases and can be either primary or secondary. Primary pollutants are directly produced, such as the exhaust from a bus, and secondary are formed in the air when pollutants react with the air or with each other.

Ground level ozone is a secondary pollutant, as it is formed from a reaction of volatile organic compounds in the atmosphere with nitrogen oxides. Ozone can damage the growth of plants and trees. Many pollutants can be both directly emitted or formed by chemical reaction of different pollutants from completely different processes. Acid rain is a form of precipitation that contains sulfuric acid or nitrogen oxides, and contaminates fresh water, vegetation, and can harm aquatic life, including killing fish population in lakes.

Air pollution exacerbates a number of health conditions including respiratory infections, heart disease, and stroke and can contribute to lung cancer. Severe air pollution may affect individuals who have difficulty in breathing or heart disease. The health effects of compromised air quality affect mostly the respiratory and cardiovascular systems. Children with asthma can be most vulnerable to air pollution, specifically tiny particulate matter. Air pollution leads to increased spending on health care.

The Clean Air Act

The Clean Air Act is the United States federal law designed to protect humans and the natural environment from the effects of air pollution. Under the Clean Air Act the EPA regulates emission of dangerous pollutants. This Clean Air Act has an incredible track record of cutting hazardous pollution, since its inception in 1973. In the last four decades' major progress has been made in pollution prevention across all sectors including transportation, and seemingly, more stringent federal regulations have helped.

The understanding that many pollutants have major effects on the health of the populace has led to a renaissance in reducing pollution levels in the United States. According to Fig. 4.1, since 1980 carbon monoxide levels in the atmosphere have been reduced 84%. Stricter emission levels of tailpipe exhaust placed on vehicles is most likely at the center of this reduction, with a large drop from 1980 to 2005. Since 2000 fine particulate matter has seen a 45% reduction, with the reduction in coal burning, and the substitution of cleaner burning natural gas in lieu of diesel fuel the most likely contributors to this success.

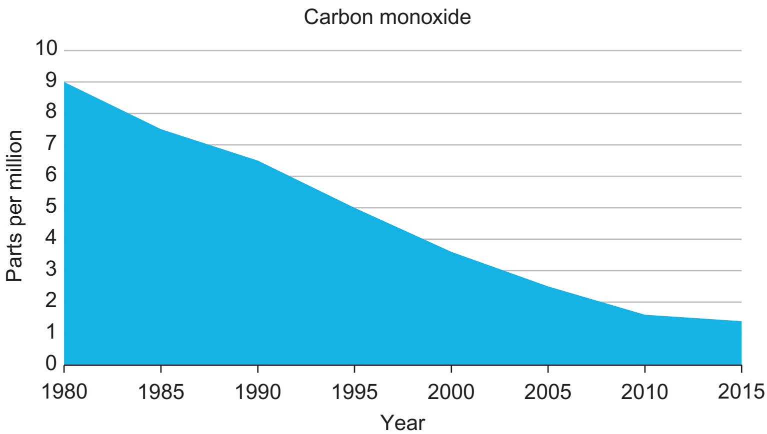

FIGURE 4.1 Carbon monoxide.

BUS DEPOT IMPACTS

Bus depots include fueling infrastructure, oil water separators, bus washing apparatus, maintenance bays, parts and equipment storage, and bus parking. In many instances, office space, locker rooms, and other employee amenities are also included. Bus depots normally include maintenance areas required for inspections, engine or transmission repair, tire replacement, oil and fluid changes, and areas for minor defect repairs or touch up painting. Maintenance bays are also equipped with tailpipe exhaust removal systems so bus maintainers are not exposed to harmful exhaust when inspecting or fixing bus engines which may have to be running to complete the inspection or maintenance task.

Since diesel buses emit toxic pollution through the engine exhaust of the tailpipe, when buses enter the depot, emissions will start to build up in the bus depot, compromising the indoor air quality. Bus depots with the requirement to house buses indoors, must have a robust air exchange system to keep the air fresh inside the depot. For safe working conditions a constant fresh air exchange system that changes the air several times an hour is required, so those who work inside the building can breathe air at an acceptable level. The dilution factor of the fresh air exchange system reduces the level of pollutants inside the depot. Some depots have outdoor parking that avoids this concern altogether, however buses parked outside are not protected from the elements, and outside parking has other environmental impacts.

Inner city bus depots can be located adjacent to residences or commercial districts. Rooftops of bus depots can contain HVAC units and other mechanical equipment. Emissions coming out of the bus depot include the exhaust of large boilers and domestic hot water heaters, which may use natural gas, and the exhaust from the vehicles themselves. Bus depots are usually large above ground facilities located in areas in close proximity to the lines that the buses will serve.

Underground Storage Tanks

As part of the bus depot infrastructure, fueling stations are an integral part of the facility. Buses are fueled, usually when they return from completing their route, with fuel which is dispensed into the bus from large underground petroleum storage tanks. The past century of underground diesel fueling systems has left a pool of contaminated sites in its wake. Traditionally, underground fueling systems leaked through corroded tanks, spilling oil into the ground, and in many instances, contaminating the groundwater.

Leakage of historic old tanks is almost a given, in addition to leakage through piping that connected the dispensing system and the tank. Gasoline and diesel fuel tanks consistently were found to leak when old tanks that required replacement were dug up. Contaminated soils impacted by oil spills are one of the primary pollution discharges of the last century, requiring millions of dollars in cleanup activities. Modern underground storage tanks have leak detection systems and secondary containment to prevent spills.

Petroleum that leaked from an underground storage tank can form what is called a plume. Once a leak reaches the groundwater it becomes more dangerous because flowing groundwater can spread the petroleum contamination on top of the water table, potentially impacting fresh water supply. Tanks that require removal, leave behind in most cases soil and groundwater that will require remediation. Excavated petroleum contaminated soil typically involves laboratory analysis to quantify contaminant concentrations in the waste material. Aromatic volatile organic compounds benzene, toluene, and xylene, which are suspected carcinogens, are found in petroleum contaminated soils.

Oil Water Separators

Surface runoff from cities, specifically in urban and industrial areas, often pick up the residual oil spill contamination, and one of the biggest environmental impacts is hydrocarbons and volatile organic compounds getting into oceans, rivers, streams, and lakes, which have disturbing effects on fresh water supplies and wildlife. Oils and their derivative products are known to contain harmful metals, hydrocarbons, and PCBs. Appropriate storm water collection and drainage systems for bus outdoor parking lots must be equipped with oil water separators and prevent runoff contamination.

Oil water separators, often installed below ground, isolate and separate oil from water. Bus depots must be equipped with drainage from all parking or maintenance areas, connected to oil water separators, to prevent spills of gasoline, diesel, motor oil, or other fluids from entering the sewer system. As sludge builds up in an oil water separator, it needs to be pumped out often to avoid clogging. Oil water separators, much like underground storage tanks, when uncovered usually reveal a certain amount of contaminated soil from leakage and erosion.

VISUAL IMPACTS OF MASS TRANSIT INFRASTRUCTURE

Mass transit infrastructure that is below ground, poses no visual impact on the urban landscape, either positive or negative because it is hidden beneath the street of a city. Station and terminals may impact the urban environment, as they will be the public entryways into the system. The station environments should be true to neighborhood aesthetic and be in step with any neighborhood motif. Elevated line, light rail, or streetcar service, bus rapid transit infrastructure design should also blend into the existing urban landscape to attempt to be aesthetically pleasing and simpatico with neighborhood architecture. Bus depots and maintenance shops should also be designed into the fabric of the neighborhood.

Visually, an elevated train line or light rail system becomes part of the neighborhood landscape in cities, and because of their size, they usually are hard to miss, so they must be designed to look as natural as possible to fit in with the cityscape. In addition, at grade or elevated train lines may unintendedly create barriers within cities, which can break up neighborhoods, and impact pedestrian or car traffic patterns. At grade crossings can also be very dangerous so careful planning and trustworthy security is needed to avoid potentially dangerous situations with cars and trains crisscrossing each other.

Light Pollution

Light pollution is unnecessary, unpleasant, or misdirected artificial light positioned into the environment. Mass transit infrastructure requires lots of lighting for safety, and light that shines in an obtrusive way toward residences can be disruptive. Lighting must be positioned to provide optimum illumination directed toward only the intended area. Lights that become misdirected wastes lighting. Excessive indoor lighting can become misdirected off-site that could lead to discomfort to adjacent neighborhoods, commonly referred to as light trespass.

Misdirected light off-site can also be detrimental to adjacent ecosystems not used to being illuminated at night. Light pollution is a natural byproduct of urban society. It includes both exterior and interior lighting, streetlights, billboards, industrial factories, and security lighting. Mass transit infrastructure has significant lighting requirements, specifically in the station environments. Entrances need to be well lit, stairways, mezzanines, and station platforms especially at night require lighting.

ENVIRONMENTAL REGULATIONS AND MANAGEMENT

Environmental impacts must be managed in such a way as to reduce, minimize, or eliminate the potential hazard. Some impacts are unavoidable; however, most are manageable. Some adverse impacts on the environment are allowed based on regulations. Environmental impacts in many cases are subjected to regulatory compliance, however, being within regulatory levels, is not to be confused with harmless or safe levels. The reality is in many instances; environmental regulations are in fact "allowable" pollution levels.

As an example of allowable pollution levels, for an industrial facility that exhausts toxic air pollution, there are regulatory levels that the exhaust stream must stay under to be in compliance. Staying within the threshold limits, however legal, still may pollute the atmosphere. If a permitted chimney stack exhausts pollution right up to the edges of regulatory levels, the exhaust is still filling the air with toxic materials, and damaging the environment. Environmental mitigation measures that go beyond compliance to reduce pollution far below regulatory levels, is a form of environmental sustainability, commonly referred to as pollution prevention.

FINANCIAL IMPACTS

Reducing, minimizing, or eliminating environmental impacts helps avoid costly remediation measures. Environmental impacts to the land, that require cleanup, such as soil contamination, usually require additional funding and resources. Failure or neglecting to manage environmental impacts can lead to spending exponentially more money in the long run, as environmental cleanup can become expensive, with labor, removal, and transportation costs. Managing environmental impacts limits liability and is good business practice, in that it not only protects the environment, but it prevents impacts to an agency's budget.

CONCLUSION

Environmental impacts are changes in the natural or built environment, resulting directly from an activity, that can have adverse effects on the air, land, water, fish, and wildlife or the inhabitants of the ecosystem. Pollution, contamination, or destruction that occurs as a consequence of an action, that can have short-term or long-term ramifications is considered an environmental impact. Most adverse environmental impacts also have a direct link to public health and quality of life issues. Several successful reductions in pollution levels have been attributed to stricter regulations, including levels of carbon monoxide and more recent reduction in fine particulate matter.

Mass transit, as a result of the operations and maintenance of infrastructure, facilities, and vehicles, has numerous potential environmental impacts to manage, including air pollution and greenhouse gas from energy use, noise, and vibrations, water discharges, waste removal of passenger trash, harmful materials such as lead-based paint, mercury, PCBs, asbestos, contaminated soil, and groundwater. Both train and bus operations have significant environmental issues to manage on an on-going continuous basis. Besides regulatory compliance, it befits an agency to reduce environmental impacts in order to pollute less, protect natural resources, and reduce liability and save costly impacts to budgets.

FURTHER READING

Noise Control Act of 1972 and the Quiet Communities Act of 1978, The Environmental Protection Agency, www.epa.gov.

Consumer Product Safety Commission—Final Ban on Lead Based Paint, www.cpsc.gov/en/Recalls/1977/CPSC-Announces-Final-Ban-On-Lead-Containing-Paint.

EPA Bans PCB's in 1979, https://www.epa.gov/sites/production/files/2015-05/documents/biomonitoring-pcbs.pdf.

Mercury Arc Rectifiers Edison Tech Center, http://edisontechcenter.org/MercArcRectifiers.html.

Asbestos, https://www.epa.gov/asbestos.

Air pollution, https://www3.epa.gov/airquality/emissns.html.

PM2.5 Levels in the United States, https://www3.epa.gov/airtrends/pm.html.

Carbon Monoxide Levels, https://www3.epa.gov/airtrends/carbon.html.

The Union of Concerned Scientist—The Clean Air Act, http://www.ucsusa.org/global_warming/solutions/reduce-emissions/the-clean-air-act.html#.V4Zoojbmq3A.

Chapter 5

Sustainability in Train Rail Systems

INTRODUCTION

Mass transit operations require a lot of energy. Sustainability measures implemented in rail transit help reduce the consumption of energy. Public trains run on electricity, and will for the near future. Conserving and being more energy efficient decreases air pollution, and reduces greenhouse gas emittance. For train services, the principal use of electrical power is for running the trains, with some required for tunnel lighting, line equipment, and station environments. Sustainability initiatives can be included within many facets of the mass transit infrastructure, facilities, and vehicles. Mitigating the environmental impacts of public train operations can also help save energy and preserve the planet.

SUSTAINABILITY ASSESSMENT

When implementing a brand-new transit system, heavy or light rail, or performing a major renovation of an existing system, an assessment needs to made where sustainability initiatives can be appropriately implemented. When renovating an existing system, seeking energy efficient processes is always considered; however, decisions are made to implement the processes which fit best with the existing infrastructure. An existing infrastructure already has an established foundation and framework under which sustainability initiatives need to be considered. Suggested improvements must be well suited to work with the old systems, unless the decision is complete removal or reconstruction.

Building an entirely new system from the start can include sustainable elements designed in at the start, with little or no impediment. New systems may have other constraints, such as limited or restricted space availability. Sustainability measures considered for infrastructure should mostly consider reduction in energy use; however, initiatives to save water, natural resources, and prevent pollution must also be considered to protect the natural and built environments from damage. Sustainability measures implemented in many cases require symbiosis between the infrastructure, the vehicle, and the environment.

Sustainable Mass Transit. DOI: http://dx.doi.org/10.1016/B978-0-12-811299-1.00005-8
© 2017 Elsevier Inc. All rights reserved.

ELECTRICAL CONSUMPTION REDUCTION IN TRAIN OPERATIONS

The main energy use by a train service, either heavy or light rail, is the electricity consumption required to move the trains from station to station. Electricity supplied to the train through substations arrives from a power generating plant. The power is sent to the third rail or catenary overhead wires by substations. Electricity is transmitted through wires, which have certain electrical resistance levels, and the third rail, which is normally made of steel, also includes levels of resistance. The entire electrical network is fraught with inherent electric loss, and sustainability initiatives help reduce those losses.

Aluminum Rail

Electrical material such as wires, conduits, cables, rails, etc., are required to supply electricity to the train for operations. In order to maximize energy, thought must be given to find materials that are the best conductors of electricity, with little electrical resistance. Aluminum, which has less electrical resistance than steel, has long been considered as a replacement for steel in the third rail. Legacy heavy rail systems have yet to establish real compatibility with an all-aluminum rail, specifically from a strength point of view. Since an all-aluminum third rail has not yet fared well with heavy rail transit systems, an alternative has been recommended, a composite of steel and aluminum, to replace steel.

Newly constructed heavy and light rail rapid transit systems built in the last decade most often have used an efficient aluminum and steel composite material for power rails. The composite material finds the strength of steel combined with the electrical efficiency of aluminum is an appropriate substitute for an all-steel third rail. The largest public transit systems currently replace older all-steel third rails with an aluminum – steel composite rail, saving energy in the process. Smaller light rail systems could be made compatible with all-aluminum rails.

The Demand for Energy

Once the power electrifies the third rail or overhead catenary wires, the required energy is dictated by the needs of the train car. The very first requirement that decides the amount of energy necessary to move the train is the weight of the train cars. Therefore, the lighter the weight of the train car, the less energy will be required. For safety reasons, a train car must be built with the required strength to withstand substantial impacts. If the weight of the car is reduced by substituting lighter materials, the material would still have to exhibit certain strength characteristics.

The train cars also require energy for lighting, opening doors, message boards, intercom, and ventilation. The demand for energy for traction power starts the moment the train motorman begins the process of moving the train. Trains accelerate by drawing electricity from the third rail or catenary to supply an electric motor in the train, which in turn moves the wheels of the train cars.

REGENERATIVE BRAKING

Regenerative braking is a supplemental braking system that converts the train car's kinetic energy when a train slows down, and changes it into usable electrical energy. It is a very promising sustainability initiative in the mass transit industry, considering all the stops and starts associated with mass transit. When the train is in full motion, and the motorman applies the brakes, the train's electric motor is prompted to run in reverse, which provides resistance to the moving wheels, helping to slow down the train.

As soon as a trains' electric motor is changed to run in the opposite direction, it actually becomes an electric generator, allowing it to generate electricity. To take advantage of this, a system was introduced in trains to capture the generated electricity when slowing down a train, commonly referred to as regenerative braking. Most electrical regeneration technologies were started on rail systems, and were first used in early trolley cars. During the braking process, the electric current flow is in the opposite direction to that of acceleration, and this transforms the motor into an electrical generator.

Regenerative braking is also widely used in hybrid electric vehicles, including cars and buses, with the generated electricity used to charge the battery of the car or bus that the hybrid vehicle uses for energy. To take advantage of the electrical energy that is created by the train car regenerative braking system, the energy has to be directed somewhere useful, and normally that is back into the third rail or catenary, to be used by another train. The challenge is that if the energy put back into the third rail or catenary is not used right away by another energy drawing train in close proximity, it will instead go to an on-board resistor bank, that will dissipate the electrical energy into heat.

Regenerative braking is a significant development in an attempt to save energy in any train operations; however, the percentage of savings may not be very substantial when trying to use regenerated energy within the same rail or overhead electrical supply. Most trains built since the new millennium have regenerative braking capabilities. Mass transit infrastructure must take advantage of the ability of the trains to generate electricity when braking. Energy storage systems built into the transit infrastructure are an ideal way to capture and use regenerated energy.

WAYSIDE ENERGY STORAGE

Trains that have regenerative braking systems can provide power to a nearby accelerating train to use, if the timing is right. Wayside energy storage, constructed within the track infrastructure through a large battery or capacitor, has vast potential to capture the regenerative braking electricity produced. The regenerative energy, or the electricity created by braking trains, commonly referred to as regen, can be stored in a wayside energy storage system, and then can be reused for acceleration by the next train. Regenerative braking energy, coupled with energy storage systems, is a major sustainability initiative that has the greatest potential to save energy in mass transit.

Wayside energy storage systems, which are typically made up of a battery or capacitor, can capture and store regenerative braking energy to maximize efficiency, and wayside energy storage systems can be configured to provide voltage to help stabilize the power grid. Energy storage systems can provide voltage to help reduce losses in the power grid. Space requirements for the storage system and proximity are major factors involved in implementing wayside energy storage. Substations which would be the obvious choice of where to place the energy storage system, would usually be located adjacent to the rail line, and would include transmission lines and conduits to and from the power grid.

Traction power that runs the trains is essential, and requires the largest percentage of electricity consumption. Capturing regenerative braking in energy storage systems, and maximizing the use of that energy, is a centerpiece sustainability initiative for public transit in major cities. In many cases, without any kind of storage system, regenerative braking energy is not maximized by the transit operations. A burgeoning method to take advantage of regenerative braking energy, specifically in most new light rail systems, is on-board energy storage.

ON-BOARD ENERGY STORAGE

An alternate to wayside energy storage is on-board energy storage. Light rail systems using on-board energy storage systems have an additional energy source to complement the energy supplied by the pantograph from an overhead contact wire. With an on-board battery, as opposed to providing regenerative braking energy back into the supply system, energy is brought to the battery system on board the train, for use by the train.

Light rail system overhead wires can be intrusive to a city landscape, can create hazards, and can take up a lot of space. On-board energy storage systems have allowed some light rail systems to run without use of overhead wires for some stretches. When designing a new light rail system, the use of an on-board energy system in the vehicle can also reduce the number of substations that may be necessary to support a new line. The location of substations must be spaced at minimum intervals to allow the maximum energy to be used when the train accelerates. If substations are too far apart, the electrical flow will start to lose efficiency, and create weaker points for energy demand along the train line.

Overhead line resistance increases as the distance from the substation increases. As a train pulls away from the substation, at some point further down the line the train can switch to the on-board energy system when necessary to make up for the losses created by the resistance in the wire. The on-board energy storage system can also be charged from an electrical supply while stopped at a fully equipped station for charging. Batteries and capacitors are the predominant energy storage systems used currently in mass transit, and flywheel and fuel cell technologies are also being considered for energy storage systems.

Batteries and Capacitors

A battery relies on a chemical reaction to generate voltage, and once the charge is expended the battery becomes unusable. Rechargeable batteries, when provided with an electrical supply, include the ability to reverse the chemical reaction to restore the charge. The battery cell, contains three parts: a positive cathode, a negative anode, and the electrolyte. The capacitor and the super capacitor use two conductive plates separated by a dielectric, or in the case of a super capacitor an electrolyte. When being charged, energy is stored in an electric field between the plates.

Batteries and capacitors are constructed to both store and release energy. There are big differences that help distinguish which storage system may work best in each situation. Batteries charge slowly, but generally can hold more charge, while capacitors charge quickly, but comparatively may hold less charge, and capacitors discharge rapidly as well. The choice of the right battery or capacitor depends on the situation at hand. If fast charging is the predominant necessity, then a capacitor is best. For a long-lasting charge, probably a battery is best.

A battery system requires a chemical reaction, and the cell can include large quantities of an extremely dangerous acid, thus causing a potentially damaging situation if a leak occurred, requiring progressive and essential environmental mitigation measures. This presents a most difficult challenge when using batteries on large-scale levels, such as a wayside energy storage system. The ultimate viability of batteries, capacitors, and other energy storage systems, their environmental impact, and their lifecycle cost, will play a major role in numerous future sustainability initiatives.

LIGHTING

There are many lighting requirements for mass transit infrastructure: tunnel lighting, station lighting, platform lighting, etc. It takes a great deal of energy to light the train infrastructure environment, and considerations include: the search for lighting that provides the required lumens, lighting with the least amount of energy consumption, lighting that gives off less heat, and lights that last longest. Mass transit infrastructure has continuous use of lighting requirements, especially in tunnels, where lighting is required to be on all the time.

Several decades ago the transition from incandescent lighting to fluorescent lighting took place on a grand scale, mainly because the fluorescent light bulb is more energy efficient, gives off less heat, and lasts longer than the incandescent light bulb. A fluorescent light bulb in compact form is known as a compact fluorescent lamp or CFL. The CFL brought the size of a fluorescent light bulb closer to the size of a typical incandescent bulb.

An incandescent light bulb gives off tremendous heat, because the light is produced by heating a filament within the bulb. A fluorescent bulb contains traces of liquid mercury and a gas, typically argon, that emit photons. A small electric charge within the tube heats mercury to a gas, and electrons from the mercury vapor interact with the electrons from the gas which produces photons, that hit a white coating or phosphor, which coats the inside of the bulb. The coating glows from the impact of the photons, thus creating visible light. Fluorescent bulbs use a miniscule amount of heat to create light, and are more energy efficient than regular incandescent bulbs, and CFLs can last thousands of hours longer.

A big environmental concern is that CFLs contain mercury, which makes them potentially hazardous even when being used. CFLs and lights in general can be very fragile parts of the transit infrastructure, and broken bulbs can potentially contaminate areas with mercury. In addition, at replacement and disposal time, as the bulbs contain mercury, bulbs must be removed, stored, and transported in an appropriate way to avoid damage and contamination from broken bulbs. Another environmentally friendly alternative to both incandescent and fluorescent light bulbs is the light emitting diode (LED) bulb.

LIGHT EMITTING DIODES

LEDs are a series of small bulbs without a filament, so they do not get hot, they last a long time, and their energy requirements are less. LEDs, in some cases, have a longer lifespan than that of an incandescent bulb by a factor of eight. A diode is a semiconductor, which is a material with the ability to conduct an electrical current. In the semiconductor, when excited electrons jump orbitals they release energy in the form of photons, which form light.

Light emitting diodes are made of different materials, with different gaps between the higher and the lower orbitals, and the gap size determines color.

LEDs are growing, thanks to their energy efficiency, long lifetime, small size, and different colors. The prime advantage is efficiency, as LEDs are more energy efficient than incandescent or fluorescent lighting. LEDs generate little if any heat; therefore, there is little wasted energy. LEDs have become the most cost effective lighting option over the entire lifecycle. LEDs have higher upfront costs, but in the end they last longer, therefore they need to be replaced less often, reducing the costs associated with replacement activities.

Heat release from lighting is also a concern. Transit infrastructure environments in many instances include banks or clusters of lights. Traditional incandescent light bulbs give off tremendous heat in clusters, and in transit environments extra heated areas can be problematic for structures. Subway areas with banks of tunnel lighting with incandescent lights give off a lot of heat, and have warmer tunnel air and surfaces, and warmer air means more moisture in the tunnel. Extra moisture in the tunnel areas could accelerate damage to concrete. In addition, areas that are extra heated can make the tunnel environment more uncomfortable for workers.

In the mass transit environment, LEDs have been used for signal lights, signage, station lights, tunnel lights, yard lighting, emergency exits, and included on and in the train car. A lot of new infrastructure includes LEDs. Many light fixtures in the past 20 years switched to accommodating CFLs, and fortunately some LEDs can be retrofitted to be suitable for current CFL light fixtures. LEDs have supreme energy efficiency, and some LED bulbs can last 25,000 hours.

LEDs have a high potential for energy conservation. The heat given off by light bulbs is a factor in the amount of energy required to cool a building. Lighting systems that emit tremendous heat require much more air conditioning to provide comfortable spaces in the building. LEDs give off little heat compared to both incandescent and fluorescent lights. Therefore, a building with exclusive LEDs will overall use less energy for lighting. Referring to Fig. 5.1, it is predicted that LEDs last longer, save more money on an annual basis, and importantly give off less heat than both CFLs and incandescent lights.

An important factor is the durability of LEDs. Transit environments can be very harsh environments, climate wise, and also have some vibration levels. LEDs are not very sturdy, and can break easily. LEDs usually formed in clusters, so if an individual LED breaks, there are usually a number left to continue to supply the required lumens. In a mass transit infrastructure, LEDs in signal lights may require the signal be equipped with vibration isolators to avoid destroying the lights when trains rumble by. Transit infrastructures such as bridge necklace lighting now use LEDs to save energy, but most importantly because they last longer, they reduce the number of

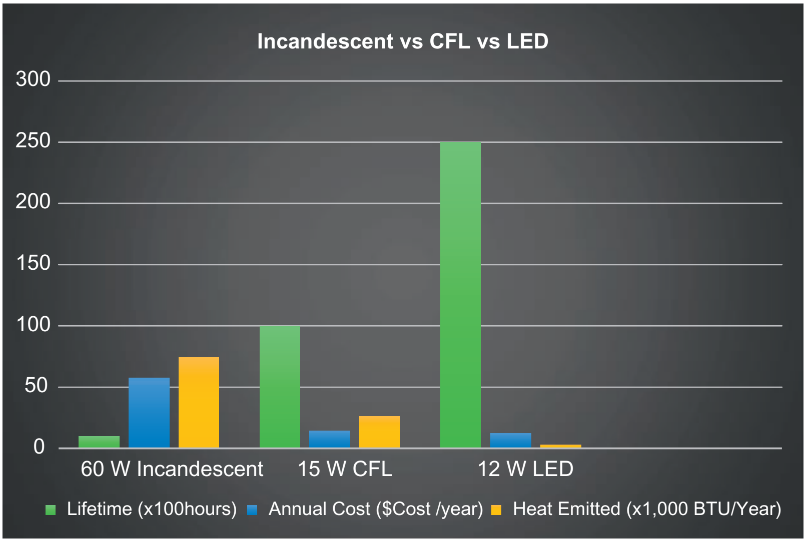

FIGURE 5.1 Light Emitting Diodes (LED) versus compact fluorescent lamp (CFL) versus Incandescent Comparison Chart. *http://www.designrecycleinc.com/led%20comp%20chart.html; http://energy.gov/energysaver/how-energy-efficient-light-bulbs-compare-traditional-incandescents*

times a laborer must climb to dangerous heights to replace bulbs. LEDs have also been used regularly in street traffic signals as well, and in numerous signs.

NATURAL LIGHTING

The sun has provided light forever. The first settlers brought light into the cave by carving large holes in the top or side of the cave to allow the natural light of the sun to enter the dwelling. They discovered a few things when allowing the sun's rays to penetrate their dwelling; one was that the sunlight came into the cave at different angles and for different durations, and that with the bright sunshine came heat. With the advent of windows, the free light provided by the sun has always been factored into the design of residences, buildings, churches, and even industrial buildings.

Mass transit infrastructure, such as terminals, stations, and large maintenance shops has traditionally included natural lighting in its architecture. Traditionally, great train terminals in Europe had giant rooftops and large canopies to protect passengers from the elements, and embedded in these rooftops and canopies were giant sized windows to allow sunlight to light the station or terminal. Most of these terminals, some centuries old, still exist today, and the daytime sunshine provides a naturally lit environment, which lessens the need for artificial lights and saves energy.

Subway station environments, depending of course on the depth of the tunnel, can include natural lighting to lessen the necessity for lighting. Mass transit maintenance shops have included rooftop windows, angled to take advantage of the sunshine, in structures referred to as skylights, which were used in ancient Roman and Greek architecture, and have been utilized ever since. Energy conservation has brought natural lighting into traditional architectural design. Skylights allow sunlight into large centralized areas such as shop floors, and special glazing can reduce glare. Skylights can also be covered to reduce heat gain with a Low-E coating, to reduce heat flow through the glass. Daylight, in combination with automatic light sensing controls, can maximize energy savings.

Studies have found the many positive attributes of increased daylight include students getting higher test scores in classrooms with natural lighting, daylight positively affects physical performance, and also increases industrial productivity. Energy costs can be reduced with daylighting. Warehouses traditionally included skylights, and the modern cost saving "warehouse" style department stores have included skylights. Public mass transit facilities have included skylights in maintenance shops, material warehouses, and several train terminals have utilized large windows, atriums, and oculus' to take advantage of sunlight.

NATURAL VENTILATION

Natural ventilation is a very practical technique for providing fresh air, reducing energy, and creating comfortable and productive indoor air quality. Natural ventilation uses wind to ventilate and cool a building. A mass transit maintenance shop, with its large shop floor, is very suitable for natural ventilation. Through openings from the windward side of the building, such as louvers or grills, and openings on the leeward side or the roof, fresh air will permeate through a maintenance shop without the use of mechanical fans.

Under the principle that heat rises, cooler air coming into the facility from the outside will cause the warmer air in the shop to rise, and exit at higher-level openings. This is referred to as the stack effect. The best way to take advantage of this effect is if the maintenance shop is positioned to take advantage of the prevailing direction of the wind. On the windward side of the shop, with louvers at the bottom portion of the shop near the floor, cooler air will naturally displace the warmer air on the massive shop floor, and will work its way across the shop floor and rise toward the ceiling, or to louvers on the opposite side of the shop, naturally cooling the building.

Large maintenance shop floors, in many industries, require a lot of energy to keep a comfortable air quality for workers. Production can be compromised with hot and humid conditions in warm weather environments. Air conditioning is very energy intensive, and it is extremely expensive to cool large industrial spaces. Natural ventilation, incorporated into a building, can help reduce energy costs. Natural ventilation, in combination with natural lighting, can make a very large energy intensive building both sustainable, and highly productive.

WHITE ROOFS AND THE HEAT ISLAND EFFECT

Mass transit support facilities include millions of square feet of rooftop space, and the overall make-up of a roof in any building or facility has a direct connection to the energy consumed. As heat rises within a building, the roof insulation plays a big part in energy efficiency. A well-insulated roof can save energy in both summer and winter. The reflective nature of the roof has a direct effect on energy consumption as well. A white or reflective roof reflects the rays of the sun, will not absorb as much of the sunlight as a black or dark colored roof, and will keep a building cooler.

Hotter rooftops, due to a blacktop or nonreflective roof, will require a building to use more energy for cooling. Albedo or reflectivity is the percentage of light that hits a surface that is reflected, and not absorbed. White surfaces reflect light, and black surfaces absorb light. A white surface has a high albedo; darker or black surfaces have a low albedo. Cities, which have many black surfaces, including blacktop asphalt streets, absorb and retain more heat in the summertime, and this keeps a city generally much hotter in the summertime. This is commonly referred to as the heat island effect.

Urban cities generally have higher temperatures than rural areas, in part due to fewer vegetative surfaces, as paved surfaces retain more heat than vegetated surfaces. Vegetated surfaces also hold moisture content that can cool air through the evaporation process. Dark surfaces, which absorb sunlight and radiate heat waves back into the atmosphere, stay hotter than light or reflective surfaces. In addition, greenhouse gases in the atmosphere absorb heat waves from hot surfaces, and re-radiate heat. All of these make summer months in urban areas much hotter. At night time, generally, rural areas will cool off, whereas in some urban cities air temperature will stay hotter because heated surface areas continue to radiate heat through the night.

The overall heat island effect of a city leads to increasing summertime energy, including use of more air conditioning, which requires more energy, and leads to air pollution and greenhouse gas emissions. White or reflective rooftops help reduce the heat island effect. Buildings with white roofs have lower temperatures recorded both on the roof, and more importantly inside the building shop areas where workers maintain train vehicles or equipment. Many urban areas, specifically those in the north and northeast, have adopted citywide painted white roof initiatives or programs.

SOLAR ENERGY

Mass transit infrastructure and facilities are massive in scope, size, and require a lot of space. Elevated train terminals or stations, either heavy or light rail platform areas, in many cases, rely on large canopies to protect waiting passengers from the elements, specifically rain and wind. On top of canopies are great places for solar panels, provided they are not obstructed from sunlight, to provide on-site electrical energy to the terminal or station environment, which requires energy for token booths, automated vending machines, turnstiles, lighting, and signage. Individual solar panels can also be mounted upon automatic ticket vending machines.

There are two basic types of solar panels. The first type is the traditional crystalline silicon solar panel, which makes up the majority of solar panels in the photovoltaic industry. The other type, thin film solar panels, are noncrystalline or amorphous silicon solar panels, which are thin and flexible. The crystalline silicon panels are thicker than noncrystalline, which allows the electrons more space to move, allowing for greater efficiency. Facilities in mass transit usually have enormous rooftops, and if taller buildings do not block the space, they are prime candidates for traditional crystalline silicon rooftop solar photovoltaic panels. Solar panels can also be placed along the right of way to supply energy for lighting or electrical equipment.

Thin film solar panels have infinite uses, and can be different shapes and be put in unusual places; however, they are less efficient than thick crystalline panels. The flexibility of thin film solar panels, allow panels to be placed over existing canopies shaped to the contour of the canopy. Many train canopies are designed to allow natural light to penetrate and shine light on platform environments. Thin film solar panels can be placed within panes of glass of the canopy. In addition, to provide solar energy, the canopy designed with thin film solar within the glass, also allows natural lighting to penetrate, and provide free light from the sun.

Solar Thermal

Mass transit ancillary facilities may require both hot and cold water supplies for maintenance or cleaning activities, and facility rooftops are perfect for solar thermal energy, for heating and hot water. Solar thermal heat energy systems, which are mounted on rooftops, can generate heat or hot water without fossil fuel combustion. There are a few basic types, but most utilize mirrors to reflect and concentrate sunlight on a medium such as water or oil that runs through a tube that can transfer heat and convert it into heat for a building or to provide hot water. Solar thermal systems can keep a fresh supply of hot water in a water storage tank. Solar thermal systems are relatively easy to connect to a building's plumbing system, and will save energy. Solar thermal systems can also help supply heat through a buildings HVAC system.

Solar Heat Wall

A solar heat wall is a metal wall which is mounted in front of a masonry wall of a building. The metal wall with tiny holes is placed on the south side of the building, facing the equator in the northern hemisphere, and when sunshine brightens the wall during wintertime, air is sucked through the holes in the wall. The air is heated as it goes through tiny holes in the wall and supplements the heat being produced inside. In the summertime, the air is not pumped into the building, but it is sent to a bypass stack. Solar heat walls are very practical, and mass transit facilities, such as maintenance shops can install solar walls to help save energy. Southern hemisphere locations should place the solar wall on the northern side of the building for maximum exposure to the sun.

VERTICAL AXIS WIND TURBINES

Small wind turbines can also be used to supply electricity to transit facilities. Wind patterns are different everywhere, so the type of wind turbine is determined by the location. There are two basic types, horizontal and vertical turbines. Horizontal turbines are the traditional large turbines utilized in both on-shore and off-shore wind farms. Vertical axis wind turbines are generally smaller, can be used in urban settings on top of buildings, such as mass transit shops, and are multi-directional, which means they do not need to track the wind direction. Vertical axis wind turbines can work in very turbulent or gusty winds.

The main rotation shaft of a vertical axis wind turbine is vertical like a helicopter, rather than horizontal, can catch wind from any angle, and like a helicopter uses the science of lift to gain more energy from the wind turbine. In urban settings, wind resources are often turbulent, because of the many buildings and structures redirecting the wind. Horizontal axis wind turbines are better suited for large-scale operations with steady winds, with the blades high above the ground or ocean where the wind is stronger and more consistent. Wind turbines can be used in conjunction with solar panels to increase on-site renewable system generation.

ENVIRONMENTAL MITIGATION

Preventing impacts on the environment, through mitigation measures, also helps avoid additional energy consumption. All negative environmental impacts eventually lead to more energy usage. For instance, oil spills, in addition to contaminating soil or water, will require clean-up activities, which entail energy to execute in practically all cases. A vacuum truck, which sucks contamination from an inadvertent spill, requires fuel to perform the clean-up service. Preventing a spill from occurring in the first place means less future added expense, and less destruction of the environment. Noise and vibration impacts mitigated during train operations, in addition to preventing noise pollution and damage from vibrations, can save energy due to environmental mitigation methods.

NOISE AND VIBRATION MITIGATION

Public trains emit sound from the steel – wheel and steel – rail interface as trains run in underground tunnels or on elevated train structures. Smooth rails, and smooth wheels, help reduce the noise of the wheel – rail interface, and provide an even and smooth ride. The less friction working against the train as it moves means less energy is required to move the weight of the train. Rails can be ground from time to time to retain a smooth surface. Wheels can also be conditioned to keep smooth surfaces.

Train wheels are subject to defects known as flat spots. When trains come to an abrupt halt or skid, the wheel sometimes will be damaged with a flat spot. Wheels with flat spots will emit an unusual sounding clank as they pass over the rail. An alert motorman, or in some cases a residential complainant, will hear the unusual sound and report the disparity. The wheel will require maintenance to fix the flat spot. Train car maintenance shops often include wheel-truing machines, which literally shave an extremely thin layer off the steel wheel, all around the circumference, to ensure a smooth wheel. The remnants of wheel truing are thin layers of steel referred to as shavings, which can be sent for recycling.

The miles of steel rail used for train tracks come in much smaller lengths, usually 39 or 78 feet long. Therefore, rails have to be pieced together to make miles of track. Tiny gaps between the rails that become slightly off kilter can damage wheels and inhibit a smooth ride, which can increase energy use, and can create loud bangs as trains pass over the gap. Welding the rail together can eliminate the gaps. This process is called continuous welded rail, and is more likely to be found in subway tunnel tracks. Outdoor track is less likely to be continuously welded to the rails, due to climate fluctuations.

In normal climates that have both hot summers and cold winters, expansion of the track in summer due to heat, and contraction of the track due to cold temperatures are factors to be considered in whether to weld the rails together. Designing track to compensate for the expected high and low temperature that it will be exposed to is critical to preventing gaps, reducing noise, and preventing wasted energy use. In addition, designing track environmental mitigation measures, when the rail requires some curvature, is essential.

Public train wheels are straight; however, rails often curve, and depending on the level of curvature, special lubrication systems are needed to complement the track to decrease friction, and lessen the usual screech. Lubrication houses or friction modifiers are placed adjacent to the train track, usually before a curved piece of right of way. A lubrication house is attached to sensors that activate the system when a train is coming and squirt a liquid, usually grease, to ease the friction around the curve. Solar panels can help power lubrication houses, and grease and oils, which can have environmental impacts, should be biodegradable and environmentally safe for use on tracks. Lubricants can also reduce wheel and track wear, and control friction on surfaces of the running rail.

Vibration Control

Steel rails are connected perpendicularly to ties, normally made of wood, and the ties are held in place by ballast. The rail is connected to the tie with baseplates and clips. Baseplates can include rubber pads called resilient rail fasteners, to attenuate the vibration. Resilient rail fasteners are used on heavy and light rail, and commuter lines, to effectively isolate and lessen vibration transmitted through the soil and rock, perhaps impacting adjacent buildings. Resilient rail fasteners increase track stability, which reduces wasted energy. Ballast tamping also helps increase track stability. Another vibration reducing system is called high stability or low vibration track.

In a low vibration track system, the rails are clipped to concrete blocks, instead of wood ties, along the length of the track. The blocks are placed in a boot, which has a rubber pad lining the boot to provide the vibration attenuation. The concrete blocks, in their boot, are placed in a concrete base slab of the tunnel invert. Low vibration track does not require any wood ties, and these systems have great stability, which decreases and virtually eliminates vibration. Generally, these systems are low maintenance.

Railroad Ties

Railroad ties made of wood have been used for centuries for train tracks, and the majority of railroad ties are made from wood preserved with creosote, which are oils made up of aromatic hydrocarbons. A product of coal tar, creosote is toxic, and has been historically used as a water proofing treatment for outdoor wood structures, including bridges, telephone poles, and fencing.

Wood railroad ties wear out quickly, potentially exposing the environment to contamination from the creosote, and therefore require constant and frequent replacement. New composite railroad ties made from recycled materials, specifically plastic bottles, are beginning to proliferate through the mass transit industry; however, wood ties still completely dominate the industry.

CUSTOMER TRASH RECYCLING

Each day millions of commuters board trains, and carry with them newspapers, food, water bottles, drinks, snacks, and other personal items. Station environments, including waiting areas and train platforms, have trash bins for personal passenger trash. The majority of this personal trash consists of newspapers and plastic bottles. On some train platforms, recycling bins allow passengers to place newspapers into green bins, and plastic bottles and cans into blue bins, which allows the transit agency to recycle the customer waste as individual streams of newspaper, plastic or aluminum cans, separated by the passengers.

Separate bins, in most cases environmentally friendly, may require extra effort to handle all of the different waste streams, and may require two or more trucking services to move the respective trash to the various recycling facilities. In some cases, all the passenger trash goes into one type of bin, the trash is taken by one trucking company (comingled) to a recycling center, and at the recycling center the trash is separated. The bulk of customer-generated trash is newspapers, and newspaper can be recycled into other paper products.

The quality and usefulness of the recycled newspaper trash can be compromised by any liquid, specifically coffee, that may render the paper unrecyclable. As long as most of the newspaper debris remains dry, the newspaper can be recycled into usable paper. Recently, some new trash bins have included a separate vessel for liquid only built into the container, and this helps eliminate mixing liquids with newspaper. The subway trash works well as a single stream that is separated at the facility because there is a dominant waste, the thrown away newspaper, and paper-recycling systems are perfect for trash that is predominantly newspaper. Plastic bottles and cans can also be separated from the main garbage collected at the recycling facility.

SENSORS, TIMERS, AND MONITORS

The 21st century has brought widespread computerization to the mainstream. Several types of automation in many cases use sensors, timers, and monitors to allow systems to run routinely. A light sensor can detect the amount of light in a room, and raise or lower the brightness as programed. Light sensors can be programed to automatically turn on or off, both inside or at night. Programmable electromechanical timers can control sequence events. Temperature sensors can accurately measure and monitor ambient temperatures. Systems can be programed to alert and monitor energy, and ensure sustainable outcomes.

Heavy rail train operations in many colder climates in the United States, such as the Northeast or Midwest, are exposed to temperatures below freezing, and this dictates that third rail heaters must be employed to ensure ice does not form on the third rail of the above-ground train tracks, which would inhibit service. In the past, those heaters would be turned on manually in the late fall, and in many cases kept on through the spring, even though some days had higher temperatures that would not require their use, wasting a lot of energy unnecessarily. Third rail heaters now can use sensors that will only turn on the heat when the temperature dips below freezing at 32°F.

Building Management Systems

Sensors, timers, and monitors can be utilized in many applications to maximize energy efficiency. A prime example is the Building Management System (BMS), which is a computer-based system installed to monitor and control a building's services, including heating, ventilation, air conditioning, and lighting. In many cases, a BMS can be internet enabled. BMS can help manage energy demands, and other systems such as closed-circuit television, motion detectors, fire alarm systems, and elevators.

The systems in the BMS interact and talk to each other, can be sequentially programed, and help to make a building smarter by detecting problems and identifying areas that require energy reduction. Energy consuming functions such as electrical lighting can be programmed to work in tandem with natural lighting. Heating and cooling can be combined with temperature sensors to act in concert with natural ventilation. Importantly, fire alarm systems can be programmed into the BMS, with activation to close ventilation systems appropriately to avoid the spread of fire or smoke in the building.

CONCLUSION

Rehabilitating older transit systems infrastructure and facilities at times will consist of small component replacement, minor system repair, major rehabilitation, or complete reconstruction. Sustainability initiatives can be included in a more substantial way with either the major rehabilitation or complete reconstruction. In sort of an odd twist, a major system deterioration that requires complete system replacement is an ideal situation to provide new and enhanced systems that feature sustainable initiatives.

Sustainability assessments should be used to determine what the best sustainable elements are that are most suitable given the situation. New systems have a great opportunity to include sustainable initiatives by introducing concepts that can build off each other, maximizing sustainable benefits right from the start. The primary target of sustainability initiatives in train operations is the reduction of electricity, and regenerative braking, which generates electricity while a train car slows down, is a noteworthy contributor to energy reduction.

Regenerative braking coupled with energy storage provides great potential for significant energy efficiency. Energy storage systems, and the rapid progress in battery technologies, will play a key role in future conservation of energy initiatives. Lighting is a considerable energy-consuming requirement in mass transit, and light emitting diode bulbs last a long time and save energy over the long haul. Taking advantage of the natural light of the sun through skylights saves considerable energy, and taking advantage of the wind direction for natural ventilation saves energy in mass transit buildings and facilities. White roofs reflect sunlight, absorb less heat, and require less energy for cooling purposes in buildings. Solar energy provides emission free electricity, and solar thermal panels can provide sunlight heated hot water. Solar heat walls can provide additional hot air to supplement winter heating requirements.

Environmental mitigations, which reduce noise and vibration, can also lead to saving energy as smooth wheels and smooth rails save electricity by reducing friction. Customer-generated trash can be recycled at paper mills. Most trash is newspapers, which can be recycled into paper products, thus saving trees. BMSs using sensors, timers, and monitors can help program buildings to operate sustainably.

FURTHER READING

http://www.futurecars.com/technology/how-regenerative-braking-works.

http://www.cvel.clemson.edu/auto/systems/regenerative_braking.html.

http://www.septa.org/sustain/blog/2011/07-06.html.

https://www.energystar.gov/products/lighting_fans/light_bulbs/learn_about_led_bulbs.

http://www.renewableenergyworld.com/solar-energy/tech.html.

http://www.dec.ny.gov/chemical/42394.html.

http://www.motherearthnews.com/renewable-energy/vertical-axis-wind-turbines-zmaz08fmzmcc.aspx.

Chapter 6

Sustainable Initiatives for Public Bus Networks

INTRODUCTION

Over the past 20 years, public bus fleets have incorporated some of the most effective sustainability initiatives in mass transit. In fact, bus emission reduction and fuel consumption reduction have set a great example for all in the transportation sector to follow. Starting with the initial use of low sulfur diesel, with diesel particulate filters, and the continued consideration of alternative fuels and vehicles, including the evolution of hybrid buses, the transformation in the bus industry has been profound.

Depots which house, maintain, and fuel buses, have great potential to include sustainability elements in their facilities, which save energy, save potable water, and help reduce storm water runoff. Bus depots are usually very large facilities, massively spread out with large rooftops, perfect for sustainability initiatives including green or vegetated roofs. Inner city bus depots are included in a city's landscape, mixing in within the neighborhood, and can have environmental impacts on adjacent residential areas.

Mass transit agencies which run a bus network, and almost every city in the United States has a fleet of buses, started a renaissance in regard to seeking air pollution reduction about two decades ago. The appropriate starting point for this massive reduction was to reduce pollution from the tailpipe exhaust of existing diesel buses. Public bus transit was one of the first transportation entities to put in motion the consideration of new advanced diesel engine emission control technologies, and the use of cleaner burning diesel, prior to their regulatory compliance and widespread use.

ULTRA-LOW SULFUR DIESEL

Crude oil, which diesel fuel is refined from, includes considerable amounts of sulfur. Removing the sulfur in diesel during refinement helps reduce particles generated when burning diesel fuel, because lower sulfur means combustion is more efficient. The initial advance of cleaner burning diesel began with the use low sulfur diesel, with less than 500 parts per million,

Sustainable Mass Transit. DOI: http://dx.doi.org/10.1016/B978-0-12-811299-1.00006-X
© 2017 Elsevier Inc. All rights reserved.

and subsequently advanced toward the widespread use of ultra-low sulfur diesel (ULSD) fuel, with a content below 15 parts per million of sulfur.

Public mass transit agencies began using ULSD as early as the mid-1990s, with most of the stock of existing public bus fleets already in place, somewhere in the middle of their expected lifespan. Buses ran almost completely on diesel fuel; however, in order to take advantage of ULSD, to see emission reductions, an existing diesel engine had to include a diesel particulate filter. Most public buses at the time did not have these filters, but many transit agencies decided, for the benefit of the environment, that buses would begin to be retrofitted to include the diesel particulate filters, enabling the use of ULSD.

The diesel particulate filters accumulate particles or soot from the exhaust stream, and then subsequently burn up the trapped particulate matter to prevent solid particle release. Extremely high levels of particulate reduction of elemental or black carbon released have been achieved since diesel particulate filters were first retrofitted on a vehicle with a diesel engine. Prior to the use of particulate filters, the remnants of black soot were always visible on the backside of a bus. Black carbon or elemental carbon is the result of incomplete combustion of fossil fuel. Reducing sulfur frees up more oxygen in the combustion process to react with the carbon to form carbon dioxide, instead of unburned or evaporated carbon that pollutes the air.

Black carbon also influences climate change, as the particulate matter in the atmosphere absorbs heat, and then radiates more heat in the atmosphere. The Environmental Protection Agency (EPA) mandated that the majority of diesel be refined as ULSD in 2006, and subsequently all diesel bus engines, starting in 2007, included some form of diesel particulate filters to be used with ultra-low sulfur diesel. Older diesel engines, without the diesel particulate filter, could not use ULSD, as it would not work well, and it would ruin an older engine.

Advanced Emission Control Devices

Public buses started to retrofit diesel engine fleets to be able to use and take advantage of ULDS, which helped proliferate the widespread use of cleaner burning diesel in the transportation sector. Another advanced control device is the diesel oxidation catalyst, which also helps reduce particulate matter when hot exhaust contacts the catalyst, and pollutants are converted into carbon dioxide and water. In addition to a diesel particulate filter and diesel oxidation catalyst, another device to reduce emissions is the urea injection system, which is a device that emits a small amount of urea and water into the exhaust line, which also reduces nitrous oxide and carbon monoxide. Similar to diesel particulate filters, and diesel oxidation catalyst, the urea injection systems were first retrofitted into existing engines. New bus diesel engines built since 2010 are equipped with a urea injection system.

COMPRESSED NATURAL GAS

Natural gas is a fossil fuel, and as an alternative to diesel fuel burns cleaner than diesel fuel. Natural gas or methane is extensively used through utilities to provide gas for homes, including heat, hot water, and for cooking. Natural gas is used to generate electricity, and is replacing coal as the leading electricity generator in the United States. Numerous bus agencies added compressed natural gas (CNG) vehicles to their bus fleet. The natural gas requires specific storage in high-pressure fuel tanks, compressed to less than 1% of its volume. Natural gas is odorless and colorless, and the fueling infrastructure requires natural gas detection in the entire facility, with emergency ventilation systems built into the facility as well.

Natural gas in the United States is predominantly produced and extracted domestically. CNG buses emit less nitrogen oxide, hydrocarbon, and carbon monoxide compared to diesel. By far the most drastic and significant reduction is in particle emissions, where CNG produces much less soot compared to diesel. This is important in inner cities, where high levels of particles can affect people, specifically those afflicted with asthma.

CNG vehicles emit less carbon dioxide, generally, than diesel bus engine counterparts; however, natural gas has a lower energy output than diesel. Studies show CNG buses average 27% fewer miles per gallon than diesel. Methane is also a strong greenhouse gas, so wasted gas or leaks contribute to global warming. Liquefied natural gas is used in selected fleets of transit buses as an alternative bus fuel, and there are others in pilot stages.

Other Alternative Fuels

Alternative fuels, whether renewable or nonrenewable, that are considered for diesel replacement must have similar energy characteristics to power a bus full of passengers, and more importantly be readily available for use and delivery. Ethanol is an alternative and renewable fuel that is made from corn, sugar cane, or wheat. Ethanol is often blended with gasoline, and has reduced greenhouse gas emissions, compared to fossil fuels. Methanol, extracted from wood, is another alternative fuel which is renewable. Switching to an alternative fuel is dependent on consistent availability, and while diesel fuel is the most readily available and abundant fuel, there is a growing supply of biodiesel.

BIODIESEL

Biodiesel is a renewable energy source which can be made from vegetable oils, recycled cooking oil, and animal fats. Biodiesel is a slightly cleaner burning diesel fuel replacement, and for the most part can be used in existing diesel engines. Biodiesel is made from a chemical reaction called transesterification, where glycerin is removed from oil, yielding a long chain fatty acid or methyl ester. Pure biodiesel is termed B100. Many blends of petroleum diesel and biodiesel are produced, most prominently a mixture of 20% biodiesel and diesel, commonly referred to as B20. Therefore, a 5% blend would be B5, and so forth, and in just over a decade, biodiesel production has increased from 25,000,000 gallons produced to over 2,100,000,000 gallons.

As a replacement for diesel fuel, biodiesel must comply with strict standards comparable to petroleum in terms of energy and performance. Biodiesel emits carbon dioxide while being burned in an internal combustion engine. In the lifecycle examination, if crops are grown specifically to be used as biodiesel, they will absorb carbon dioxide over their lifetime, so after the crops are processed into biodiesel and used in an internal combustion engine, the byproduct carbon dioxide during ultimate combustion is forgivable.

Biodiesel releases less pollution and greenhouse gas emissions compared to petroleum diesel. The lack of sulfur in biodiesel allows for more complete combustion, and results in reduced particulate matter, carbon monoxide, and hydrocarbon in the engine exhaust emittance. The higher the blend of biodiesel used in the diesel engine, the higher the emission reduction. Carbon dioxide is slightly less, and nitrous oxide emittance using biodiesel actually increases compared to petroleum diesel. Many public bus fleets use a blend of biodiesel, with B20 a most popular blend, or smaller blends such as B5 or B2, to help with emissions reduction.

A biodiesel blend for many transit agencies was preferred mainly because it generally requires little or no modification either to the existing engine or to the storage tanks, and could be implemented quickly. Biodiesel does tend to gel in cold weather, and the use of biodiesel in cold weather requires additives to ensure performance, especially in North, Midwest, and Northeast climates. Other methods to prevent gelling include engine block and filter heaters, and indoor storage with controlled climate. Biodiesel, unfortunately, also degrades gaskets, seals, elastomers, plastics, and rubber compounds, which are primarily vulnerable.

For a pure or neat biodiesel B100 bus fleet, the vehicle engine and fueling system need to be designed with the appropriate material to reduce the negative effects of biodiesel. Biodiesel blends of 20% or less were the safe choice for existing vehicles to utilize, in both hot and cold climates. Another issue that dictated the choice of blend was what blend would an engine company cover under an existing warranty. Most warranties would cover blends up to B20, some would only go as far as B5, and some would not even consider anything but what was specified. Biodiesel is better for the environment and is biodegradable; however, the decision to switch to pure biodiesel or a blend included some risks and cost considerations to contemplate.

HYBRID BUSES

The major benefit offered by diesel hybrid buses is that they produce lower emissions through increased fuel efficiency. Hybrid buses most often include a large battery to supply electricity to an electric motor. The most dominant diesel hybrid bus is where there is both a diesel engine and an electric motor that can both concurrently supply power through a normal transmission, called a parallel hybrid. The energy storage system or battery charges up through the regenerative braking system, or the diesel engine can help charge the battery with a generator.

A parallel hybrid bus can run at times on the battery-supplied electric motor, or a blend of battery power and diesel engine, or the bus may run on the diesel engine alone. In series hybrids the electric motor drives the bus, as a diesel engine works only as a generator to power the electric motor or to recharge the batteries. It is common to both parallel and series hybrids to use regenerative braking to help recharge the batteries. Hybrid buses are prominent in many city transit systems, and gained exposure many years ago on various environmentally conscious college campuses as the prime transportation for students.

Hybrid buses are generally the same typical size as a standard diesel bus, and usually perform better than diesel in terms of emissions and economy. Hybrid buses, in some cases, perform better in urban stop and go traffic, because with the heavy use of regenerative braking, the constant use of the braking system allows more energy to be generated to constantly recharge the battery, allowing many more miles to be traveled using the electric motor, supplied by a battery. The regenerative braking system in a hybrid bus is similar to the system in trains, except the energy regenerated is supplied directly to a battery, and therefore less of it is wasted.

Hybrid buses still have a diesel combustion engine, which pollutes; however, it is smaller than standard buses, and will release less emissions if a good portion of power comes from the battery supplied electric motor. Hybrid bus drivers take training to maximize the use of the electric motor, and rely less on the internal combustion engine, to use less fuel. According to studies conducted by the National Renewable Laboratory, hybrid buses save around 20% of fuel usage compared to standard diesel, and are relatively quieter. Batteries for hybrid buses are both expensive and heavy, and require maintenance and replacement through the life of a hybrid bus. The upfront costs are higher for hybrid buses; however, the federal government has funded many hybrid bus fleets across the United States in recent decades to help proliferate the use of hybrids, and many city and state transit agencies have reaped the benefit of that funding.

Diesel Electric Hybrid Bus technology has grown over the last few years, improving hybrid vehicle technology. On-demand hybrid buses can shut off the combustion engine during idling or coasting, when the electric motor provides sufficient power. Dramatic reductions in emissions and fuel consumption, coupled with similar vehicle performance, help proliferate hybrids in the public bus transit sector. Hybrid buses are fueled identically to standard diesel, requiring no modification to the existing fuel storage infrastructure.

HISTORIC REDUCTION

To illustrate the dramatic reduction in fuel consumption, while maintaining core business, please refer to Fig. 6.1. In the year 2000, the reported amount of diesel fuel consumed by public transit buses was 635,000,000 gallons of diesel fuel, and as per Fig. 6.2, the annual total of bus commuters, per census data, was 3,207,000 people who used the bus as their primary mode. Thirteen years later, the annual reported diesel fuel consumption dropped over 32% to 428,000,000 gallons of diesel. In the same period, bus commuters were a reported at an annual figure of 3,793,000 people in 2013.

During this period of sustainability initiatives, the public bus transportation sector was able to reduce diesel emissions and the emittance of greenhouse gases by approximately one third, while both maintaining core business and seeing a steady, albeit with some fluctuations, rise in the numbers of paying customers. A combination of increased usage of hybrid buses, CNG buses, and government funding has led to this historic reduction. The ability to operate and continuously improve environmental performance is a significant sustainability management achievement for the entire mass transit industry.

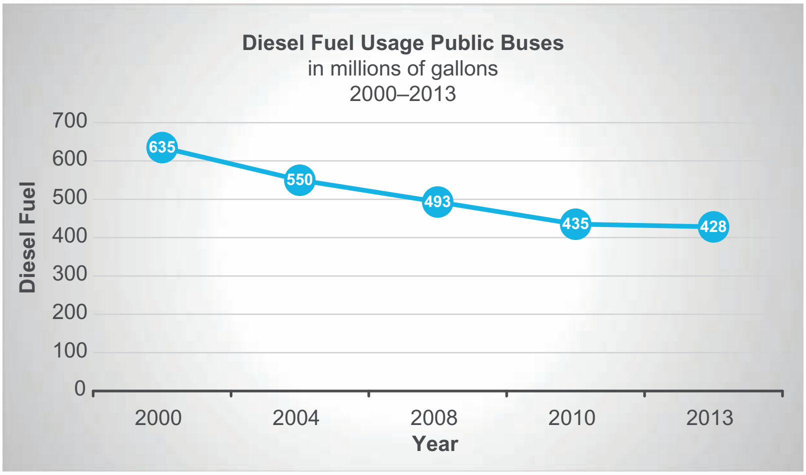

FIGURE 6.1 Diesel fuel usage public buses 2000–13.

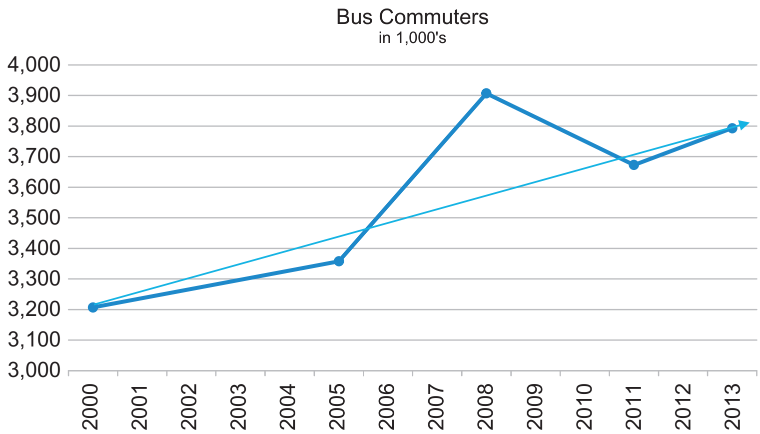

FIGURE 6.2 Bus commuters 2000–13.

ELECTRIC BUSES

Electric buses are powered solely by rechargeable batteries, which receive their charge by plugging into an electrical power source, most often from the power grid. Public mass transit buses travel in various lengths, in stop and go traffic, moving traffic, etc., and to utilize an electric bus, the battery supply must be considered, and whether the need for charging stations strategically located, at particular bus stops or stations, will be necessary. This is the major challenge in implementing an all-electric bus fleet, almost anywhere. Electric buses are equipped with regenerative braking to help continuously recharge the battery; however, the current electric bus battery range is considered low for many different situations.

Technological advances in batteries, super capacitors, and energy storage systems in general are making strides to help the future proliferation of an electric bus route. Reliability is a cornerstone of mass transit, and the application of an electric bus must consider that any delays to passengers due to buses requiring long stops to recharge, could discourage passengers from choosing to take the bus. Charging stations along an infrastructure require space for the bus and the system to connect, without disrupting the flow of traffic.

The cost of an electric bus, including charging stations, can be substantial over the cost of a standard diesel; however, savings in fuel costs can be just as substantial. Emissions are overall much less with an electric bus, compared to a diesel or hybrid bus. The centerpiece of an electric bus is what kind of battery is used, how quickly it can be recharged, and the weight of the battery. The heavier the battery, the more energy it takes to move the bus. All things need to be considered prior to implementing an all-electric bus line, including the specific bus route, landscape, and economics. Pilot programs and testing are ongoing, and several small all-electric lines are currently operating in the United States, complete with recharging stations along the bus right of way.

Fuel Cell Buses

Fuel cell buses produce no emissions while driving, and are powered from the electricity generated by a reaction of hydrogen and oxygen, which produces water vapor. Hydrogen fueling stations are required, and there are relatively very few of them. Hydrogen can be extracted from water; however, in many cases it is the combustion of methane which creates the hydrogen for a fuel cell, and of course, that creates emissions and greenhouse gases. Fuel cell buses, including a hybrid fuel cell bus, are being piloted around the world.

Nitrogen Tires

Nitrogen filled tires help to keep tire pressure constant, which helps save fuel. Nitrogen molecules are larger than oxygen molecules, therefore nitrogen leaks through rubber tires less than oxygen, which keeps tire pressures more stable. Nitrogen tires also help keep all tires at a consistent level, providing a smoother ride, and nitrogen filled tires contain less moisture, which will affect pressure levels with temperature rise and fall. Less water vapor or moisture in the tire means that there is less potential corrosion to the wheels or rims, saving maintenance costs. Nitrogen in tires can help save a small amount of energy per bus; however, the energy savings add up for an entire fleet. A costlier nitrogen compressor would be necessary, in lieu of an air compressor to fill tires; however, that cost could be offset with savings from the reduction in the labor needed for continuous refilling with air.

ENVIRONMENTAL PROTECTION AGENCY EMISSION STANDARDS

The EPA has finalized upcoming new standards for bus diesel engines for model years 2017–25, which will mandate new standard diesel buses to be cleaner than ever. The EPA emission standards apply to the year the vehicle is produced. For example, all buses manufactured in 2010 had to have engines that complied with regulations required for 2010 models; all buses manufactured in 2004 had to have engines that complied with regulations for 2004 models, and so forth. Consequently, older vehicles technically and legally can pollute more than newer vehicles. Policies prohibiting older vehicles from the road are being proffered around the world, as an example France has banned the use of all vehicles registered earlier than 1997.

BUS DEPOTS

Many cities have a bus network providing mass transit for the riding public, and there are millions of buses which travel city streets during both the daytime and nighttime, with some large cities having an all night bus service, running 24 hours/day. Bus service volume is greatest during the morning peak rush hour periods, and the rush hour afternoon drive home. In between both rush hour periods and overnight, fewer bus services are provided, and therefore, buses while not operating need places to be stored.

The bus depot provides a variety of service functions for buses, including parking, fueling, washing, and maintenance. A bus annex or garage in most cases houses buses, but may not fuel or maintain buses. In many instances, the prime functions are spread out to different facilities. The conventional bus depot, especially those in the inner city, include all of these functions, traditionally in one single large transportation building or facility. Bus depots are not to be confused with bus stations or terminals, which usually are places where people actually board a bus for initial departure.

The inner city bus depot usually fits everything, including administrative offices, employee locker rooms, maintenance areas, fueling bays, and parking, within a massive facility. Some bus depots have adjacent outdoor parking for buses. The most important environmental aspect of the bus depot is when the bus enters the building, and drives through the building with the diesel engine tailpipe exhaust adding toxic substances to the indoor air quality of the depot. Diesel engine exhaust, even with the benefit of diesel particulate filters, can emit small particles made up of mostly elemental carbon, because of incomplete combustion.

Exposure to high levels of diesel particulate matter can cause eye, nose, and lung irritation. Long-term exposure can compromise the cardiovascular or respiratory systems, and potentially can cause lung cancer. Engineering controls such as numerous air exchanges and micro filters can reduce the environmental impact of diesel particulate matter on adjacent neighborhoods. In order for people who work in the depot to be able to breathe acceptably clean air inside, with the constant influx of buses entering and exiting through the building, a robust air exchange system needs to be able to dilute the indoor air with fresh air from the outside.

During the air exchange process, air from the outside can be filtered of very small particulates, prior to entering the bus depot. The exhaust on the way out of the depot, which includes particles from the tailpipe exhaust, can also be filtered to help protect the neighborhood from advanced particle accumulation in the air. Inner city bus depots, in many cases, are right in the middle of an urban neighborhood, and can be adjacent to homes and buildings, so continuously filtering outgoing air helps reduce particles in the ambient environment of the local community.

HEAT RECOVERY UNITS

Ventilation is a critical part of a bus depot's operations. A large bus depot, during colder months, will require the necessary heat to keep people comfortable who work in the building, including the maintenance workers who work standard shifts in the depot maintenance and fueling areas, those who work in the supervisory, dispatch, and administrative offices, and of course the drivers who convene at the depot. Mechanical ventilation heat recovery units can provide the required hot air for heating in the cold weather season, and work as a fresh air heat exchanger, saving a lot of energy in the process.

The heat recovery unit is placed on the roof of a bus depot, and in addition to providing heat through the combustion of natural gas, when fresh cold air comes in through the intake of the unit, it also exchanges heat with outgoing already warmer air from the depot. The heated outgoing air passes heat to the colder incoming air without the two airstreams mixing, warming the cold air coming in, and requiring less energy to heat the building. The heat recovery unit is a basic heat exchanger.

The more heat recovered during heat exchange, the less energy is required. Heat recovery units are equipped with fans to help with intake and exhaust, so an electrical energy source is required to run the unit, which can filter air on both the intake and exhaust, removing and preventing fine particles from releasing into the atmosphere. The filters, which can trap particles as low as 1μm, helps remove particles from the atmosphere. On large bus depots, which require robust air exchange, some facilities can have many units working in tandem to save energy and prevent pollution.

Heat recovery units can help prevent pollution by filtering the air, and reduce greenhouse gas by saving energy. Heat recovery units work best in cities with cold winters, such as the North, Northeast and Midwest climates. The more effective the heat recovery unit, the lower the amount of natural gas required to be consumed. In addition, in the summer season, the heat recovery unit can work in reverse, cooling incoming hot air by heat exchanging cooler inside air with the hotter incoming summer heat.

GREEN ROOFS

Vegetative or Green Roofs have numerous environmental benefits. Bus facilities including depots, garages, annexes, and maintenance facilities have large expansive rooftops. Green roofs can help reduce energy costs by providing an extra layer of insulation and weather protection to a rooftop, absorbing storm water, sequestering carbon dioxide, helping reduce the heat island effect in urban areas, attenuating noise from rooftop ventilation units, and most importantly, green roofs filter floating particles.

Green roofs help filter particles that are in the air, specifically from the combustion of gasoline and diesel engines, that are typically floating in the atmosphere everywhere, especially in urban environments. People who suffer from asthma, especially children, have a very hard time when there are advanced levels of particles in the air. Fine tiny particles are problematic for many people, because they are so small they can penatrate people's lungs, and cause irritation and illness.

The tiny particles that float in the air eventually settle on the leaves of the green roof, and stick to the leaves until rain comes down. When it rains, the particles will be flushed into the soil of the green roof, and the particles will then neutralize in the soil. Therefore, in a sense, green roofs filter the air of small particulate matter. In addition to helping filter particulate matter and absorbing carbon dioxide, green roofs also help manage storm water impacts by absorbing rainwater.

Most urban areas are almost completely paved over with very little natural ground infiltration, and the majority of rain that hits the ground, unless captured in a storm or combined sewer, will run off into a nearby water body, bringing whatever contamination is with it into the water body. Green roofs help minimize storm water runoff. A green roof uses an engineered soil that is very fluffy and porous to allow substantial rainwater to be absorbed. Green roofs also protect the roof membrane from extreme temperatures, and help minimize heat gain, saving cooling energy. The green roof temperature will most often be cooler when the air temperature is hotter, than black-top roofs, which absorb sunlight.

The plants within a green roof are selected based on their ability to withstand severe weather conditions. Suitable plants include drought, wind, and cold weather resistant sedum species. Each layer of a green roof has specific functions, including a root barrier to prevent root penetration into the roof, a mositure retention protection mat, a drainage layer to safely drain oversaturated soil, a filter sheet to prevent particles of soil from draining out, a growing layer or medium of soil, and of course the plants that grow in the soil.

Green roofs can be either extensive, which means they sit in trays on top of the roof membrane, or intensive, which are constructed right on top of the roof, and are comparable to a rooftop garden. The potential plants in an intensive green roof, in addition to sedum, could be any type of vegatation including trees, as intensive green roofs tend to have a much larger growing medium than extensive green roof systems, which tend to be more shallow.

Bus depots using filters on the intake and exhaust to remove particles, combined with a green roof, can eliminate a lot of floating particles in the air, and reduce impact on the environment. A building or facility roof's structural integrity must be strong enough to hold up the weight of a fully saturated green roof. A drainage system for the excess rainwater needs to be integrated in the green roof system, which could also be combined with a rainwater collection system that helps manage storm water, and also conserves potable water.

RAINWATER COLLECTION SYSTEMS

Harvesting rain as part of a building or facility is a practice that is utilized to save potable water and reduce storm water impacts. Rainwater collection reduces water that may go into a storm sewer, combined sewer, or may run off into a nearby water body. Rainwater collection systems drain water from rooftops into water storage tanks, which can be above ground or underground. Rainwater rooftop collection systems can be used for washing buses in a bus depot, by connecting the storage tank to the bus washer to supplement water used to clean, wash, and rinse, which will save potable water.

Rainwater collection and harvesting can reduce the impact on aquifers, minimize flooding, and save energy. Filtration should be implemented to reduce and prevent any particles that have settled on the rooftop from getting into the water storage tank. Using rainwater for bus washing, and for flushing toilets, requires little pretreatment except for filtration. To use collected rainwater for normal potable water use, in addition to filtration, ultraviolet sterilization can be used to kill bacteria.

Collecting rainwater in the end can save energy in certain ways. Urban areas commonly have combined sewers, which are storm sewers that combine with the sanitary sewer; therefore, rainwater ultimately mixes with sewage, adding unnecessary volume for the wastewater processing plant. Many cities during rain events see their wastewater treatment plants get so overburdened that they no longer have the capacity to handle the increased volume of sewage supplemented by the rain event, and the sewage often must be directed to the nearest water body, compromising water quality with sanitary waste.

Rooftop rainwater collection systems prevent excess volumes of rain from entering into the combined sewer system, lessening the burden on treatment plants, and the energy necessary to process waste is reduced. Collecting rainwater lessens potential contamination carried by storm water that runs off into an ocean, river, lake, or stream. The extreme volume of typical rain events has dramatically increased over the past several decades, and rainwater collection helps mitigate the effects of more severe storms.

Recycle Bus Washers

Bus washer systems usually found within the bus depot look a lot like a neighborhood car wash, with the exception of size. The height and width are sized to accommodate a bus, with similar wash, rinse, and dry cycles. In a bus wash system during the rinse, wash water is recycled for reuse, often within a continuous loop recycling system. The system should be designed to remove oils, filter particles, and remove organic material. Activated carbon is used to adsorb organic compounds in water treatment processes. Carbon adsorption is the physical process of accumulating a substance, and activated carbon is a good adsorbent because of its high level of porosity.

Potable Water

Potable water is defined as water that meets the standards for drinking water. Everybody in large volumes uses water every day. Industry, energy, agriculture, people, etc., all require tremendous amounts of water. This puts a heavy burden on reservoirs and acquifers, and in many parts of the world drought conditions exist, so saving water is always an ongoing conservation effort. Nonpotable water is taken from lakes, rivers, and ground water that has not been treated, and therefore would not be safe to drink, shower, or bath in.

Greywater is wastewater from bathrooms, sinks, and showers, and can be used to save potable water. Greywater is not considered potable water, although it can replace potable water to irrigate plants, and fill toilets. What comes out of the toilet is considered black water, and must be sent to a wastewater treatment plant. Using greywater helps reduce the burden on wastewater treatment plants, by reusing water for different purposes, therefore saving potable consumption. Low flow or high efficiency plumbing fixtures can also help save water.

Energy and Water

Energy and water are explicitly linked together. Water is used in tremendous volumes to help generate electricity and fuel. Energy is required to process wastewater. Electricity generation often depends on the use of water for steam to power turbines. Hydroelectric energy is derived from the action of water, and often water from a river or lake is used to cool nuclear power plants. Recycling loops, specifically where steam is cooled back into water, and then used as steam again, helps save water. Irrigation in agriculture uses incredible amounts of water. Saving water is essential in that human and animals need it to survive, and our societal needs require great amounts. Saving water saves energy.

STRATEGIC INITIATIVES

Conserving fuel for the benefit of the environment can come in many forms, including sustainable initiatives that reduce bus miles traveled. All cities, towns, and counties have their own streetscapes for buses to navigate through. While every city is different, there are many similarities in configuring bus routes and networks. The bus corridor is selected based on potential customers, and transit agency operations planning departments use census and ridership data to help maximize where and when passengers embark and disembark most frequently, to create bus routes. Bus operation planning has to be based on what routes do the greatest good for the greatest number of people.

The ideal situation is to pick up passengers at selected bus stops, and move as quickly as possible to the next stop. However, the more likely scenario is that after a bus picks up passengers, it slowly moves behind traffic to the next stop, and continues on the route. The more traffic there is, the higher the combined concentrated levels of pollutants from all the vehicles on the street in the localized area, and at crowded intersections, these are referred to as hot spots. Air pollutants found at traffic intersections can become high pollution hot spots due to increased traffic congestion.

When drivers are continuously decelerating and stopping, in heavy traffic, they rev up the engine more quickly, constantly releasing bursts of pollution. In contrast, during a smooth long drive, with the engine running close to peak efficiency, less pollution is released. Peak particle concentration is exponentially higher in standstill traffic than in free-flowing traffic conditions. In addition, cars close together in traffic add to the likelihood of driver exposure to vehicle emissions.

Any time you can improve traffic conditions prevents excess pollution buildup in both localized areas and overall urban communities. Bus rapid transit inherently reduces traffic, first by removing the bus from traffic, allowing the bus to run more efficiently and more often, as opposed to stop and go traffic, which wastes fuel and emits more pollution. In addition, buses off the road will help ease normal traffic as well. Another way to save energy is to limit the number of miles a bus travels with no passengers inside. Bus depots, annexes, or garages need to be as close to the starting point of the bus route to minimize distance traveled with an empty bus. Sometimes strategic layover locations need to be established, to avoid long empty miles being traveled.

Many commuter buses, which bring people daily for sometimes-lengthy rides from the suburbs to the city, drive people in the morning to work, and again back home in the afternoon. Often the same bus that brings people to work drives back empty to the home base depot, and then in the afternoon drives back empty into the city to pick up people and bring them home. With a carefully established layover in the city, the bus could actually park during the day, and then drive home passengers, saving two empty trips. An additional parking lot may have to be bought or leased to avoid the emissions of wasted trips, but the saved fuel cost could help offset the expense of the additional lot.

CONCLUSION

Public bus transit has made many inroads into reducing emissions, and has been an exemplary model for reductions, due to sustainability initiatives.

The bus industry made big strides in emissions reduction, even making substantial changes to existing vehicle engines used at that time. Using the reduction of sulfur content in diesel fuel, combined with an addition to the existing diesel engine in the form of a diesel particulate filter, significant emission reduction has been achieved over time. The public bus mass transit industry has a long list of sustainability initiatives to celebrate.

Starting with the use of ULSD to reduce emissions, alternative fuels, environmentally friendly buses such as hybrid buses, CNG, fuel cell and all-electric vehicles, have all contributed to saving fuel, and reducing greenhouse gas emissions and tailpipe exhaust. In the past decade and a half, the public bus transportation industry considerably reduced diesel consumption while maintaining core business, with the combination of hybrid buses and natural gas buses. The ability to improve environmental performance continuously is a tremendous ongoing achievement for the public mass transit industry.

Bus depots can also include sustainable initiatives that will save energy. Heat recovery units save energy, and can be fitted with filters to remove small particles in the air. Green roofs provide an extra layer of insulation to help save energy and protect the existing roof membrane from the elements, absorb rainwater, absorb carbon dioxide, help reduce the heat island effect, and help remove floating particles, as a result of emissions.

Rainwater collection systems help store rainwater for use as supplemental bus washing water, and can provide relief to overburdened sewer systems. In addition, bus wash reclamation or recycling systems help reduce the use of potable water. Strategic initiatives, such as bus rapid transit, help prevent the buildup of emissions from forming traffic hot spots. Strategies that reduce or eliminate the amount of bus miles traveled without passengers help save fuel, and with proper and appropriate placement of layover staging, can help save money. Future initiatives may include newly created advances in technologies or engineering, or may take the form of a combination of existing sustainable ingenuities, that when working together make an even stronger impact.

FURTHER READING

http://biodiesel.org/reports/20071127_tra-56t.pdf.

http://publictransport.about.com/od/Transit_Vehicles/a/Electric-Buses-An-Introduction.htm.

http://www.zinco-greenroof.com/EN/greenroof_systems/intensive_green_roofs/index.php.

http://www.clean-diesel.org/vehicle_performance.html.

http://www.apta.com/resources/statistics/Documents/FactBook/2015-APTA-Fact-Book-Appendix-A.pdf.

http://biodiesel.org/docs/ffs-basics/clean-cities-fact-sheet-biodiesel-blends-april-2008.pdf?sfvrsn=4.

theverge.com/2016/6/1/11818990/paris-old-car-ban-pollution-smog-traffic.

Chapter 7

Future Challenges and Sustainability Opportunities

INTRODUCTION

Mass transit, which is inherently sustainable, has met the current challenge of reducing emissions, preventing pollution, and limiting the release of greenhouse gases, and there are an endless number of further opportunities to add more environmentally sustainable innovations. The past two decades, public transit agencies in the United States have set a great example to all sectors on how to incorporate sustainability into their core operating business.

By adding sustainable elements to many projects, and through many programs, there are many sustainable initiatives in mass transit for all to emulate. Successful pilot sustainability initiatives, when put in place, may well be expanded on much larger scales by transit agencies to continue to meet the challenge of reducing emissions. Regarding climate change, adaptation measures must be considered and designed to expect differing future weather conditions and extreme events, and include the prevention of flooding of subway train systems, especially in coastal cities.

Mass transit public agencies have included numerous sustainability initiatives in their infrastructure, facilities, and vehicles. An extremely important accomplishment in mass transportation engineering over the past two decades has been the relative swiftness of incorporating new sustainable best practices into already established engineering design procedures and construction guidelines, and seamlessly incorporating sustainable elements in capital design and construction projects.

There is now, and will continue to be, experimentation in mass transit, and many small pilot programs have great potential to grow. Many sustainability initiatives start out as a pilot program, and then grow into an established practice. Hybrid buses, in the mid-1990s, started out as several small experimental pilot programs, and now make up a significant portion of public bus services. A popular current pilot initiative, such as the use of a small number of all-electric buses within a fleet, should move forward into a full-fledged all-electric fleet, which will have great benefit to the environment and great potential toward becoming a standard industry practice.

Sustainable Mass Transit. DOI: http://dx.doi.org/10.1016/B978-0-12-811299-1.00007-1
© 2017 Elsevier Inc. All rights reserved.

ALL-ELECTRIC BUS FLEET

The future of a public transportation bus service is the expected growth and proliferation of an all-electric bus fleet. An entire fleet of all-electric buses would see a significant reduction in air pollution and greenhouse gases, in direct comparison to a diesel, hybrid, or compressed natural gas fleet. The big challenge when it comes to an all-electric fleet is how quickly a bus can be recharged, and how far can it go on a single charge. There are many individual all-electric buses currently on the road, and several small-scale examples of an all-electric bus line in the United States. Converting a large city's entire bus fleet to an all-electric bus fleet is a big challenge, not only for the transit agency, but also for a whole city.

The all-electric fleet would most likely require necessary charging stations along the bus route, taking up space and requiring consistent maintenance. The fast charging capability of the docking station will vary depending on the battery system in the vehicle. Therefore, distance traveled on the battery supply of choice determines whether mid-route charging is required. Charging stations at the end points of the bus run would be ideal, specifically if they can be incorporated into the natural waiting time of the bus layover. Charging stations are a natural fit to include solar panels to augment supplied electricity with renewable energy. An all-electric fleet would benefit from a charging station built into the parking storage area for overnight charging.

An electric bus is currently more expensive individually than a diesel or hybrid electric bus. Many transit agencies are piloting electric buses within their fleet, and many have plans to purchase more. Agencies are pledging to convert their entire fleet; however, it will take time and money for complete conversion. The additional cost of charging stations adds to the cost. An entire fleet using electricity as its energy source would prevent pollution and significantly reduce greenhouse gas emittance. Also, electric buses are generally quieter than diesel buses, reducing noise pollution. The electric motor is much like the motor in a hybrid, and electric buses are also equipped with regenerative braking, with the braking energy or regen supplied into the battery system.

As the hybrid diesel bus business grew, the demand for and improvements of components such as batteries and electric motors to be included in a hybrid bus, began a natural progression toward the all-electric bus. With the batteries continually improving, and the cost of batteries decreasing because of the increased demand for similar hybrid batteries, the cost of an individual all-electric bus is decreasing. Docking stations with fast charging capabilities are an important consideration, and a determining factor in bus route planning, for an all-electric bus fleet.

Overall, an all-electric bus fleet would increase emission reduction in comparison to a diesel or hybrid bus, and in determining the overall reduction and environmental benefits of converting to an all-electric bus fleet, the source of the supplied electricity generation needs to be identified. If much of the electricity comes from renewable sources, such as hydroelectric, solar, or wind, the environmental benefits of the all-electric bus fleet become even more profound. An all-electric bus uses an electric motor powered by a rechargeable battery, and in many cases it is a lithium-ion battery.

Lithium-Ion Battery

The lithium-ion type is the fastest proliferating battery today, which has many applications, including electric or hybrid bus battery storage. The best advantage of the lithium-ion battery is the lightweight nature of the battery. Lithium is the lightest metal, and has a capable electrochemical potential. Compared to most other metals, it has larger energy density per weight. Originally, using the pure lithium metal posed many safety concerns during recharge, because of the instability of lithium. Lithium-ion is safer, although it is lower in energy density. A lithium-ion battery has relatively low maintenance during operation; however, the battery commonly will deteriorate after a few years. Disposing of lithium-ion batteries causes minimal harm to the environment if they are appropriately recycled. The lithium-ion battery has seen constant improvement over the past several years, and new types get introduced seemingly each year.

ELECTRICAL ENERGY STORAGE

The next steps in the energy storage evolution are moving very quickly, as cutting-edge research into different forms of electricity storage is ongoing here in the United States and around the world. The US Energy Department is funding many different projects developing electricity storage, working with scientists at many esteemed universities. The Advanced Research Projects Agency—Energy has plans for different types of batteries, looking for improvements in capacity, weight, and of course cost. A considerable advance in the technology of energy storage can help renewable energy grow. Closing the gaps created by the downtime of solar or wind, by storing energy created for later use, will surely help toward more reliance on renewables in the future. The continued growth of both wayside and on-board energy storage has the most growth potential for future significant increases of energy efficiency in train systems, both heavy and light rail.

Taking advantage of stored energy in a battery or capacitor for later use is a landmark electrical achievement of modern society, and a technology that continues to evolve in mass transit, on its infrastructure and vehicles. On-board storage in light rail vehicles can allow light rail systems to travel without wires, and save energy. Regenerative braking provides the energy for these storage systems; however, wayside systems can also be supplemented by solar energy panels to increase the amount of stored charge. After collecting regenerative braking from trains, wayside energy storage provides a big opportunity to help increase energy efficiency in mass transit. Many US transit infrastructures are including wayside energy to reduce electrical consumption, and have plans to add more.

DEDICATED RENEWABLE ENERGY

Large electrical consuming energy users should use as much renewable clean energy as possible. Often, a city's mass transit agency is among a city's biggest electrical clients. The high premium on renewable clean energy prevents agencies from seeking more solar, wind, or hydroelectric energy. In some cases, and in some states, even if a transit agency wanted to purchase all renewable energy, it is not a given that sufficient renewable energy would be available in their respective state. Mass transit agencies could help invest in more renewable energy, to aid its growth, and ensure that it is available in bigger quantities for their future use. At a minimum, portions of renewable energy should be dedicated to mass transit. New renewable clean energy generating power plants could be built specifically to provide electricity for a new mass transit system.

A new solar or wind farm, or a hydroelectric dam, could conceivably produce most or a good proportion of the electric power required for a moderately sized mass transit system such as light rail, or most likely all the necessary power for an all-electric bus fleet. The required space for the generating plant, substations, and power transmission lines would be necessary. This complex endeavor, and a project of this magnitude, would require a collaborative effort between the transit agency, and state, city, and local utility officials to succeed, and most likely would also require federal funding. Back-up electrical supply from traditional sources such as the power grid would need to be added as a supplement during nonproducing electrical periods during the nighttime with solar, or when there are periods of little or no wind. Adding a battery storage system could supply the energy necessary to save renewable energy produced for later usage. In lieu of a dedicated power plant, renewable energy certificates could be purchased for some or all electricity needs.

Historic Power Generation

A dedicated power generating plant is nothing new for mass transit. Early historic transit utilized its own power generation going back to the trolley car steam generator. At the beginning, New York City had dedicated coal burning power plants, with the first one built on 11th Avenue and 59th Street in Manhattan for the earliest power generation for the initial

New York City subway system. The power plant burned coal to create steam, to power turbines. Coal was shipped by barge to the waterfront location of the electricity producing power plant. A dedicated renewable power generated solely for a mass transit is certainly an achievable engineering challenge, although within an inner city, significant changes in existing infrastructure would be required. It is conceivable a renewable power generating plant, located just outside a city, could also supply much of the energy for a city's mass transit system.

GROUNDWATER USAGE

Subway tunnels have historically been designed and constructed to be as watertight as possible. Tunnels dug into the ground must be designed to withstand the tremendous pressure of the ground water against the tunnel walls and foundations. In lieu of watertight walls, future subway tunnels could be built to allow ground water to infiltrate into and out of the system. This would allow the use of the cool ground water as a medium to save energy by reducing the need for electricity consuming air conditioning required in the tunnel for cooling electrical equipment.

Shallow ground water in most of the United States, at about 10 ft below the ground, is a nearly constant 55°F (12°C), and while the temperature can fluctuate minimally in both summer and winter, this basically cold water could be used to cool spaces in the subway station environment. Below ground, which can get very hot in summer and sometimes in winter, a tremendous amount of energy is required, not necessarily to cool people, but to cool underground subway electrical equipment.

Electrical, signal, and communications equipment must be kept in cool places within the underground tunnel environment, and there is required consistent energy needed to help cool equipment, and keep it at the required operable ambient temperature. Ground water which is rerouted through the subway system can be used to help cool the air spaces in electrical distribution rooms in the transit infrastructure, saving energy. Ground water can also be used in facilities outside the transit infrastructure, to help cool offices, computer equipment rooms, data centers, etc., and save the economic and environmental cost of air conditioning.

Beneficial Use of Dewatering

Subway tunnels are built to include ground water pumping systems or pump rooms, to remove ground water that has penetrated the tunnel. In some cases, the ground water table is so high or shallow that the tunnel is the subject of fierce ground water pressure, resulting in the constant infiltration at such volume that the existing pump rooms built into the infrastructure cannot handle the heavy ground water load. To prevent this constant infiltration, the construction of a series of pumping wells alongside the outside of the subway tunnel to consistently pump out ground water lowers the water table below the subway tunnel structure, making it impossible for ground water to enter the tunnel.

Utilizing pumping wells to relieve the over-burdened pumping stations of additional volumes of ground water also presents an opportunity to reuse the pumped ground water for other purposes, both within and outside the transit infrastructure. The ground water pumped out of the ground from the dewatering process must be discharged somewhere, usually to a nearby water body via direct discharge or storm sewer connection. Prior to discharge, the ground water flow stream can be used as an energy medium for heating and cooling, or it could be used for landscaping or car washing, or if carefully engineered, the ground water discharge stream can be used in a turbine to create electricity.

GEOTHERMAL

Many geothermal related processes utilize the subsurface of the earth's energy sources, for both heating and cooling. Direct geothermal energy is where hot springs or reservoirs, found near the earth's surface, provide natural hot water. This geothermal water can be used to transfer heat into a building. Some hot springs can provide steam, which can be used to generate electricity in a power plant. Geothermal power plants produce clean renewable energy, with very little carbon dioxide emission. For the most part, the shallow part beneath the earth's surface is normally a constant temperature of 55°F or 12°C, and therefore, knowing the near consistency of the temperature, the earth can be used in a geothermal heat pump.

The shallow constant earth temperature can be used to lower the temperature of a liquid or gas above 55°C or raise the temperature of a liquid that is below 55°C. Pipes filled with a liquid medium, normally either water or a refrigerant, with a compressor and heat exchanger in a certain sequence, can be run underneath the ground to extract or exchange heat with the earth, to supply heat and hot water throughout a building, and in the summer the process can be reversed, to provide cooling. Pipes can be either horizontal or vertical. Some geothermal heat pump arrays have several very long pipes drilled into the ground or a multitude of shallow wells drilled. The number of wells is determined by the amount of heating or cooling required.

Other than the electrical energy needed for pumps, compressors, etc., no other emissions are released during the geothermal heat pump process. Considering the tiny fraction of emissions, it is regrettable that there is not nearly the amount of geothermal use of energy worldwide yet that could be achieved. Much is to do with the higher upfront costs associated with drilling, and the perceived limited space availability. Mass transit facilities are perfect for geothermal heat pumps, because they usually have large space requirements above the surface, and that allows a lot of space for a geothermal well-field. Maintenance shops, storage yards, and bus depots usually are buildings with adjacent large parking areas, where wells for a geothermal field could go into the ground in multiples.

GREEN INFRASTRUCTURE

Rain falls on our city sidewalks, streets, and rooftops, and therefore usually water cannot infiltrate naturally into the ground, as nature intended. Storm water drains into sewers, and is discharged into the combined sewer that goes to a waste water treatment plant, a storm sewer, or a nearby water body. Green infrastructure is an alternative method of managing storm water in an urban environment. Traditional concrete pipe drainage and sewer systems are referred to as grey infrastructure, which are designed to collect storm water, and directly discharge to a water body, or waste water treatment plant.

Green infrastructure collects and treats storm water in place. Storm water runoff can collect contamination and debris in urban areas, and deposit into a nearby water body, thereby increasing water pollution. Green infrastructure reduces runoff by using vegetation and soil to naturally absorb rainwater and filter contamination, before it can get to a water body. Green infrastructure, which can include rain gardens, planters, bioswales, trees, green roofs, and engineered wetlands can also provide flood protection. Mass transit infrastructure is built into a city's urban landscape, and runs both adjacent to, above, and underneath the city streets.

Train stations are focal points of the city landscape. Where transit infrastructure meets with the city landscape, this is where a lot of green infrastructure can be built to help reduce storm water runoff. Station entrances lead right to the city sidewalk, and where these meet, green infrastructure can be implemented. Many station entrances, which can be adjacent to a park, can include large open spaces where green infrastructure could be included. Elevated station canopies can collect rain water and direct rain to any type of green infrastructure.

Rain gardens, planter boxes, and bioswales all are vegetated containers or basins, that absorb rain water, and either slowly filter water into the ground, or hold water until it evaporates, to reduce or lessen storm water runoff. Rain gardens can be installed in the street or on the sidewalk to collect runoff and slowly infiltrate into the soil below. Often a rain garden includes an engineered soil capable of holding larger volumes of water, on top of a gravel bed, which can slowly infiltrate water into the ground. Planter boxes can collect rain water from rooftop canopies, and can be placed along sidewalks, but usually cannot be expected to hold a lot of water, so a series of planters often works best. Bioswales can be utilized in parking lots to slow down storm water flow, and reduce runoff.

The mass transit infrastructure can incorporate green infrastructure in many places, but specifically at the meeting point between station entrances and sidewalks. Green infrastructure reduces storm water that would flow directly into a combined sewer system. Any reduction in the volume of rain water that can be eliminated from going to a waste water plant will help save energy. Green infrastructure also helps beautify public space, absorb carbon dioxide, filter particles in the air, and keep a city cooler, because of the consistent evaporation that helps cool the atmosphere.

Train terminals or stations that are large enough to incorporate green infrastructure landscaping, can provide open space for neighborhood enjoyment, including planting and maintaining trees. Also, parking areas can incorporate permeable concrete or asphalt, which are porous pavements, which allow water to naturally infiltrate into the ground. Light rail systems or bus rapid transit running on their own dedicated right of way, can incorporate green infrastructure along the path, like green streets that are within many inner city urban areas, to help reduce runoff and an overburdened sewer system.

CLIMATE ADAPTATION

The earth has experienced numerous natural occurrences which have affected climate. Earthquakes, which create shifts in the tectonic plates, can cause the earth's climate to change. When volcanoes erupt, they emit particles into the atmosphere that reflect sunlight, and this cools the planet. When there are more greenhouse gases in the atmosphere the planet warms. These and other phenomenon can lead the earth's climate to change. There is a link between global warming and extreme precipitation. Warming causes more moisture in the air which leads to more extreme precipitation events, and this includes heavier snowstorms in regions where snowfall normally occurs.

Globally, atmospheric water vapor has increased, and the extra moisture in the air is expected to produce record snowfalls. This is consistent with the expectation of more extreme precipitation events. Mass transit infrastructure must adapt to these changes in conditions, based on a transformed climate, and it must anticipate more severe weather events, including hurricanes and blizzards, and more frequent flooding. In flood-prone areas, subway entrances must be equipped with watertight doors, or be built with the entrance staircase going up several feet, before descending into the subway, so that high flood waters cannot get into the subway system. Gaps in the infrastructure need to be eliminated in manhole covers and emergency hatches. Ventilation gratings need to be located high above the floodplain, or be equipped with a mechanical closure system which will prevent water from getting into the subway tunnel.

Electrical equipment, which is so critical to public mass transit, needs to be placed higher above the ground so that it cannot be affected during a flood, and in some cases, electrical equipment may have to be encased and waterproofed for protection. Severe snow and ice conditions also effect electrical systems including signal systems, so anticipation of increased snow and ice removal must be considered. Mass transit systems in the lower part of the United States are faced with very infrequent snow, but occasionally and more recently, southern cities have been hit with severe winter weather, and the transit systems have begun to adapt to these changing winter events. Future transit infrastructure that may go over a river or stream must be designed to anticipate higher sea levels than were previously anticipated for bridges.

Mass transit infrastructure can also be constructed and double as a seawall or flood barrier. All new public works infrastructure projects must incorporate flood protection for the benefit of the areas which they are serving. What elevation they must be raised to in anticipation of future rising sea levels is a stout challenge for the entire engineering field. A light rail or bus rapid transit infrastructure can be built along a coastal area, simultaneously move people on a dedicated right of way, protect a city from potential rising seas, and incorporate natural flood barriers. Natural infrastructure offers flood protection to a coastal community. Wetlands, dunes, and riparian forests provide natural flood protection. Compared to the built infrastructure, such as seawalls, natural infrastructure protects existing ecosystems.

COMBINATIONS

Numerous sustainability issues have been incorporated into the transit infrastructure, facilities, and vehicles, including wayside energy storage, regenerative braking, solar panels, green roofs, etc. Individually, these initiatives have helped save energy; however, working in tandem can provide even greater efficiency savings. When building a completely new system, it is easier to add initiatives in combinations that will help compound the results, because you can design them in from the beginning.

Heavy rail and light rail train cars equipped with regenerative braking work best when the regen is supplied directly to a wayside or on-board energy storage to capture a larger percentage of the electricity regenerated. A new bus rapid transit infrastructure can be designed specifically for an all-electric bus fleet, with built in battery charging stations designed into the bus stops, shelters, and stations along the dedicated right of way. Solar panels can also help feed the charging stations, so that when buses make stops, or when necessary, buses can quickly get a recharge. When buses are not charging, the solar panels can feed energy back into the power grid.

A transit facility can be equipped with a combination of a green roof and white roof. Facilities can combine natural lighting from skylights with natural ventilation, and skylights or windows can be encased with thin film solar panels, and coated with low energy glass to reduce heat gain, allowing natural light, while producing electricity. Heat recovery units can be used in combination with a solar heat wall, because both rely on drawing in outside air, so they can share the same heating, ventilation, and air conditioning system. Mass transit facilities such as subway car maintenance shops and bus depots can take advantage of all these individual initiatives, or many in appropriate combinations.

INTERMODAL BIKE SHARING

As biking as a mode of transportation grows, its relationship with mass transit is clearly linked. Most commutes in inner cities are too long for a solitary bike ride, and are more often attached to a train or bus trip. Many, but certainly not all, buses are equipped with a bike rack at the front end of the bus. In most cases, bicycles are allowed on trains; however, during rush hour, the bike becomes difficult to carry, and takes up much needed room. In recent years, many US cities added bike lanes and sidewalk bicycle racks as part of the city landscape, to inspire bike usage.

Bicycle storage at train stations is essential to encourage the combined use of a bicycle with a transit commute. German subway stations have built into stations large, secure, storage areas that commuters can simply bike their way into, lock their bike, and continue their commute with mass transit. Many bike sharing programs are locating their docking stations adjacent to subway stations. This is encouraging more use of the intermodal connection between biking and mass transit, for that last mile traveled in the daily commute.

Biking as part of the daily commute is foreign to most in the United States, especially regarding people's aversion to building up a sweat in the morning during their commute, in their professional work attire. While many people do work out and perform their daily exercise in the morning, most prefer to do that wearing gym clothes, and with time management limitations for a lot of professionals, showering and changing clothes at numerous times during the work day adds another layer. A potential answer is the electric bicycle.

Electric Bicycle

Electric bikes, with just a few pedals, begin the engagement of an electric motor, powered by a small battery. Recent advances in the electric bike include sensors that can assist in detecting mountainous environments, which will promote more power from the motor necessary to climb the hills. The bicycle is poised to join urban mass transportation as a significant contributor to mass transit. The essential part of the new advanced electric bike is the ability to switch modes from electric to manual, this will allow the morning commuter not to sweat through their work clothes on the way to work. The dual mode allows the same commuter in the afternoon to get in a workout on the way home.

ENERGY SAVING DEVICES

The mass transit station or terminal environment sees millions of people moving in and out, up and down, walking on many surfaces, and spinning many moving parts. Many worldwide experiments are taking place trying to generate electricity without the use of fossil fuel, while passengers are performing routine tasks such as walking. Electrical equipment such as escalators are required to move millions of people quickly into and out of the subway. Many subway stations are deep into the ground, demanding the primary use of an escalator. Sustainability measures embedded into the escalator can help reduce energy consumption.

Sleep Mode Escalators

Sleep mode escalators are equipped with sensors that make escalators slow down when no one is using them, and increase to normal speed when an approaching customer is detected by the sensor. These sleep mode escalators consume less energy, during inactive periods, and have been popular in mass transit systems in Europe and Asia for many years. Sleep mode escalators are beginning to catch on in the United States. Another technological advance is the installation of an efficient motor that detects the weight of the people currently using the escalator, ensuring that only the appropriate amount of power is utilized.

Most escalators are designed to operate at one speed, and at full power, so variable speed and efficient power based on the actual weight of passengers will help reduce energy consumption. Elevators can also take advantage of weight detecting efficient motors to save energy. Many escalators usually fit the width of two people, and the unwritten mass transit passenger protocol would seem to indicate that the right side is for standing passengers, and the left is for people in a hurry that walk up the moving escalator. Therefore, the quicker the person gets off the escalator, the less energy the motor requires. Passengers can help reduce some energy in the subway system, by walking up or down the escalator.

Piezoelectricity

The piezoelectric effect is the capability of certain materials to generate electricity, when subject to vibrations. Material that exhibits the piezoelectric effect such as quartz, can be placed between two metal plates, and when the material is subject to vibrations, it produces electricity. Quartz is a crystal, where atoms are arranged in an orderly fashion, and have balanced positive and negative charge. When the piezoelectric crystal is pressed, it disturbs the balance of positive and negative charges and creates an electrical charge. Mass transit stations in Japan have experimented with the piezoelectric effect, producing electrical energy as people pass through the subway turnstile, with a piezoelectric floor powering the turnstile.

Turnstile Energy

Hand-powered generators were originally used by the military to generate power in the field, and they works exactly like other generators, except the turning shaft is moved by a human hand. Health clubs employ some exercise bicycles that will power a computer attached to the "dashboard" of a bicycle, and work only when continuously exercising, as the bike pedals' circular motion generates electricity. Millions of people travel into the subway through spinning turnstiles, so it would seem to make logical sense to attempt to tap into the spinning turnstile to generate electricity in the subway station environment. In China, they have developed a prototype turnstile system which produces energy, which could be used for the power requirements for card swiping and people counting.

CONCLUSION

Mass transit agencies have taken on the challenge, influenced by the consensus onerous climate projection, to begin the energy reduction necessary to help combat climate change. By implementing numerous sustainable initiatives in many projects and pilot programs, many have grown from pilot stage to best practice quickly. Much energy reduction is possible to reduce greenhouse gases, and future sustainability initiatives will very likely focus on improving battery storage. Using stored energy can work in combination with regenerative braking, solar energy generation, wind power, and many applications in the transit infrastructure.

The potential growth of an all-electric bus fleet will most certainly center around the prowess, reliability, and cost of a battery. Numerous battery technologies are in research and development, which will allow more choices for engineers to test new scientific technologies in new vehicles. This will certainly mean that even more efficient energy storage technologies will be tested and evaluated for use in mass transit, and hopefully government funding for rapid implementation. Renewable energy generated power should be developed to support new mass transit, such as a light rail system or bus rapid transit.

An opportunity exists with the chance to utilize subway tunnel water as an energy medium for heating and cooling. Ground water which gets into the subway tunnel infrastructure is normally pumped out of the subway tunnel and discharged to a sewer. Ground water at depths normally where a subway tunnel would sit, is normally a consistent 55°F, and water at that temperature can be used to help cool electrical equipment. Geothermal is a renewable energy source that has not even come close to fulfilling its energy potential, and should be studied more frequently for use in mass transit applications.

Green infrastructure can be incorporated in the mass transit landscape to the great benefit of the public. Green infrastructure helps manage storm water, and in the process, save energy. Green infrastructure absorbs the rain, thereby reducing the volume of storm water runoff. Lessening the amount of water in the sewers reduces energy consumption at the waste water treatment plant. Vegetation helps filter particles, absorb carbon dioxide, and helps reduce the heat island effect. Climate adaptation measures must be considered in new projects and the rehabilitation of older infrastructure. Extreme weather events of the recent past have prompted agencies to provide flood protection, and anticipate extreme events to minimize harm.

Future sustainability initiatives on mass transit facilities work well in combination with each other, such as a combination green and white roof, natural lighting and natural ventilation, and special architectural glass, that allows natural light, reduces heat gain, and produces electricity. New and innovative advanced technologies are always being considered, including energy efficient inventions such as sleep mode and variable power escalators. Special material is being used to produce electricity by the vibrations created when people step on the floor of a subway station. Pilot stage electricity generating turnstiles are potentially being considered.

There are many challenges and opportunities that engineering, transportation, and sustainability professionals face to save energy, prevent pollution, and reduce greenhouses gases. Every day, new and potentially significant advanced technologies are being offered to be included as sustainable initiatives, and judging by the track record of past success in the mass transit, both the public train and bus networks, it is anticipated that further innovation and further emission reduction will materialize.

FURTHER READING

http://arpa-e.energy.gov/.

http://publictransport.about.com/od/Transit_Vehicles/a/Electric-Buses-An-Introduction.htm.

http://www.transitchicago.com/electricbus/.

http://batteryuniversity.com/learn/archive/is_lithium_ion_the_ideal_battery.

http://www.renewableenergyworld.com/geothermal-energy/tech.html.

https://www.epa.gov/green-infrastructure/what-green-infrastructure.

http://www.energymanagertoday.com/nyc-subway-buys-kone-sleep-mode-escalators-086017/.

http://www.explainthatstuff.com/piezoelectricity.html.

http://www.nycsubway.org/wiki/The_Interborough_Power_Plant.

Chapter 8

Environmental Mitigation of Construction Impacts

INTRODUCTION

Mass transit infrastructure is massive, widespread, and very old, in many cases in urban cities. Subway tunnels, elevated structures, substations, maintenance shops, train storage yards, and bus depots, are all constructed as part of the built environment. In addition to regular infrastructure maintenance, major rehabilitation or reconstruction of infrastructure may be necessary to ensure continuous and safe transit services. Expansion projects including new subway tunnels, elevated lines, or stations are required in many cases to accommodate increased service demands. These types of projects, in many instances, are large construction projects located within a crowded inner city.

Transit infrastructure construction projects have potential major environmental impacts to mitigate during construction, to prevent pollution, and save natural resources. In a large infrastructure project, construction and demolition debris can be recycled to save virgin resources, minimize landfilling of material, and conserve energy. Construction material, such as concrete and steel, can also include a significant amount of recycled product, to take advantage of previously used material. Numerous materials encountered during an infrastructure rehabilitation, are hazardous, toxic, or regulated, and must be appropriately handled to prevent release into the environment.

Many infrastructure projects are within inner cities, and environmental protection or containment measures shield neighbors and prevent contamination, such as dust escaping the confines of the construction sites. Staging mass transit projects is very difficult within the confines of a neighborhood street landscape, and closing streets for stretches of time can cause traffic impacts. Some projects have adjacent sites requiring protection, including ecological areas, such as wetlands. Each transit construction project must begin with a good hard look at the potential environmental impacts of a project, to prevent pollution, ensure worker safety, protect the surrounding environment, and save natural resources and energy.

ENVIRONMENTAL REVIEW

A thorough environmental review is required for all mass transit capital construction projects, to ensure that proper mitigation protocols are in place

Sustainable Mass Transit. DOI: http://dx.doi.org/10.1016/B978-0-12-811299-1.00008-3
© 2017 Elsevier Inc. All rights reserved.

to maximize environmental protection during construction, and that all environmental impacts are either reduced, minimized, or avoided altogether. The best place to start the environmental review process is at the very beginning of a project, the scope development stage. A completed scope should include all likely encounters, with possible environmental impacts and mitigation measures required. To get to this level of understanding of a project, a detailed survey needs to be performed at the very start of a construction project, and a follow-up analysis of potential impacts should be included in the scope of work.

To understand the environmental impacts of any project, the project boundaries must be established, and the components that will undergo rehabilitation need to be identified. Those components may be structural, architectural, electrical, mechanical, or involve a system such as the lighting or signal system. An understanding of what parts of the system are to be demolished, and which should be retained to continue working with the newly installed components, needs to be specified. When all the components that are affected by the project are identified, they should be highlighted in the project's scope of work.

Electrical equipment that requires replacement, such as transformers, rectifiers, electrical circuit boards, or light ballast, must be clearly denoted in the development of a project's scope, because potential hazards such as asbestos or polychlorinated biphenyls (PCB's) may be encountered. It should be added that special containment and spill prevention will be necessary to protect the environment while removing and disposing of such material. Structural reconstruction may include the demolishing of concrete and steel, causing concerns related to historic lead based painted surfaces and issues with dust contamination. Facilities requiring rehabilitation may require underground storage tank remediation, which could include the necessity to remove contaminated soil. The possible beneficial reuses of the contaminated soil can be outlined in the environmental review phase of a project to maximize its reuse options.

The location of any project is critical to identifying potential sensitive receptors that could be impacted, including a residential neighborhood, park, or wetland. If the location of adjacent historic, ecological, or parkland sites may be impacted during construction, the first goal is to eliminate any impact from the beginning, by avoiding encroachment on sensitive or regulated areas altogether. Understanding the adjacent areas of a project is critical in deciding construction means and methods, and possible containment alternatives to prevent environmental impacts. An environmental analyst must review the potential environmental impacts on both the natural and built environments, while ensuring that a project's needs are accomplished.

RECYCLING

The environmental review stage is also a good place to suggest potential sustainability initiatives in the construction phase, including the type of recycling that is a possibility, to make the most of waste material and save natural resources. Construction and demolition debris is made up of concrete, bricks, iron, steel, copper, cinder block, rock, stone, soil, dirt, asphalt, wood, sheetrock material, glass, plastics, and numerous other building materials. These materials make up much of construction debris generated by a mass transit construction project, and these can all be recycled or reused. Any of these waste materials can be recycled if they are considered uncontaminated, and are not mixed with or do not contain any hazardous waste or asbestos.

Recyclable construction and demolition debris may be sorted on-site in separate containers, or in a designated container for mixed recyclables on-site, to be sorted off-site at a properly permitted recycling facility. Construction and demolition material is a large component of the waste stream in the US, and much of the material is recyclable (Table 8.1). Recycling reduces the impact on the environment by utilizing waste material in a productive way. Recycling saves quickly decreasing landfill space. Currently, more landfills are forced to close because of lack of space, and most incinerators cause air pollution. Recycling conserves natural resources, and saves the water and energy required for mining natural resources.

Cost analysis varies, with a lot depending on operating circumstances, the material in question, volume of waste, etc. Every situation in recycling is completely different; however, in mass transit infrastructure and facilities, it is consistent to find that concrete, brick, asphalt, wood, steel, aluminum, and copper are the most significant contributors to construction and demolition debris waste. Scrap metal, such as copper wire and cable, has traditionally been a money-making salvage material for contractors, and many have built the salvage price of recycling copper and other materials into the price of demolition when bidding on a construction job. Material used in construction,

TABLE 8.1 Construction and Demolition Debris Recycling Options

C&D Material	Recycle Options
Concrete	Recycled concrete can be crushed and used as gravel, track ballast, or backfill, and used as aggregate in new concrete
Brick	Bricks can be cleaned and reused, or crushed and use as aggregate
Asphalt	Asphalt can be reprocessed into new asphalt
Steel	Steel can be melted and reused again in new steel
Copper	Copper can be melted and reused again in new copper
Aluminum	Aluminum can be melted and reused again as new aluminum
Wood	Wood can be reused again as mulch, or as a biomass fuel

including wood used for scaffolding, bracing, etc., can be reused if these materials are safe to be reused by a contractor from one site to another.

BENEFICIAL REUSE OF EXCAVATED SOILS

Large excavation areas are also common in mass transit construction projects, including digging up the ground for a foundation for a structure, large trenches necessary for conduit or sewers, or the spoils from tunnel digging or tunnel boring machine operations. The removal of soil from an excavation can provide material for a wide variety of reuses, including backfill on-site, if necessary. The reuse of the soil is mostly determined by the level of contamination in the soil, and even if it is compromised by petroleum contamination, there are several ways that soil can be reused. Soil contaminated by leaking underground storage tanks of gasoline or diesel, can be sent to an asphalt manufacturing plant to be reused for new street material.

Different types of beneficial reuse of excavated contaminated soil are permitted for certain uses based on many factors. Unearthed soil removed as part of a transit property will most likely be somewhat compromised by the industrial nature of transportation, and reuse options should never include soil for a residence, playground, or parkland, which would require the cleanest soil possible. However, there is rarely a documented regulatory definition of clean soil. Excavated soil from a construction site is usually classified as hazardous, petroleum contaminated, acceptable for reuse as backfill on site, or for disposal at a waste treatment facility. Applications to reuse construction derived soil off-site must pass local or state level beneficial reuse protocols.

Reusing excavated soil on-site, in addition to conserving the use of new backfill material, is a sustainable practice in many cases, including a reduction in the amount of trucks that enter and exit a construction site. Each truck hauling waste needs to pick up waste and travel back and forth to the recycling or treatment facility, and making the assumption that the truck uses diesel fuel, each truck trip eliminated from a construction site reduces pollution and greenhouse gas emissions. Project staging areas allowing room to store excavated soil on-site can allow the soil that was removed, provided the excavated soil meets backfill requirements, to be reused as backfill on-site. Without proper room to store soil located at the construction site, soil may be forced to be removed from the site, with the added environmental impacts from truck exhaust.

In many ways, the best possible way to beneficially reuse excavated soil is to move it directly from one construction site to another. Soil sharing options include a scenario where two different construction projects, with good coordination and timing, arrange a transfer of soil from the excavation of one site to another construction site that requires backfill. This takes exquisite planning to accomplish between two parties, as coordination between private contractors, working for public agencies, can become complicated. Some cities and states have collaborated and set up a soil bank as a way of reusing soils from different projects. Contractors can drop off excess soil not needed on their site, and another contractor can pick up soil for backfill when necessary. This cooperative effort saves a lot of natural resources, and in the long run a lot of landfill space.

LANDFILLS

The disposal of trash in a landfill is the dumping of waste into extremely large holes in the ground. The landfill is the most common and cheapest form of waste disposal, and there are many environmental impacts potentially from landfills, including space issues, emissions, and leaching out, which is a toxic leak that could potentially contaminate ground water. Landfills include mechanisms to capture leachate before it reaches ground water with special liners. In most cases, it is very likely that over time landfill liners leak, allowing the leachate to contaminate the ground water. There are thousands of closed landfills that potentially could still do damage as far as leachate is concerned, and must be continuously monitored.

Methane gas is produced from landfills due to decomposing organic material, and escaping methane from a landfill adds to the amount of greenhouse gas in the atmosphere, and methane is a much more potent greenhouse gas than carbon dioxide. Some resourceful landfills are capturing methane to sell as natural gas. As the population grows, the need for more landfill space will become more prevalent, and finding a suitable place is very problematic. It is very difficult to find potential landfill space. Urban cities usually have their landfills on the outskirts of a city's perimeter, and few people want to reside adjacent to a landfill. Recycling materials helps to solve this big dilemma of more landfill space and waste treatment plants.

Another complication in trying to find space for more landfills is that the preferable location of any new landfill is favored to be a longer distance away from the populace. New landfills, incinerators, treatment and disposal of wastes, are not coveted as neighbors, which is an understandable objection. However, locating new landfills in places further away from the urban areas normally utilizes land that is less disturbed, and generally more pristine. The preservation of our undisturbed and protected land areas is essential for the continuation of many species, the enjoyment that many people get from the natural environment, and the benefits derived from allowing nature to take its course.

WETLANDS

One of nature's most valuable natural assets in the environment is a wetland, which is characterized as the areas between the land and the water. It is where the water table meets the surface, and is usually covered by shallow water. Wetlands absorb water, and include plants that live within the water. Wetland destruction through the years has reduced the total effectiveness of nature, and they are becoming scarce, which is why they are firmly protected with federal, state, and local environmental regulations. There are many mass transit systems located near or adjacent to wetlands.

Wetlands are found in coastal areas, and many transit systems run along coastlines, over streams and rivers, right up to, and in many cases into, what is referred to as a wetland buffer zone. Wetlands are so highly protected that a designated zone prior to the wetland is offered the same regulatory land use restriction as the wetland itself. A new transit system that may impact a wetland may have to rebuild any disturbed wetland areas, usually two or three times as much land that may be impacted. Existing transit infrastructure that may need to be rehabilitated or reconstructed that is adjacent to a wetland, must avoid any damage or destruction to the wetland area during construction.

Wetlands are where water is present at the surface of the soil. Wetlands absorb water much like a sponge, help filter contaminants in soil, support aquatic life, and encourage the growth of specially adapted plants. Wetlands differ in many aspects, and are found all over the world. Two basic types of wetlands are tidal wetlands and nontidal wetlands. Tidal wetlands are found along the coastlines. Nontidal wetlands are found along rivers, streams or lakes, and ponds, in low lying areas, where rain can saturate the soil. Some wetlands are seasonal, and can be dry at certain times of the year.

Wetlands recharge ground water and provide water to streams. Wetlands reduce flooding by storing water, and because of their level of nutrients, are a very productive ecosystem, containing an eclectic array of plant species. Wetlands support a variety of insects, amphibians, and fish, in addition to providing food for larger predatory fish, reptiles, birds, and mammals, contributing to the food chain, and playing an integral role in an ecosystem. Many species of birds and mammals depend on wetlands for shelter throughout migration and during breeding. Wetlands also store carbon within their soil, instead of releasing carbon dioxide, and therefore destruction of wetlands leads to greenhouse gas emissions.

When a mass transit infrastructure that is adjacent or goes through a wetland is about to undergo rehabilitation or reconstruction, robust mitigation measures protecting the land against damage should be included in construction plans to avoid damaging protected land. Damaging wetlands resulting from construction can increase flooding, if the wetlands are relied upon for flood control. Environmental impacts, and most notably irreparable damage to ecologically or protected lands, reduce nature's ability to absorb storm water naturally, and can alter other ecosystem functions. Mitigation measures include the installation of silt fences or hay bales to protect drainage that leads to the wetland. Timber mats should be used when working in wetlands, or adjacent areas, when heavy equipment or vehicle access is required.

DEMOLITION PHASE OF CONSTRUCTION

When a decision is made to demolish a piece of mass transit infrastructure, a survey to identify hazardous or regulated material must be performed first. The objective is to identify, remove, and dispose of the hazardous material prior to demolition of the structure. Surveys are required for asbestos, lead paint, PCB transformers, fluorescent lights, light ballast, and batteries, to name some of the more prevalent traditional problematic material found in the mass transit infrastructure. A comprehensive survey, which highlights hazardous, toxic, or regulated material, is required, and specific contract documents are prepared with strict specifications and guidance for contractors to follow.

It is best when all demolition can be performed free of hazardous material, without compromising the health of workers, or the environment, and when all regulated and hazardous material is free from the structure, the infrastructure can be demolished, and the construction and demolition debris can be recycled. Freeing a structure of asbestos prior to demolition ensures the uncontaminated nature of the demolition debris. Asbestos containing material is heavily regulated by the Environmental Protection Agency (EPA), and is probably the most dangerous substance encountered on a construction site. Consequently, in many states it has its own rules, regulations, and abatement procedures.

Asbestos Removal and Disposal

Asbestos is a danger when materials containing asbestos become airborne due to deterioration, damage, or disturbance, and is particularly a concern for maintenance and construction workers. Asbestos abatement is strictly regulated, and requires extreme safety procedures to ensure environmental and worker protection. Asbestos fibers are very light, easily float in air, and are so small they cannot be seen by the naked eye. Abatement often requires air tight containment, made of polyethylene plastic sheeting and wood, under negative pressure, to ensure no emissions leave the work zone, and workers must be appropriately protected, including the use of respirators.

After completion of asbestos removal, air monitoring to ensure that the abatement has been successful is required. Asbestos must be disposed of in special landfills that will take double bagged or specially contained asbestos material removed from an abatement job. Many asbestos landfills are approaching capacity, and alternate disposal methods can be considered in lieu of placing in landfills. Recycling asbestos into nonhazardous silicate glass can be accomplished through thermal decomposition. Microwaving asbestos can transform some asbestos containing material into ceramic bricks. Asbestos can also be chemically destroyed, and converted into nontoxic sludge. Environmental Protection Agency approved procedures exist for the destruction of asbestos. As landfill space for asbestos becomes more scarce, destruction and possible reuse may become more common.

Lead Based Paint Disturbance

Steel and concrete surfaces in mass transit infrastructure are traditionally painted, and going back over a century, most paint applied to steel or concrete surfaces included large amounts of lead to help prevent corrosion. During reconstruction activities, lead exposure to construction workers during a disturbance of a painted surface that contains any amount of lead are subject to Occupational Safety and Health Organization (OSHA) regulations, which outline effective procedures to avoid being exposed to the health hazards of lead. Containment during lead disturbance activities such as paint scrapping, demolition, or rivet busting, is usually configured with tarps or plastic sheets, and must prevent paint chips from getting into the environment. It is important to ensure lead paint chips do not get into a sewer or nearby water way.

Construction site cleanliness is important, so that construction workers do not bring home lead contamination that may remain on a worker's clothes or work boots. Children are more affected by lead contamination, so construction workers are required to shower and change clothes, prior to leaving the work site, to prevent contamination from spreading into their homes. Prior to any demolition activities, all loose and flaking paint should be removed from painted surfaces. Collected paint chips should then be stored in hazardous waste storage containers, as drummed lead paint chips can be a hazardous waste based on laboratory analysis. Usually, drums full of paint chips from old mass transit infrastructure will test positive for lead, and therefore be considered hazardous, and must be removed as hazardous waste and disposed of in a hazardous waste treatment facility.

HAZARDOUS WASTE

Hazardous waste is a distinct type of waste, because it can be a threat to public health, and cannot be disposed in a typical or common fashion. Usually treatment, solidification, or stabilization is required. A waste is considered hazardous if it has one or more of the following qualities: ignitability, reactivity, corrosivity, or toxicity. Many industrial processes generate hazardous waste, including construction, in the form of a solid or a liquid. For example, lead paint chips are a solid and are potentially hazardous, and PCB oil is a liquid, which is also potentially hazardous. It is rare that a hazardous gas is generated during construction; however, some spent construction equipment may contain portions of leftover gas, requiring removal from the site as hazardous.

The US EPA lists some specific wastes as hazardous, and under the Resource Conservation and Recovery Act (RCRA), the EPA created regulations to manage hazardous waste, including the mandatory use of a hazardous waste manifest to track all waste from generation to disposal, and all steps in between. The EPA requires that all facets of hazardous waste management are subject to strict permission requirements, including the handling, treatment, storage, transportation, and disposal of hazardous waste. The most common treatments are solidification and stabilization.

Some hazardous wastes can be recycled, including lead-acid batteries, and some waste is not considered as potentially harmful as hazardous waste, and falls into the category of universal waste. These discarded materials usually are typically mass produced, such as fluorescent light bulbs or batteries, and have smaller risks to the environment. They still require special handling, just not as rigorous as hazardous waste handling. The storage requirements are more lenient, and many universal wastes have treatment options to avoid landfills. In construction, hazardous waste generated includes PCB contaminated transformers, which must be drained of all PCB oil, and the remaining carcass should be cleaned, treated, and recycled. PCB oil with over 50 parts per million PCB, must be removed, treated, and disposed as hazardous waste.

Hazardous Waste Facilities

Hazardous waste treatment and disposal facilities must be permitted to accept and treat a specific type of hazardous waste. Each facility will receive a permit to receive waste based on the treatment process outlined in the approved application for permit. There are many different types of disposal facilities for different solid or liquid waste, and the treatment usually involves neutralizing and stabilizing the waste to below hazardous levels, so that if it is ultimately buried in a landfill it cannot leach out or impact the ground water when buried in the ground. Most hazardous waste is landfilled in special landfills or sections of a landfill that is separated from the main solid waste area.

Waste to energy facilities burn or incinerate discarded material and produce energy from the burning. Hazardous wastes, such as oils or solvents can be incinerated, and gas exhaust can be used in a turbine generator to produce electricity. More efficient incinerators are employing engineering control methods to reduce toxic emissions, such as the starved air incinerator, used to treat hazardous wastes. During the burning process, the oxygen level is controlled to maximize combustion, and to minimize air pollution. Many hazardous waste treatment facilities that bring in metal carcasses that were subjected to a contaminated liquid include an extremely high temperature baking process to burn the contaminated material from the surface of metal. If the metal is free of contamination through testing, it can then be sent to be recycled.

CONSTRUCTION MATERIAL WITH A RECYCLED CONTENT

Using construction material with a recycled content, such as concrete and steel, provides major benefits to the environment, as material with recycled content normally requires less energy and water than that for processing an equal amount of virgin material. Concrete is a composite material consisting of cement, both fine and coarse aggregates, and water. Cement, which is considered the binder, is mixed with water to create a paste, which is then mixed with the fine aggregate such as sand to make mortar. The mortar is mixed with a course aggregate or stone to make concrete. Admixtures can be included to control setting properties in the concrete.

For recycling purposes, concrete and masonry from demolished buildings can be reused as aggregate in concrete. Recycled materials such as fly ash, slag cement, and silica fume, which are industrial byproducts, can also be included in the concrete mixture. Fly ash is a byproduct of the combustion of coal, slag cement is produced from an iron blast furnace, and silica fume is a byproduct from an electric arc furnace which produces a silicon alloy. Manufacturing cement requires a lot of energy, and high temperature cement kilns have been burning hazardous waste such as spent solvents, inks, paints, and motor oil to produce cement. Cement kiln dust can then be recycled back as an ingredient for new cement, and used tires and medical waste can also be used as fuel in cement plants.

Steel is the most recycled material on earth. Virtually all steel used in the construction of mass transit infrastructure, including beams, girders, columns, etc., has a robust recycled content. Concrete reinforcement or rebar is made mostly from recycled steel. Steel is recycled at an extremely high rate, and includes little degradation after recycling. Other metal recycling such as copper, which is heavily used in electrical wiring and in cables, loses very few of its initial properties after recycling. Steel, copper, and aluminum are constantly being recycled and reused many times.

ENVIRONMENTAL IMPACTS IN THE CITY

Mass transit infrastructure is mainly adjacent to or directly under urban city streets and sidewalks, and during construction, equipment, materials, and vehicles require close access to the transit structure. As part of the environmental review process, the neighboring area of a transit infrastructure rehabilitation site is important to understand, to avoid significant environmental impacts, specifically those that can affect passengers and pedestrians, and the community at large. Environmental impacts can be generated from the adjacent staging areas, construction equipment, and activities, and should be mitigated and/or reduced as much as is practical to avoid impairment. Strategies to reduce impacts should be included in construction work plans and procedures.

Staging

Staging is the arrangement and placement of equipment storage, truck parking and loading, crane access, worker access, etc., during construction. Staging areas are the necessary space adjacent to or near the work area, i.e., required for the overall construction project. Closing streets and sidewalks can impact pedestrians and traffic, and traffic impacts that lead to congestion at affected intersections can lead to carbon monoxide hot spots. Any alteration in traffic patterns because of construction vehicles entering and exiting the construction areas that increase traffic could also create hotspots. Staging plans that close streets or sidewalks, agreed to by the appropriate transportation or traffic authorities, should include approaches and strategies to avoid the creation of carbon monoxide hot spots. Traffic impact analysis, including traffic modeling, can help create an effective maintenance and protection of traffic plan.

Noise and Vibration

Large construction projects normally produce noise and vibration levels, due to the use of construction equipment and construction related vehicles that regularly travel on- and off-site. Construction equipment generates various levels of noise, depending on the specific activity. Construction noise is usually intermittent and temporary, and impacts can vary based on the distance to sensitive receptors. Noise barriers and other noise mitigation measures are utilized to try and keep the noise that emanates from a construction site low, and to keep the continuous noise generated from annoying residents or neighbors. Noise walls surrounding a construction site can be made with normal building material, including plywood, and can be angled, and lined with a sound absorbent material to maximize the noise shielding effect.

Noise emanating from a construction site adjacent to residents can force neighbors to close windows to eliminate unwanted sound, and can force residents to use air conditioning, which requires additional energy. Equipment that generates noise and vibration include, among others: pile driving, jack hammering, excavation equipment, on-site vehicles, and compressors. Construction workers can employ earmuffs or ear plugs as appropriate, to prevent loss of hearing. Operation of construction equipment can cause vibrations that spread through the ground, which can impact buildings, and interfere with sensitive equipment, in such places as schools, doctors' offices and hospitals, and high vibrations can scare residents. Vibration attenuators such as antivibration isolation mats can help reduce ground borne vibrations.

Dust Control

During construction activities, dust can develop specifically during demolition phases of construction, including land clearing, drilling, blasting, ground excavation, and fill operations. On-site emissions can result from construction vehicle traffic moving over make shift or temporary dirt roads at the construction site. The demolition of concrete can cause tremendous amounts of dust particles. Containment with tarps, both horizontal and vertical, rigid barriers, vacuum attached equipment, and the use of water mist to wet down the work area can minimize dust spreading off-site. Any visible emission of dust can be a potential hazard, in addition, particles that are not visible can be much more problematic. Concrete traditionally contains crystalline silica or quartz, and these tiny particles are hazardous to people's lungs. Construction workers can potentially be exposed to silica during concrete demolition, and must wear proper protective equipment when required. During dust generating activities, construction barriers to protect the environment should be erected as appropriate.

Use of Chemical Commodities

Construction projects require all kinds of chemicals and materials to be used. The safe and appropriate use of chemicals begins with a review of the safety data sheet (SDS). To ensure safety in the work zones where chemical commodities are being used, information must be available about the identities and hazards of the constituents of chemicals. Manufacturers are required to evaluate the hazards of chemicals they produce, and prepare a SDS that lists the hazard information relating to their products. Construction sites must have SDSs readily available to employees for all hazardous chemicals used on-site.

A SDS is a significant document with data regarding the properties of a chemical, and includes procedures on how to use, and how to dispose of unused portions of chemicals. Data included on the SDS includes melting point, boiling point, flash point, toxicity, reactivity, storage requirements, disposal, protective equipment, health effects, first aid, and spill-handling procedures. Improper use of chemicals can lead to spills into the sewer system, or directly into the environment. SDSs are usually kept on-site in a binder, so that immediate access to the information is available without leaving the work area.

CONCLUSION

Mass transit infrastructure and facilities must be kept in a state of good repair, for the sake of the riding public. Infrastructure and facilities in good working order keep services running, and provide a safe and reliable commute for millions of people. The discipline of environmental sustainability has emerged as a major part of the engineering field, and requires knowledge of operations, construction, and the science of environmental protection. Mass transit construction projects, including new construction, rehabilitation, or reconstruction, can include characteristic environmental impacts that require mitigation measures and strategies to prevent pollution and save natural resources.

Each construction project should start with an environmental review that should identify all potential environmental impacts, and indicate what likely hazardous waste may be encountered during demolition or rehabilitation. The environmental analyst, whose job it is to review the potential environmental impacts on both the natural and built environments stemming from mass transit rehabilitation projects, has a role unlike any other in project development. The project's goals need to be accomplished, while ensuring the environment is well protected.

The environmental review should also highlight the potential positive initiatives that may be included in the overall project that might benefit the environment. There are also opportunities to be sustainable in construction, including the use of recycling initiatives, and using material with a recycled content. The recycling of construction and demolition debris, or the beneficial reuse of soil, helps reduce waste that may have ended up in a landfill. This is perhaps the most sustainable construction practice in mass transit infrastructure projects. Recycling helps save natural resources, the energy required to process natural resources, and landfill space. Using construction material, such as concrete and steel, with a percentage of recycled content, can benefit the environment by saving virgin resources.

Prior to demolition of portions of a subway tunnel, train structure, or facility, it is optimum when all hazardous waste, asbestos, PCBs, or other potential contaminants are removed and disposed of, prior to any major construction activity. This frees the demolition debris of contamination, and creates uncontaminated construction and demolition debris that can be recycled. Landfills are the most widespread solid waste management process, and currently they are quickly running out of space, requiring either alternative disposal methods or new landfills, and nobody wants in their "backyard" a landfill, waste disposal, or treatment facility.

The alternatives to building new landfill space far from where people live and damaging to pristine land that should be saved, are more types of recycling, and reusing, to avert waste from landfills. Another possibility includes waste to energy facilities, where waste including much hazardous waste is incinerated, and energy is produced. Hazardous wastes such as spent solvents and used oils can be used to make cement in a kiln. Hazardous waste, treatment and disposal facilities, and landfills are eventual places where waste ends up. Many transit lines run parallel to or through protected natural areas such as wetlands. During the construction of new projects, or the rehabilitation of a mass transit infrastructure that is located near a wetland or wetland buffer zone, plans to avoid, reduce, minimize, or eliminate environmental damage to wetlands, should be utilized.

In the city environment, construction staging, noise and vibration, and dust control strategies lessen environmental impacts on surrounding neighborhoods. Construction projects require all kinds of chemicals be brought on site, and require a review of SDSs, to ensure requirements to protect the environment, and reduce exposure of workers. Managing environmental impacts in mass transit, during operations, design, and construction, requires a complete understanding of infrastructure, facilities, and vehicles, and how they interact with the environment. The environmental review process at the beginning of any design and construction project is the best time to ensure environmental mitigation, and is when other sustainability initiatives should be introduced into the project.

FURTHER READING

http://www.dec.ny.gov/regulations/30902.html.

http://www.nj.gov/dep/srp/guidance/alternative_fill/afp_guide.pdf.

http://www.cement.org/for-concrete-books-learning/concrete-technology/concrete-design-production/recycled-aggregates.

http://www.steel.org/sustainability/steel-recycling.aspx.

https://www.researchgate.net/publication/279200478_Asbestos_Destruction_with_CO2.

https://www.epa.gov/laws-regulations/summary-resource-conservation-and-recovery-act.

https://www.epa.gov/pcb.

http://www.ejnet.org/landfills/.

http://www.defenders.org/wetlands/basic-facts.

http://www.nyc.gov/html/dep/html/noise/index.shtml.

https://www.osha.gov/Publications/OSHA3514.html.

http://www.mass.gov/eea/docs/dep/recycle/reduce/06-thru-l/cdrguide.pdf.

Chapter 9

Environmental Management Systems

INTRODUCTION

An Environmental Management System, or EMS, is a structured and specially organized framework under which an entity can manage environmental impacts by ensuring compliance and helping to continually measure and improve environmental performance. At the foundation of an EMS is compliance with environmental laws and regulations. Many mass transit agencies in the United States have embraced the structured EMS to help ensure compliance, and select appropriate sustainability initiatives that go above and beyond environmental compliance in the operation of existing transit services.

The ISO 14001 EMS standard is the recognized best management practice which provides thresholds to measure environmental performance through analysis and internal self-evaluation with the best interests of the environment in mind. A certified EMS brings a third-party verification to validate the effectiveness of the EMS. Initiatives can also be included in the design and construction of mass transit infrastructure and facilities, based on evaluations coming out of the EMS process. In support of an EMS, numerous "green" rating systems such as LEED, Energy Star, and Envision can help ascertain the overall effectiveness of sustainability initiatives included in the design of mass transit buildings, equipment, and infrastructure.

An EMS is in many ways centered around communication and awareness of environmental issues to all personnel in an organization, from the top on down, to both internal divisions and external partners to an organization, with the intention of having participation and understanding from every corner of an agency, facility, or department. An EMS can help to make proper, and appropriate, business decisions, with protection of the environment always under consideration.

ENVIRONMENTAL MANAGEMENT SYSTEMS

All entities have an environmental management routine. An industrial facility, a restaurant, a college campus, a house, etc., all have habits, customs,

Sustainable Mass Transit. DOI: http://dx.doi.org/10.1016/B978-0-12-811299-1.00009-5
© 2017 Elsevier Inc. All rights reserved.

and procedures, including energy needs and requirements, which interact with the environment. Raw materials come in, and waste comes out. Energy is required for operations, production, and comfort. Water is always needed in many ways. The inside air quality is important for the health of people. The exterior events and actions, while outside the boundaries or fence line of the entity, also have interactions with the environment.

A structured EMS is a formulated and documented procedure or guideline, that helps manage the impact on the environment in the operation and future expansion of an entity. It is usually expressed as a management tool, that systematically ensures environmental compliance that works towards continuous environmental improvement. It starts with an environmental policy, and includes a self-analysis of the all operations, activities, and environmental aspects, that can lead to an impact on the environment. It also includes a monitoring and measurement piece that can quantify metrics to show environmental improvement, and help set environmental goals to strive to achieve.

A lot like many management tools, it works within a process cycle of plan, do, check, and act. The cycle starts with a decision to do something, whether it is a brand-new procedure or program, or a revised procedure or program, then moves to carry out the plan under normal conditions, and continues with the evaluation and analysis of the plan in motion. The cycle ultimately winds toward recommended corrective actions necessary to improve or bring some enhancements to make the result better. This process continues in a cyclical format, hopefully producing better results as the cycle spins and time moves forward. A documented plan or guidance procedure to influence these actions is at the center of an EMS.

Mass transit subway and bus operations interact with the environment every day, and face the challenge of reducing environmental impacts and improving sustainability performance. Under a structured framework of planning, self-analysis, and corrective action that leads to continuous improvement, many mass transit agencies have benefitted from working under a formulated EMS. A major part of an EMS is a communication procedure to inform and make people aware of environmental issues. For an EMS to work efficiently, it must be embraced by the entire organization, facility, or department.

The EMS fence line is the boundary which defines the EMS, and it can be placed around an entire mass transit agency, or a component of an agency, such as a single transit facility or department. If the fence line surrounds the entire organization, every part is subject to the framework of the EMS. In many cases in mass transit, a single maintenance shop or bus depot will be subject to an EMS, which may or may not be extended to any part of the main agency. Another fence line is one centered around a department, such as an engineering department, which would feature a framework around planning, design, and construction. An EMS requires an environmental identity and position formulated from the top of an organization, facility, or department, and always begins with an environmental policy.

ENVIRONMENTAL POLICY

An environmental policy helps set the tone for an organization, facility, or department regarding environmental protection and sustainability, must be clearly articulated from the top, and must permeate all the way throughout an organization, facility, or department's structure. There are many substantial federal, city, or local level laws and regulations regarding protecting the environment. However, in many cases, there is still an awful lot of room for improvement when it comes to preventing pollution, saving energy, and limiting greenhouse gases, which means going far and above compliance.

Environmental policies must include a pledge to continually measure and improve environmental performance, and many include a promise to seek ways to reduce energy, limit fuel consumption, lessen emissions, prevent pollution, reduce greenhouse gases, and reduce potable water consumption, or an infinite number of other appropriate metrics, that when measured can show improvement in environmental sustainability. The environmental policy decrees to the entire organization what is of utmost importance to an organization, beyond financial and budgetary concerns.

In most organizations, especially a private entity, it is the financial bottom line that is the focal point of business, and for a public organization, it is the "stay within budget" mentality that should prevail throughout an organization. For many private and public organizations, the protection of the environment is not a prime objective. Fortunately, many public mass transit agencies have embraced environmental sustainability as a pillar or standard to be included in the evaluation and effectiveness of a subway, train, or bus operation. Many mass transit systems have constructed an environmental policy to help an organization, facility, or department find and build upon a culture of environmental sustainability. Policies can also be set to include other cultural agency sensibilities, including benchmarking, mentoring, and partnering, with outside entities such as colleague agencies or academic institutions.

ASPECTS AND IMPACTS

An internal self-evaluation process called an "aspect and impacts analysis" is in many ways the center of an EMS. The analytical process is necessary to bring to the forefront the most significant environmental aspects of an organization, facility, or department. An "environmental aspect" is an aspect of an activity that can lead to a probable environmental impact. The "aspect and impact," or A&I, analysis will lead to the most significant environmental aspects of an organization, facility, or department. These significant environmental aspects are the ones that require preventative mitigation measures to reduce environmental impacts, or enhancements to help accentuate positive outcomes.

As a modest example, a careful and thoughtful facility aspect and impact analysis has determined that a most significant environmental aspect of the facility is the operation of an interior forklift, since the forklift runs on diesel. The forklift, which emits pollution, creates indoor air quality issues that require numerous air exchanges, adding an increased and additional amount of energy. As a significant environmental aspect, it stimulates thoughts and potential actions about how to reduce pollution and save energy from forklift operations. One possible solution, a decision to switch to a battery-operated forklift, could be an action to reduce emissions, prevent pollution, and save energy. Going further than just utilizing a battery-operated forklift fleet within a facility, if the energy was supplemented by a solar panel to charge the batteries, this would be an enhancement to accentuate a positive initiative.

The aspect and impact analysis begins with formulating a scoring system based on activities, aspects, and impacts against probability, frequency, and severity. In any large organization's activities, including a public mass transportation agency, facility, or department, the list of environmental aspects can be extremely lengthy. Each environmental aspect that has the potential to produce an impact, whether to the built or natural environment, is rated and scored, and the top environmental aspects are deemed the most significant. A key feature of the aspects and impacts analysis is that there is not a one-size-fits-all standard, in fact each entity creates their own aspect and impact analysis, based on the appropriate understanding of issues and concerns facing an organization.

The basic principle of the aspect and impact analysis is that all activities which have aspects that lead to environmental impacts must be rated and measured based on the probability, frequency, and severity. There may be aspects that have severe consequences regarding impact on the environment, but are not very likely to happen, or the frequency of coming into play is very low. Some aspects can lead to minor impacts on the environment, but are more probable, and come frequently. For instance, within construction, lead paint disturbance is quite frequently encountered, and negative issues will probably occur, but the consequence is moderately severe.

On the other hand, polychlorinated biphenyls (PCB) transformer removal and disposal is less frequent, and the probability of harm is low because the PCB oil is contained; however, the severity of a PCB oil spill can be catastrophic. Depending on an organization's culture and standard of care, rating these aspects with a scorecard based on probability, frequency, and severity will determine which of the aspects are most significant. An entire chart of activities, aspects, and impacts will need to be established with a unique scoring system, based on an organization's culture, and this aspect and impact analysis establishes the most significant environmental aspects. An organization should create a representative team to establish its significant environmental aspects.

Significant Environmental Aspects in Mass Transit

The word "significant" in environmental language is extremely noteworthy, in that it connotes that caution and action are to be taken to prevent harm or damage. Environmental regulations use the term significant to determine what level of environmental analysis, mitigation, and documentation will be necessary for a proposed action. In environmental management, the term significant environmental aspect generally means what aspect of an organization's activities can cause the most harm and potential damage, and therefore is where the most thought and action should be given regarding significant environmental aspects.

Significant environmental aspects for a train service traditionally have included electrical consumption, which leads to pollution and greenhouse gas emissions, and for a bus service is diesel fuel consumption, which also leads to release of pollution and greenhouse gases. In mass transit, in addition to energy usage, significant aspects that lead to significant environmental impacts can include: noise and vibration issues in inner cities, transportation facility stack emissions, and hazardous waste removal and disposal. Energy use is the most significant environmental aspect of the mass transit industry overall.

Many other significant environmental issues depend on regional importance, e.g., in drier climates, saving water may be a more significant issue for some transit agencies, than for others in wetter climates, and climate adaptation is an important consideration for all, perhaps especially in coastal cities. Once the significant environmental aspects are brought to the forefront, processes and programs with achievable environmental goals need to be established.

ENVIRONMENTAL BENEFIT PROGRAMS

Once significant environmental aspects are established, environmental benefit programs with the goal to help lessen environmental impacts can be put in place. Environmental programs can be in the form of changing procedures or practices, or a major expenditure that hopefully will have a large effect in mitigating environmental impacts. A structured EMS, with buy-in from every corner of the team, can help influence a decision to allow funding to be available for the big change necessary, as suggested by the EMS team.

As an illustration, a major environmental aspect of a bus service is fuel consumption, which leads to increased air pollution and greenhouse gas release. Therefore, environmental programs should be put in place to lessen fuel usage. Some choices for environmental benefit programs can be procedural, and some more extreme considerations may require additional funding. Procedurally, a "no idling" protocol can be put in place to reduce fuel consumption, which can help on a small scale. On a larger scale, a switch to hybrid buses would greatly help reduce pollution and greenhouse gases, but would only happen with a major expenditure.

Environmental benefit programs based on significant environmental aspects are a large cog in an EMS. As significant environmental aspects are afforded environmental benefit programs, hopefully their significance will reduce, and then the next most significant environmental aspect will get the benefit of an environmental program. Progress made in this area of an EMS can help indicate, validate, and contribute a good percentage to the overall continuous improvement. The setting of goals, to provide an appropriate target to shoot for, is another component of an EMS, which can show continuous improvement.

Objectives and Targets

A significant environmental aspect, that leads to an environmental program, should have a set goal to achieve. The goal should be set realistically, but not be too easily achievable for maximum effect. As a case in point, if a facility has set an objective to recycle as much waste as possible, it can prescribe a modestly achievable goal, say, e.g., 75% recycling can be set. All those who work at the facility, with some responsibility for success, would understand and plan to work toward that goal. Hopefully, with a target set, and a new program in place with an objective to recycle waste, the 75% will be achieved. Most objectives and target processes will be based on measurable metrics. Another hallmark of an EMS is monitoring and measuring, and tracking progress toward goals set to help achieve continuous improvement. Legal requirements should not be part of an objective and target program, because they are required; however, surpassing legal requirements and doing better than regulatory levels is a trademark sustainability ideal.

LEGAL ENVIRONMENTAL REQUIREMENTS

Whether in operations, maintenance, planning, design, or construction of mass transit, there are a plethora of environmental laws and regulations to adhere too. Federal, state, and city environmental regulations, or local town environmental ordinances, must be followed so mass transit entities remain in compliance with the law. Environmental regulations pertaining to public train or bus services are, in many cases, a compilation of federal, state, and city laws aimed at preventing air, water, noise, or soil pollution, and also at the protection of worker and public health. Therefore, there are a monumental number of regulations for a mass transit agency to adhere to in operations, maintenance, and rehabilitation to ensure environmental compliance.

An EMS requires the identification, listing, and documenting of pertinent environmental laws which help to pinpoint which regulations pertain to specific activities. Utilizing the completed aspect and impacts analysis each environmental aspect, which potentially may lead to an environmental impact under an EMS, will have a detailed description of the environmental laws or regulations that must be followed to remain compliant. Often, in addition to laws limiting pollution, the location requires adherence to a law, such as coastal or ecologically sensitive lands like wetlands. Also, an agency, facility, or department may have their own internal procedures or directives with legal implications. These "other" requirements can be added to the statutory and regulatory requirements in a matrix with environmental aspects, to form a Legal and Other Requirements active document as part of an EMS.

Federal laws apply to state transit agencies, when a federal action, such as impact on coastal areas or national parks is required. A federal permit from the Army Corps of Engineers may be required for US transit agencies using federal money for new or expanded services affecting coastal areas. The very first environmental law in the United States was the Rivers and Harbors Act of 1899, which prohibited the alteration of coastlines or harbors without a permit, and it is still in effect today under the Army Corps of Engineers. Since 1970, many major federal environmental regulations were promulgated or enhanced from earlier regulations to help protect the environment, such as the Clean Air Act, Clean Water Act, Noise Control Act, and the National Environmental Policy Act (NEPA), which is the chief environmental regulation in the United States. See Table 9.1 for short list of the major environmental regulations.

NATIONAL ENVIRONMENTAL POLICY ACT

The National Environmental Policy Act, or NEPA, was adopted in 1970, the year of the first official earth day, and was put in place to protect the environment. The law was established to allow humans and nature to coexist, without compromising future generations, and find a balance between rapid development and environmental protection. Major construction projects, such as new highways and new transit lines, were a major activity that influenced the adoption of NEPA. A major component of NEPA during the decision-making and planning process for a major action, is the preparation of an Environmental Impact Statement or EIS.

An Environmental Impact Statement requires an evaluation of realistic alternatives, and consideration of any environmental impairment, in addition to engineering and economic concerns for major actions. The most essential part of an EIS is that it is produced to allow the public to comment on a proposed action. The EIS must be prepared in language that is understood by

TABLE 9.1 Major Environmental Laws in the United States

Environmental Regulation	Year
Rivers and Harbors Act	1899
Fish and Wildlife Coordination Act	1934
Air Pollution Control Act	1955
The Clean Air Act	1963
National Environmental Policy Act (NEPA)	1970
The Coastal Zone Management Act	1972
The Clean Water Act	1972
Noise Control Act	1972
Safe Drinking Water Act	1974
Toxic Substances Control Act	1976
Resource Conservation and Recovery Act (RCRA)	1976
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	1980
Energy Policy Act of 1992	1992

the public, it cannot be complete technical jargon that most people are not qualified to understand, but must be in a format that gives the public an opportunity to weigh in on the subject project. In this manner, the information presented can receive proper public feedback to help make the best possible final decision about an action.

Mass transit agencies, which utilize federal money for proposed major actions, must first inform the public through a notice of intent, to begin the public involvement. During an EIS preparation, at multiple points in the process, the public participates and is encouraged to make comments on the proposed action, and the laws relevant to the action need to be identified at the outset of the EIS process. The purpose and need for the project, which defines the basis for the proposed action, is the foundation under which alternatives are to be evaluated. A no action or no build alternative, which defines what will happen if no action is taken, must also be evaluated. An EIS project can be presented to the public in many types of forums, including a public hearing. Once an EIS is completed, and a preferred alternative is suggested by an agency, it is forwarded to the public for review.

An ensuing public comment period allows interested parties to send their comments and be part of the decision-making process. All federal projects that are subject to a NEPA evaluation do not always require an EIS, in fact some actions are routine and procedural, and will normally not have a significant impact on the natural or built environment. These projects fall into the category called categorical exclusions, and are usually based on a repetitive action that previously was seen to have little impact. Routine replacement or rehabilitation may fall under this category, provided there are no circumstances that may lead to a potential significant impact, such as an impact to sensitive land or natural resources.

Projects from the outset that are not categorically excluded, but are not clearly at the level of an EIS, may opt to first complete an environmental assessment (EA), which can help determine if an EIS is required. Like an EIS, an EA evaluates alternatives, and presents a document for the public to weigh in on. In many cases, an EA includes the mitigation measures to reduce, minimize, or eliminate a potential environmental impact. If an agency believes that the impacts are relatively minor, or that minimal adverse impacts are anticipated, an EIS will not be necessary. On the other hand, if the agency feels that the impacts are significant, then an EIS may be required.

Agencies with proposed capital projects using state or local funding are not subject to NEPA; however, most states and many cities have formulated their own environmental review process, and most are based on NEPA requirements. The environmental review process under NEPA, which determines the requirement for addressing environmental impacts, is a great way to begin the planning process for any proposed project, and often it is where the identification of the most significant environmental impacts can be addressed. An organizational, facility, or departmental EMS can use the environmental review process, and all pertinent environmental regulations, as the starting point to help control environmental impacts.

ISO 14001 ENVIRONMENTAL MANAGEMENT SYSTEM STANDARD

Several mass transit agencies in the United States, have adopted the ISO 14001 EMS international standard, to help develop a formal commitment to the environment. The EMS 14001 ISO standard helps an organization, committed to continual improvement of environmental performance, to utilize a formal procedure that assigns roles and responsibilities, and ensures that environmental impacts are managed to avoid unintentional impairment. Most importantly, adhering to the standard, and having a third-party auditor evaluate whether the entity does commit to environmental sustainability, validates the effort for all to see and emulate.

The EMS ISO 14001 commitment begins with a top management signed environmental policy, signifying to every person what is senior management's position on protecting the environment. Under an ISO 14001 EMS, the structured framework consists of an aspect and impact analysis, an environmental awareness campaign, adherence to legal requirements, assignment of responsibilities, and training of competent personnel. It also includes major communication, monitoring, and measuring, and an internal self-assessment with a corrective action process, all based on the Plan – Do – Check – Act cycle. The standard requires the identification of significant environmental aspects, and everything must be documented, especially for those that seek ISO 14001 EMS certification.

The ISO 14001 EMS standard does not specify how an organization must carry out their actions, but requires them to develop their own procedures documented in a manual that discusses all elements of the EMS. The EMS manual outlines how all elements of the EMS should be carried out, including all roles, responsibilities, and authorities for each position, and all involved divisions or subdivisions. An important section of an EMS manual describes how an evaluation of compliance processes is performed, with a corrective and preventative action procedures protocol. The manual should include a senior management review process, as well as third-party external audit protocols.

ISO 14001 Environmental Management System Certification

The benefits of ISO 14001 EMS certification are wide-ranging and diverse, and by adhering to the comprehensive standard the formalized structure helps to prevent and minimize unintended consequences to the environment. Since the standard requires organization wide commitment to the environment, it must permeate from the top all the way to field level operations, and this provides system wide constant control of environmental impacts. Third-party validated certification requires a devoted organization, facility, or department commitment to the protocols of an EMS, and in many cases, that requires extra manpower.

The extra effort required for an organization to seek and attain certification helps boost the potential for positive and continuous improvement efforts. A public transportation agency which utilizes tax payer funding can show through third-party validation, that adherence with and certification to an EMS ensures how tax dollars are being spent by an agency while always considering impacts to the environment as decisions are being made. Transit agencies that have obtained ISO 14001 EMS certification as of 2016 are included in Table 9.2.

TABLE 9.2 US Transit Agencies With ISO 14001 Environmental Management System (EMS) Certification[a]

Agency	Year
MTA New York City Transit	1999
Utah Transit Authority	2005
Sun Tran Tucson, Arizona	2006
Sound Transit Seattle, Washington	2007
Los Angeles County Metropolitan Transit Authority	2011
Foothill Transit, San Gabriel Valley, California	2013
Southeastern Pennsylvania Transit Authority, Philadelphia	2013
Champagne – Urbana Mass Transit District	2013
Intercity Transit, Olympia Washington	2014
City of Asheville, North Carolina	2015
Hillsborough Area Regional Transit, Tampa, Florida	2016
Lane Transit District, Eugene, Oregon	2016
Greater Cleveland Regional Transit Authority	2016
Golden Empire Transit District, Bakersfield, California	2016
Kitsap Transit, Bremerton Washington	2016

[a]*Includes certification of facility, operation or department.*

THE ENVIRONMENTAL MANAGEMENT SYSTEM FENCE LINE IN MASS TRANSIT

The EMS standard does not belong to a specific entity or type, and can be applied to an entire organization, a component of an organization, or a single facility or department. This is referred to as the EMS fence line. If an EMS fence line is the entire mass transit agency, the entire footprint of the operation, including subway lines, train or bus routes, and all infrastructure, vehicles, and facilities would be subject to the structured EMS. While the fence line defines the boundaries, potential environmental impacts cross over into the natural or built environments.

A fence line may be a single transit facility, but the activities associated with the building include aspects that begin or end outside the facility into the environment, such as the energy in and the exhaust out, or raw materials that come in and the waste that goes out. The impacts may affect the air, water, or land before it gets within the fence line, such as energy generation, or after it leaves the fence line, such as toxic exhaust or hazardous waste disposal. An entire organization EMS requires a far greater commitment than a single facility, and some transit agencies have only a single department or program that adheres to the ISO 14001 EMS standard. This all depends on where an organization puts up the EMS fence line.

ENVIRONMENTAL MANAGEMENT SYSTEM TEAM

At the very core of an EMS are the people, the real heavy lifters who run the EMS. An EMS should have a team consisting of representatives from various departments within an organization. The EMS cross-functional team, with a responsible leader with authority recognized organizationally, will run the EMS. It is best when an EMS team includes a broad mix of appropriate employees that not only have the technical expertise, but also understand the culture of an organization. Team representatives from operations, maintenance, facilities, supplies, safety, and engineering, among others, should be involved with the EMS Team.

An EMS team must have support from top senior management to carry out an EMS. The intention of an EMS is to have participation and buy-in from every essential part of the organization. Therefore, those individuals within an organization who participate in the EMS, who are not environmental professionals, need to be provided with awareness of environmental issues through awareness training. Employees more directly involved with the EMS should receive appropriate technical training. The EMS team members, who all come from different places within an organization, can cross train each other while working within an EMS.

MONITORING AND MEASURING

There are many ways to monitor and measure environmental performance under an EMS. The most reliable way to quantify continuous improvement of environmental performance is the monitoring and measuring of selected environmental metrics. Environmental metrics are statistics utilized that measure environmental performance, and they can include, among many others: the percentage of recycled material; the amount of fuel consumption; the kilowatt hours of electricity used; or the volume of water saved.

Physical statistics that normally already exist for other reasons, such as paying bills, are the simplest metrics to rely on. These metrics are easy to come by because they are received through an established billing processes with a public utility, which normally depicts consumption. For example, for reducing heating fuel usage and electrical consumption in a facility, the monthly billing data will help tell the story, and will include pertinent statistics such as gas consumed or electricity provided. Saving water, and measuring water consumption is also a standard metric, with water metering information almost always available.

Metrics may also be correlated from another metric. For example, reducing diesel gas consumption also reduces the amount pollution and greenhouse gases released into the atmosphere. For mass transit facilities with an electrical meter, measuring electrical consumption is easy as well; however, in many cases there is no submetering to measure specific components. Therefore, it may be easy to assess total electrical usage for a subway line or facility, but without submetering specific components, such as lighting, may not be as easy to measure. Diesel fuel tanks are normally accompanied by a fuel dispensing system, which measures fuel usage, so that is normally an easy metric to measure.

There are also less tangible ways of measuring sustainability performance. A metric that is more qualitative would be the growth of something that adds indirect sustainability value to an organization, such as the total number of trained individuals in a certain topic, or a department that targets a certain accreditation for employees to attain. A counterpoint metric to measure environmental performance may be the elimination of negative consequences such as violations, fines, or additional work orders. Another effective way to measure sustainability is with a reputable green rating system.

Environmental rating systems can also be used in conjunction with an EMS to evaluate the effectiveness of a building, equipment, or infrastructure design. Rating systems have been established to encourage the use of sustainability initiatives, and systems measuring sustainability are normally either outcome based, which measure environmental performance during operations, or design based, which try to predict the environmental performance, based on evaluation, analysis, and, in many cases, modeling.

LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN

The US Green Building Council's Leadership in Energy and Environmental Design, or LEED, rating system has quickly, within the last decade or so, become the world leader in determining the effectiveness of sustainability initiatives incorporated in buildings. Through its LEED rating system, the US Green Building Council has established a monitoring and measurement tool and a third-party validation process that can be a critical tool to help a public transportation agency adhere to an EMS. The LEED rating system was not developed specifically for industrial buildings, but the spirit and focus of energy reduction, saving water and natural resources, and quality indoor air quality, works for transportation facilities as well. Mass transit buildings, such as subway car maintenance shops, bus depots, and transportation hubs of some agencies, have all achieved individual LEED certification.

The LEED rating system values sustainable sites with the intention of having healthy buildings to live and work in, by creating performance standards with an accompanying scoring system. Using LEED is totally voluntary; however, some transit agencies have made certification a requirement and part of an EMS, with encouragement to develop sustainable facilities. The LEED standard can be applied to many building types; however, it is quite an achievement for an industrial transportation building, such as a maintenance shop or bus depot, to achieve certified or higher status. The LEED system provides levels of achievement starting with certified, and moving up to silver, gold, and then toward the top platinum level. The LEED rating tool and subsequent certification is another type of third party endorsement of the sustainable effectiveness of a mass transit entity.

Energy Star Equipment and Buildings

The Energy Star program was developed by the Environmental Protection Agency (EPA) and Department of Energy, initially as a labeling program to promote energy efficient products, starting with computers, it then expanded to air conditioners and major appliances. Thousands of products have an energy star label, which means they run with less power consumption, and devices with the Energy Star label commonly use 20%–30% less energy than required by basic standards. The Energy Star program has been widely successful, and it has expanded into buildings and industrial facilities with a rating system. The EPA has established a free on-line tool to see if buildings qualify for recognition. Energy Star recognition is included in the existing building LEED rating system for credits.

ENVISION

Mass transit ancillary facilities, such as subway car maintenance shops and bus depots, have found success utilizing sustainable rating systems, such as LEED, to validate environmental effectiveness. However, the LEED rating system pertains to buildings, and much mass transit infrastructure is not applicable. Much transit infrastructure is not a building type, but includes miles of interconnected structures that traverse neighborhoods and connect counties. A comparatively new infrastructure rating system called Envision may be a more applicable rating system for subway tunnels, stations, elevated train, light rail, or bus rapid transit systems. The Envision rating system is a sustainability rating system that aspires to cover all major civil infrastructure project types.

The Envision system evaluates and assesses transformational and collaborative approaches, with a goal toward a more sustainable future. It is designed for major infrastructure, and not specifically for buildings. It is intended to be applied to, among many others: highways, waste water treatment plants, water tunnels, sewer systems, and electricity generating power-plants. The Envision system is designed to be used during any phase of a project, including planning, alternative analysis, conceptual engineering, scope development, design, and construction. It is a collaboration of the American Society of Civil Engineers (ASCE), the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design, and the Institute for Sustainable Infrastructure (ISI). The Envision system is well suited for mass transit infrastructure, and in 2016 it began to be applied to assess many train rehabilitation projects, and some new light rail systems.

Professional Accreditation

Leadership and Energy and Environmental Design (LEED) and Envision rating systems have a common theme of bringing education and accreditation into the environmental sustainability industry. Each offers accredited levels of accomplishment for professionals to aspire to: the LEED Accredited Professional or LEED AP, and the Envision Specialist or ENV SP. Both systems were fully developed with academic and practitioner collaboration, with associated write ups describing each section, and theory behind each of the individual credits. Any professional interested in becoming part of either association is going to be tested on the basis and foundation of the decisions made in putting the rating system together.

The academic background lends much credibility to both systems, and the spirit of sustainability lies within each system. Accreditation to LEED AP and ENV SP can be obtained by engineers, architects, planners, building professionals, lawyers, and many other professions, in both public and private entities. The collective brainpower of an agency workforce is what makes things happen, progressively, toward more state-of-the-art projects and programs. Continuous educational programs help keep professionals technically sharp, smart, and aware of the latest changes, alterations, or improvements in the environmental sustainability field.

ENVIRONMENTAL TRAINING

A very large portion of an EMS is centered around appropriate training of all personnel in an organization, facility, or department. Providing the proper amount of environmental training to the workforce is an essential part of an EMS, and the correct amount of training to technical staff, and general awareness level training to all other levels of an organization, is also an important component of an EMS. A trademark of a successful EMS training program is the ability of the central environmental staff to internally fulfill the training requirements of outside department personnel within an organization. An external "train the trainer" program can help fulfill this requirement.

Training staff is a specific budgetary item, and the level at which training is offered to both field and managerial staff is contingent upon the ideology of the agency. Discretionary training is often the subject of great debate within any organization; however, some training is mandated by law and regulations. Environmental training regarding handling hazardous or regulated materials, or health and safety, are usually mandated by state or federal regulatory authorities, and usually include certificates of completion and follow-up annual refresher classes. As part of an EMS, an environmental, health, and safety training matrix can be created, to help employees remain in compliance.

BENEFITS OF AN ENVIRONMENTAL MANAGEMENT SYSTEM

An EMS is a great way to formally introduce sustainability into operations, maintenance, and design. When any entity, including a mass transit agency, decides to embrace an EMS, it is signaling that at its core values is a respect for the environment, while still maintaining the core business at hand. Mass transit operations are right there in the middle of the built environment, right up against and adjacent to the natural environment. The interaction between mass transit infrastructure and the environment is intertwined. Mass transit has many environmental impacts to manage, and an EMS is recognized as a best management practice in the field of environmental sustainability. An EMS begins with a commitment to stay within all legal requirements set forth by federal, state, or local regulators, and provides a framework and structure to help confirm compliance.

EMSs bring all facets of an organization, facility, or department together to make team decisions, which embraces the holistic spirit of sustainability, and an EMS brings awareness of environmental issues to the forefront of an organization. Most of all, EMS's do help organizations reduce pollution, and save natural resources. Several mass transit agencies, through the development of an EMS, implemented numerous sustainable initiatives, and many mass transit agencies have reported continuous improvement in environmental performance based on fuel savings, reduced electrical consumption, saving water, and saving money.

An EMS is not intended to save the environment at any cost, but as a management tool to help make good, balanced, decisions, and consider impacts to the environment, as well as financial implications, when making potential changes or upgrades. An EMS can help an organization make proper and appropriate economic decisions, and a certified EMS can help lure funding that is earmarked for sustainability initiatives. The Federal Transit Administration, which provides mass transit funding, has valued participation in an EMS, and encouraged certification to the ISO 14001

Certified EMS standard. Federal grant money, which is usually available for public mass transit, is often linked with benefits such as energy efficiency and environmental conservation.

CONCLUSION

An Environmental Management System, or EMS, is a structured framework under which an entity can manage environmental impacts, and is a formally documented procedure or guideline that supports the management and monitoring of impacts on the environment in the operation and future expansion of an entity. Many mass transit agencies have incorporated a structured EMS to safeguard compliance, and to inspire sustainability initiatives that go beyond compliance. An EMS is a management tool that systematically ensures environmental compliance that works towards continuous environmental improvement, and it must start with an endorsed environmental policy.

At the center of an EMS is a self-analysis of all operations, activities, and environmental aspects that can lead to an impact on the environment, and includes a monitoring and measurement requirement that quantifies selected metrics that can demonstrate environmental improvement. The ISO 14001 Environmental Management Systems standard is one of the world's most recognized best management practices in sustainability. The ISO 14001 EMS standard requires documentable evidence of agreement with the standard to achieve third-party certification.

An EMS is balanced around communication and awareness of environmental issues, with the intention of having participation from each member of a cross functional team, comprised of well-trained representatives from many parts of an organization, facility, or department. Environmental rating systems can be valuable verification tools to predict future improvements in design projects. In the end, an EMS is a management tool to help measure environmental performance to ensure environmental compliance and authenticate continuous improvement. Public mass transit agencies can benefit from an EMS, and by strengthening its commitment to the environment, it can prove that public funding is being spent with the consideration of the environment as a priority.

FURTHER READING

http://www.iso.org/iso/iso14000.
http://www.usgbc.org/LEED/.
http://sustainableinfrastructure.org/.
https://www.energystar.gov/.
https://ceq.doe.gov/.

Chapter 10

Continuous Sustainability in Mass Transit

SUSTAINABILITY

Sustainability has been described in many ways in today's modern world. The generally accepted conclusion is that the present generation should not compromise future generations with over-consuming resources for present-day needs. A few words cover this description, with an infinite amount of meanings, directions, and interpretations, including: saving natural resources; preventing pollution; ensuring healthy, safe, and clean living, while maintaining an appropriate quality of lifestyle for humans; and the survival of all current and future species on the planet. In addition to environmental sustainability, both social and economic sustainability issues are intrinsic to maintaining current lifestyle. Simply, sustainability commands that the future be considered when present-day changes are contemplated.

AT THE FOREFRONT

As an inherently sustainable entity, public mass transportation has been at the forefront of the modern sustainability movement, which is generally thought of as starting on the first earth day celebration, April 22, 1970. In these current times of accepted man-made climate change, entities worldwide have incorporated sustainable initiatives to help curb emissions, with mass transit a leader in many areas including engineering, green design, and construction, maintenance, and operations. Mass transit agencies have continually added initiatives to save natural resources and energy, prevent pollution, and reduce greenhouse gases.

Mass transit has continuously evolved as a common sustainability solution for all cities to consider. Since mass transit's early years of horse drawn carriages on rails and coal burning steam locomotives, urban public train and bus operations, from its beginning, has had to operate within the natural and built environment, providing mitigating measures to thwart environmental impacts while operating. As trains advanced to an electrified system requiring on-demand electricity and subway tunnels, with lighting and built in sewer connections, to operate safely and efficiently, technological advances

Sustainable Mass Transit. DOI: http://dx.doi.org/10.1016/B978-0-12-811299-1.00010-1
© 2017 Elsevier Inc. All rights reserved.

have helped spur changes constantly to make transit service better in terms of energy consumption. Public bus transportation evolved along with the advance of the automobile, and evolved toward much more environmentally efficient vehicles.

Mass transit, which provides mobility options to millions of people in cities to go to work, school, or to recreational activities, exemplifies the three common pillars of sustainability: environmental, social, and economic. From a social perspective, inner city transit fare is a significantly lower cost option which allows many people more opportunities to take advantage of what social amenities a city does offer, including school opportunities, therefore improving education and upward mobility. Inner city transit can connect individual neighborhoods within large cities to allow people who do not own a car to visit more frequently with friends and family, specifically those disabled or sickly, who may require constant family attention.

For people who have long commutes, comfortable transit with a large seating capacity can help convince a commuter not to use a car, and attract more ridership. Space that allows people to read or utilize their smart phone or laptop while traveling, can help people to be more productive during their commute. Improving mass transit, and providing a faster more reliable service, can help save people time. These time savings can add up to more productive and enjoyable lifestyles for many people. As an example, if a normal commute for a person is one hour in both directions, i.e., two extra travel hours added to their work day. If mass transit service improvements were to shave 15 minutes off the one-way trip, that would add up to an extra two and a half hours per week for that individual to be more productive or to simply enjoy. Economically, transit systems have always help spur development.

TRANSIT ORIENTED DEVELOPMENT

Since the institution of public transit in cities, major commercial development and housing have always grown in and around the transportation route. This is commonly referred to as transit oriented development. Mass transit service has always helped spur economic development to revitalize cities, both in the United States and around the world. Public transportation attracts people that want to live in thriving cities, helps to stimulate the economic growth that comes with more people settling in cities, and people who live in cities are generally more sustainable.

The federal government investments in mass transit in the last few decades have not only helped provide additional transit service in cities, or the rehabilitation of an existing system in a city, but also the investments ultimately put money back into the economy that helps stimulate growth. Mass transit operations move people sustainably, provide a cleaner and greener way to travel, and help sustain a numerous amount of other entities economically.

THE MASS TRANSIT BUSINESS

Mass transit is operated as a business, facing similar issues that many private entities must overcome, including labor, infrastructure, space, assets, and finance. Public transportation is a vital cog in the economic engine of a city, both in terms of supplying transportation, and in the vast amount of economic connections which are an essential part of operations, maintenance, and capital construction.

Mass transit is an intrinsic part of cities, and the infrastructure, facilities, and vehicles that make up a mass transit agency are essential components of, and a large part of, the very fabric of some cities. Public transit agencies employ thousands of people, are financially and contractually connected with numerous private businesses, and utilize available government funding to build and rebuild infrastructure and purchase vehicles. Public transportation is a required service, much like other crucial services such as electricity, gas, sewer, water supply, public lighting, telephone, sanitation, and the police.

Mass transit agencies provide jobs to both blue and white collar employees, and contract with numerous vendors for supplies, goods, and services. Transit agencies require a steady amount of materials, products, and services, therefore, there are many private vendors with steady business contracts supplying services to a transit agency. Mass transit agencies can bring in supplementary income, in addition to the fare box, with infrastructure and vehicle wide advertising, and commercial establishments such as news and coffee stands in the station or terminal environments.

Station locations can be near or adjacent to local points of interest to stir economic spending. Public transit provides a civic service, while helping sustain outside private businesses economically. Urban public transportation networks have, throughout modern history, been the most sustainable way to move millions of people from destination to destination, safely and reliably. Trains and buses require a continuous supply of energy, and mass transit, like all entities both public or private, must always look for ways to be more sustainable for the betterment of society.

ENERGY AND MASS TRANSIT

Mass transit is a big consumer of energy, specifically electricity and diesel fuel, and more recently natural gas usage has increased. Energy is a large sector of society itself, and its use is most responsible for air pollution and greenhouse gas emissions. Energy also has an essential place in the economic affairs of any country, and is a worldwide industry. Modern society relies on energy, and it has created a history of its own. Mass transit and energy are connected, and have been since the inception of the first trolley car, and the original steam locomotive. A large component of a mass transit system is the form of energy used, whether by trains or buses. Energy consumption produces air pollution in many different forms.

Reducing the potential environmental impacts of pollution and greenhouse gas can be accomplished through energy efficiency. While stricter regulatory levels on air pollution emissions in the past several decades have significantly helped air quality in many cities, sustainable strategies such as limited idling of buses, restructuring bus routes to maximize miles per gallon, or staging bus parking to minimize empty bus trips can help save fuel, lessen pollution, and reduce greenhouse gas emissions. Mass transit helps cities use less energy, especially in cities which are dominated by the single automobile lifestyle, and instituting or increasing mass transit can help reduce pollution.

Millions of people who use mass transit rather than their personal car save energy daily. Effective mass transit is a train or bus service that rides close to or at full capacity. As much as commuters do not prefer a very crowded train, a train or bus at capacity is maximizing its energy use per passenger. To be able to run more service to have less crowded trains or buses, progress still needs to be made in fuel economy in mass transit and other sectors. Natural gas is growing fast as an alternative to diesel in the mass transit industry, as well as the fuel for electricity producing power plants.

Natural gas bus fleets are growing, with many diesel fuel buses being converted to compressed natural gas, or CNG. Natural gas is also being extracted from landfills and waste water treatment plants, and marketed in some cases as "renewable natural gas". However, natural gas is still a fossil fuel no matter how it is extracted, and when combusted it does emit pollution and greenhouse gases. Natural gas is relatively cheap and domestically produced, and new fracking techniques have made it more readily available.

Much energy is still being generated by burning fossil fuels, which pollute the air and release greenhouse gases; however, energy generation trends are moving toward renewable energy. More renewable and cleaner alternative energies such as solar, wind, or hydroelectric generated energy are being developed. Energy, in the form of electricity, of which two thirds is still being derived from burning fossil fuels, and diesel fuel make up the traditional core that help transport millions of people in public mass transportation systems.

Petroleum combustion is intended to create heat to produce steam to operate a turbine generator or expand gases to move pistons up and down to help accelerate an automobile. The major byproducts of combustion are water and carbon dioxide, which is the major greenhouse gas, and there is always a measurable amount of greenhouse gases in the atmosphere.

Humans and animals constantly exhale carbon dioxide, and while it can be sequestered with vegetation, it cannot be absorbed enough to reduce the effect that too much carbon dioxide has on the global climate. Carbon dioxide is also the greenhouse gas that all other greenhouse gases are measured against.

Global Warming Potential and Carbon Dioxide Equivalents

Greenhouse gases include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, ozone, and water vapor. Greenhouse gas molecules absorb radiated heat or infrared radiation from the surfaces of the earth, heat up the atmosphere, and continuously warm the planet. Infrared radiation, which is invisible to the human eye, is absorbed more efficiently by larger gas molecules, in terms of how many atoms they have. Nitrogen (N_2) and Oxygen (O_2) molecules have only two atoms, so the gases that make up the clear majority of the atmosphere are made up of molecules which are not good infrared absorbers.

Water vapor (H_2O), with three molecules, is a good infrared absorber; however, water in the atmosphere content is dictated by the overall atmospheric temperature, and is not affected by man-made or industrial exhaust content. Carbon dioxide is more abundant than all other greenhouse gases combined; however, the other greenhouse gases make up a significant volume, and more importantly, in some cases are more potent. Noncarbon dioxide greenhouse gases consist of a considerable amount of the atmosphere, and are a byproduct of many applications, such as refrigerants (hydrofluorocarbons) in HVAC systems.

Carbon dioxide equivalents measure other greenhouse gases, and are determined by global warming potential. Carbon dioxide is measured as 1 carbon dioxide equivalent, methane is measured at 25, and nitrous oxide is measured at 298. Reducing other greenhouse gases is also important in fighting climate change. The increase of greenhouse gases in the atmosphere is raising temperatures, melting polar ice caps, increasing sea level, and raising the acidity level in oceans. While climate adaptation measures are being put in place in reaction to global warming, it is the reduction of emissions that will be necessary for all the earth's inhabitants to survive, moving into the future. Many sustainability initiatives are focused and designed to reduce greenhouse gas release, and prevent this climatic catastrophe.

FACING THE CHALLENGES AHEAD

In the past 20 years, public mass transit has transformed itself by becoming much more conscious about its own impact on the environment, and how it impacts air quality and contributes to climate change. While mass transit's value to a more sustainable world is undeniable, it does create its fair share of environmental disturbance. Sustainability initiatives included in train and bus infrastructures, vehicles, and facilities are intended to reduce those environmental impacts. Realizing these initiatives takes a great deal of planning, design, and construction to implement, in addition to a lot of convincing, and in many cases, extra money.

Funding is always a significant challenge. Every organization's funding mechanisms are completely different from each other. Local, state, or federal politics always play a large part in mass transit funding throughout the nation. How funding is spent is always a challenging proposition to any organization, whether public or private; however, funding in many cases may not be the most challenging part of instituting a new initiative. Change, in some cases, is the most difficult part, or convincing people to change to be more precise. Mass transit agencies in some instances go back decades, have a longstanding workforce, and have established standard operating procedures that have been working, so resistance to change is high. To lower the resistance to change, the positive benefits must be spelled out and explained, and forecast with the utmost accuracy.

Prior to the implementation of a sustainability initiative, the anticipated benefits should be projected, utilizing the information available to estimate, e.g., the energy, water, or financial savings. A very first pilot program initiative should include follow-up monitoring and measuring, to verify the anticipated savings. This follow-up measurement protocol should be established and agreed upon with all parties involved with the program. Many pilot programs have been the subject of follow-up testing which helped grow and proliferate the initiative. Energy modeling has helped agencies decide the value of new sustainability initiatives, specifically in buildings. Other ways to convince people that change is necessary is if a similar action has worked previously and can be replicated.

Many new sustainability initiatives are modeled after ones that have been implemented and proven to be successful in other places. Mass transit agencies have copied successes from each other in great amounts. Other industries can also copy successes from each other. Mass transit facilities, such as bus depots and maintenance shops, are similar in nature to those industries which house and maintain fleets of vehicles. Trucking, sanitation, express mail delivery services, etc., all require similar sized depots and maintenance shops. Tunnel or highway structures that carry cars and trucks can be somewhat like subway or elevated train infrastructures.

A big obstacle facing an agency that implements a new sustainability initiative is that when a new process is implemented, specifically a new electrical or mechanical piece of equipment, it must be operated and maintained in most cases by personnel who have no experience with the new equipment. Therefore, it is necessary to include the operating and maintenance people in the decision-making process, and include robust training for operation and maintenance employees prior to implementation. Engineers may design the most energy efficient building or vehicle, but it must be operated as intended to get the maximum efficiency as anticipated.

The largest challenge is an obvious one, and that is that the implementation of a complete new system will likely require "buy in" of so many entities within, and external to, a city or state transit agency. Getting many people to agree on something as significant as a new transit system is a tremendous undertaking, and it may require the preparation of a due diligence or alternative analysis report to depict all the pros and cons of implementation. All aspects and impacts of implementation, in some cases, need to be analyzed and presented in a fashion that spells out clearly the benefits of implementation, in addition to the potential negative consequences, so an informed decision can be made by a consensus.

In more recent instances, the mode choice is the big question to be asked, specifically whether to build a light rail or a bus rapid transit. An alternative analysis would weigh several large factors such as cost, environmental impact, social impact, schedule, etc., against each other to come up with a preferred alternative. The most critical aspect of convincing people to implement change is with a good hard look at the issue, with a complete analysis with documentable rationales as to why a decision was made. A sustainable initiative also has a good chance to face all the challenges ahead, leap over or around large obstacles, and succeed if it is appropriately championed.

Sustainability Champion

Organizations which strive to become more sustainable, in many instances, are propelled by a champion. Sustainability champions can come in many forms. This "sustainability champion" can be in various positions, from top level, to mid-level, to entry level, or can be a separate department or division within an agency. The sustainable champion, wherever they fall within an organization's structure, whether it is management or staff, influences by sheer example in most cases. For instance, a maintenance person or division may act as a sustainability champion by managing to reduce waste or energy usage through more efficient operations. It is always convenient if the sustainability champion is at or near the top in an authoritative position, and can make, or at least help, set organizational policy.

When the environmental policy and direction is endorsed by an organization's chief executive, this always generates real momentum because it has strength from the top of an organization on down. This helps create the change and improve the environmental performance of an entity wishing to become more sustainable. It also helps if the sustainability champion, whether that person is at the top, middle, or bottom of the chain of command, is knowledgeable and understands both the pros and cons of the sustainable initiatives he or she is proposing.

Sustainability champions must take the time and energy to study and enhance their own knowledge, thereby they are more likely to get buy-in from others. The sustainability champion needs persistence, perseverance, and a nonstop attitude, because there will be resistance at some or even all levels, no matter how high or low in an organization the champion resides. The sustainability champion also thrives on overcoming difficult challenges, and looks for sustainable opportunities.

OPPORTUNITIES FOR SUSTAINABILITY

The largeness of a mass transit system or network, the variety and versatility of the infrastructure, facilities, and vehicles, and the connectivity with other aspects of city living from an economic, social, and engineering standpoint, present countless opportunities for sustainability initiatives. Mass transit agencies have seized many opportunities in the past decade, and have adopted numerous sustainability initiatives that in many cases ultimately have become standard practice. History indicates that mass transit agencies will seek further opportunities for more sustainability initiatives.

There are US agencies which have devoted environmental policies that indicate an understanding of the impact that their operation has on the environment. Mass transit agencies across the United States have installed initiatives that have saved energy, money, and made a difference from a social aspect. Many high level and superb sustainable initiatives have been adopted by mass transit agencies in the United States and around the world, and there have been some standout organizations that have made sustainability a cornerstone of their operations, planning, design, and construction.

From large scale engineering projects to small scale strategies, and everything in between, mass transit networks present endless choices for an agency to provide sustainable solutions for the benefit of cities, and of course to be more sustainable itself. Through knowledge sharing programs in the transportation industry, successful US projects learned from each other, and from mass transit overseas, thus exponentially growing sustainability elements included in major capital construction projects in mass transit. There are many current agencies with a complete sustainability program, with annual reports of fuel usage, electrical consumption, water consumption, recycling rates, and other environmental metrics to monitor and measure, to ascertain the effectiveness of sustainable initiatives.

The amount of sustainability opportunities is almost equal to the number of professionals associated with some part of the mass transit service, from direct employees who operate, plan, design, and maintain services, to the infinite number of people associated with transit who are contracted to provide essential services to allow a safe and reliable service. A major opportunity for a city to be more sustainable is to supplement or add mass transit, in the form of a train or bus service.

Large cities which have depended on mass transit like New York, Boston, or Chicago, for over a century or more, have embraced a state of good repair rehabilitation, to ensure safe reliable service continues uninterrupted. Rehabilitating a mass transit infrastructure provides an opportunity for sustainable initiatives to be placed into an older system, such as aluminum − steel composite rail replacement, resilient rail fasteners, composite plastic ties, recycled concrete and steel components, and Light Emitting Diode or LED lighting, among others.

A New System

Many cities today (2017) designing and constructing a complete new transit system are more likely to build a light rail system, above ground mostly, built into the existing street network. Similarly, many cities without the budget for light rail are opting to institute bus rapid transit. In creating new transit systems, sustainability measures, such as wayside energy storage and electric charging stations, can be incorporated into the brand-new infrastructure, to take advantage of regenerative braking in trains, and electric charging batteries in a mass transit vehicle.

Therefore, a city can add mass transit, become more sustainable by taking single driven cars off the road, and add sustainability measures to reduce energy consumption. Public transportation agencies have added sustainable initiatives in operations, maintenance, and construction to save energy, prevent pollution, and reduce emissions; however, there is still a lot to be accomplished to combat climate change.

LEADERSHIP IN THE MASS TRANSIT INDUSTRY

Mass transit agencies have demonstrated numerous examples of sustainable excellence, through large organizational, departmental, and capitally funded initiatives. Capital projects and rolling stock purchases in the past decade have led to more sustainable train and bus services, with technological advances in infrastructure, facilities, and vehicles that help reduce electricity and fuel consumption. Many mass transit agencies have adopted sustainable programs and processes, while continuing to provide transportation to millions of people.

Public transportation agencies have become more sustainable, as demonstrated by specific projects or procedural changes. Mass transit agencies also collaborate with each other in collegiate and reciprocating settings to share knowledge through interactive and academically influenced entities, such as the American Public Transportation Association (APTA) and the Transportation Research Board (TRB). Through conferences, committees, and seminars, mass transit agencies have come together to learn about each other's successes.

American Public Transportation Association

The APTA is a leading advocate in public transportation, catering to members of public mass transportation systems such as subways, bus, paratransit, light rail, commuter rail, high-speed rail, and ferry services. Mass transit agencies, that are large, medium, and small, who operate, maintain, plan, design, and construct, bus and train services worldwide, are typical member organizations of APTA. To help improve public transportation, APTA provides platforms for information sharing through committees, conferences, seminars, and webinars, and prepares guidance documents for all transit agencies to participate.

The APTA committees are organized to provide contact among members of numerous transit disciplines. Committee members deal with the immediate issues and challenges in mass transit, and discuss strategies and projects leading to a mutual information exchange program. The APTA includes a very robust Sustainability Committee, whose mission is to support the use and adoption of sustainable practices in public transportation. This committee holds an annual Sustainability & Public Transportation Workshop, where mass transit agencies can share their sustainability projects and programs with other transit agencies.

To help proliferate sustainability practices in mass transit agencies, the APTA Sustainability Committee has developed, with the help of transportation professionals worldwide, a collection of recommended sustainability practices contained within compendiums completed by working groups dedicated to promoting sustainable initiatives. Also, the committee has developed an extraordinary recognition program for members who voluntarily commit to certain levels of achievement. As part of the commitment of the Signatory Program, an agency must pledge to make sustainability a core part of the organization, share metrics, and present successes. The APTA is the foremost advocate for public transportation use, and collects, organizes and provides essential data of mass transit statistics for all to share and utilize to help proliferate the growth of public transportation.

The Transportation Research Board

The TRB is a nonprofit organization that promotes advancement and improvement in transportation through research, in an objective, collegiate, and multidisciplinary setting. The TRB enables information sharing about transportation practice, a forum for academic researchers and practitioners to promote technical excellence, and the opportunity to offer expert advice through academic publications on all sectors of transportation, including highways, aviation, and mass transit. The TRB is under the auspices of the National Academies of Sciences, Engineering, and Medicine, and inspires education and research to increase public understanding of all transportation matters, it is vastly supported by state transportation departments, public transit authorities, and federal agencies, including the US Department of Transportation.

The TRB engages transportation practitioners from both the public and private sectors who contribute to TRB's mission by participating on committees. The foundation of TRB is the plethora of committees, which are manned with transportation professionals including engineers, scientists, planners, and scholars, with appropriate education and experience regarding the transportation related committee topic. Committees recommend research, share information, compile reports, and sponsor special workshops, conferences, and webinars. The TRB provides a well-attended annual forum for transportation professionals to discuss important transportation issues; it includes over 200 well-respected committees, and includes numerous committees devoted to environmental issues.

The TRB environmental committees have conducted many studies on an array of topics of national significance, including energy consumption, environmental impacts, and sustainability in transportation. Studies are conducted, in most cases, with an eclectic mix of engineers, practitioners, consultants, and academic professors, with appropriate expertise. The TRB committees on the environment include, but are not limited to, standing committees on environmental analysis, noise and vibration, environmental impacts, sustainability, and resource conservation. These committees have been instrumental in sharing sustainability and environmental protection developments, projects, and programs from mass transit agencies around the country and around the world, leading to the growth and proliferation of environmental and sustainable initiatives within mass transit capital projects, and operational strategies to curb emissions. On TRB's website they list APTA and the Federal Transit Administration (FTA) as partners and collaborators.

THE FEDERAL TRANSIT ADMINISTRATION ENVIRONMENTAL MANAGEMENT SYSTEMS TRAINING PROGRAM

The FTA provides federal funding for public transit systems, and helps progress technological research. The FTA provides and helps develop technical guidance, publications, and training on the implementation and understanding of the National Environmental Policy Act (NEPA). The FTA provides guidance on many environmental issues related to air quality, climate adaptation, water quality, wetlands, threatened and endangered species, fish and wildlife, hazardous waste, brownfields, and coastal zones. The FTA's Office of Planning and Environment helps develop methods to incorporate environmental choices in programs and projects, and serves as an advocate for reducing, minimizing, or eliminating the adverse environmental impacts of transportation.

The FTA has recognized the value of transit agencies working under the framework of an Environmental Management System (EMS). An important FTA program in the past decade has been the training and encouragement of mass transit agencies in the preparation and institution of EMSs. In 2003, the FTA began its EMS assistance program to help transit agencies develop and potentially implement an EMS. Agencies in the program receive training, technical support visits, and consultation. Using the International Organization for Standardization (ISO) 14001 EMS standard as a basis, agencies learn the potential benefits of an EMS, which include reducing environmental impacts, complying with regulations, and the ability to foster greater efficiency.

The FTA has completed 4 rounds of training with 36 transit agencies participating in the program, as of 2016. Participating transit agencies report many environmental benefits as the outcome of training, documented in the final report for each of the training rounds. Mass transit agencies have numerous potential environmental impacts, and many transit agencies involved with the training program have reported various reductions in a wide range of environmental concerns, including reduction in waste and air emissions. Other agencies have reported proactive or positive improvement in employee awareness of potential environmental impacts, improved communications, increased fuel economy, and cost savings.

The sharing of the accomplishments with the entire industry through FTA's EMS program has helped provide guidance for other agencies to copy, regarding environmental sustainability. The FTA has continued with the EMS program for over 13 years. All mass transit agencies are invited to participate in FTA programs, and partake in knowledge sharing conferences and seminars. The ISO 14001 EMS standard is the foundation of the training, with an option for certification left at the discretion of each transit agency. In 2014, New York City's Columbia University graduate students performed an evaluation of the effectiveness of the program, and recommended that the FTA continue with the training program as constituted.

Many transit agencies have enhanced their obligation to environmental compliance with an EMS, and some have fully committed to the ISO 14001 EMS standard to operate. As of 2016, 15 US transit agencies have received certification. One of the outcomes of the EMS training programs is that most agencies have continued to provide an annual sustainability report, which fully discloses all environmental sustainability initiatives, and includes the reporting of environmental metrics.

Sustainability Reporting

Many transit agencies report their electricity usage and fuel consumption in annual sustainability reports, and use developed metrics to help assess their own performance. Air pollution, greenhouse gases, fuel usage, electricity, water usage, and hazardous waste are among the metrics reported in sustainability reports. Numerous transit agencies have seen decreases in this area, with many practical strategies to help accomplish the reduction. The reduction of electricity or fuel usage due to energy efficient or sustainable practices can be seen quite clearly if a downward trend is depicted annually. Large scale initiatives through capital construction projects or the procuring of more energy efficient vehicles can also help with the reduction of electricity in train services and fuel usage in buses.

SUSTAINABLE RETURN ON INVESTMENT

In the mass transit industry, there are numerous economic, social, and environmental benefits to society that are above and beyond the direct return on investment. In many cases, there may not be a traditional monetary benefit, but there is value to society in reducing pollution and lessening greenhouse gas release. Sustainability metrics have been developed by many mass transit agencies to evaluate the effectiveness of their environmental initiatives. Sustainable Return on Investment (SROI) is a way to assess the benefits of sustainability projects or programs using these metrics by assigning a monetary value to them.

The difference between SROI and conventional Return on Investment (ROI) calculations is the inclusion of social, environmental, and economic attributes of the sustainability program or project that is evaluated. In other words, SROI accounts for both the direct cash benefits of a project over its lifetime, but also its social and environmental benefits. Public transportation proposed projects should be evaluated for overall sustainability return, to make the business case for future funding approval. The SROI helps depict the full value of a capital project. In 2016, Columbia University graduate students created a potential SROI model specifically for mass transit, and with further refinement its use may allow agencies to bolster the case for increased sustainability initiatives being included in capital projects or agency programs.

ENVIRONMENTAL ENGINEERING

The person to identify potential environmental impacts and provide mitigation measures to protect the environment on an engineering design and construction project will be an environmental engineer. The discipline of environmental engineering, now a full discipline of the engineering field, started as a subdiscipline to civil engineering. A valuable environmental engineer must be knowledgeable about many kinds of topics, from the science of clean air and water, to the psychology of environmental planning; an environmental engineer, whose job it is to review the environmental impacts on both the natural and built environment, has a role unlike any other in the engineering field.

An environmental engineer working in the design and construction arena must have complete knowledge of all aspects of a design and construction project to evaluate the potential environmental impacts, and knowledge and experience is key to the growth of an environmental engineer. Most mass transit construction projects have potential environmental issues in both the construction phase and in the operating phase after rehabilitation, reconstruction, or an expansion project. Large mass transit capital projects, such as a newly installed transit system, in most cases require the preparation of an Environmental Impact Statement or EIS, with full participation of an environmental engineer.

An EIS spells out the environmental mitigation measures for the identified significant environmental impacts of a project, for the purposes of reducing, minimizing, or eliminating environmental impacts to the air, water, and soil. Mass transit operations, maintenance, and rehabilitation have the potential to produce environmental impacts on the natural and built environments. An environmental engineer throughout his or her career must act like a sponge, by absorbing as much information as possible through nonstop learning experiences, and must continue to apply what they have learned by offering solutions to help reduce, minimize, or eliminate environmental impacts to prevent pollution, and avoid environmental damage.

Environmental regulations have been established for many years, and have continued up to this point (2017) to get stricter for the benefit of the environment. While environmental regulations seek to reduce impacts on the environment, threshold regulatory levels represent levels that were negotiated in the legislative process, and are not necessarily harmless for the environment. Additionally, there are always those who would prefer to roll back existing regulations to support individual agendas.

Environmental management systems, led by sustainability professionals working as a team, that promise to go beyond compliance, help achieve continuous improvement in environmental performance. It is incumbent on dedicated environmental engineers to look beyond simply complying with regulations, and continue to go further. In essence, if some entity were to reduce or eliminate environmental regulations, the reality is that environmental sustainability professionals and those with an understanding of the effects of air pollution and climate science, should not allow anything to deter them from proposing and doing what is right for the people and the planet.

THE SUSTAINABILITY PROFESSIONAL

A sustainability professional can have just about any educational background. Almost all technical or science based educational schooling can lead to a career in sustainability including, but not limited to, engineering, architecture, environmental science, urban planning, computer science, psychology, biology, and many more. Majors in business, economics, marketing, law, statistics, etc., can also lead to a role in sustainability, as there are many types of individuals with various educational majors with a role in the sustainability field. There are sustainability components in every sector or industry. What is required of the sustainability professional is a passion about a healthy planet, and learning as much as possible about environmental protection and sustainability.

Sustainability responsibilities can be placed under the authority of various disciplines. In mass transit agencies, sustainability authority or responsibility can reside under an engineer or architect, chief planner, safety department, environmental lawyer, or various maintenance or facility superintendents. In many cases, sustainability initiatives can be under the direction of an agency's energy management department. Since initiatives can be focused on energy, water, waste, materials, etc., responsibility can be spread around a transit agency. Sustainability challenges most often are solved by a team approach, and require participation from all parts of an organization, department, or division of a mass transit agency. This means that sustainability professionals could include anyone who works for a transit agency in almost any capacity. This is one of the many reasons that make mass transit continuously sustainable.

MASS TRANSIT: A SUSTAINABILITY SOLUTION

Mass transit agencies have taken on the operational, design, and construction challenges necessary to help fight climate change, by employing numerous sustainable initiatives. There is generally less pollution in cities or regions which have reliable, comfortable, and rapid mass transportation. The foundation principle of sustainability is to not compromise the needs of future generations with the needs of the present. Mass transit is inherently and continuously sustainable in its practice, and has great opportunities to become more sustainable in its operation. The implementation of mass transit in cities helps it to grow, and makes cities more sustainable every time a network expands, or rehabilitates services to be more reliable, convenient, and safe.

Mass transit and energy are intricately related and entangled, and when transit agencies save energy it contributes heavily to a healthier planet. Energy is a vital requirement for the mass transit industry, and of the major aspects of mass transit the use of energy is the aspect with the most potential to adversely impact the environment. Energy is tending toward more renewable energy, although it is still fossil fuel combustion that dominates, releasing pollution and greenhouse gases. Two thirds of electricity is still generated by coal or natural gas combustion; however, hydroelectric, wind, and solar power are making gains, in part due to stricter regulations and guidance including the EPA's Clean Power Plan. Transit agencies should not need regulations to continue to rely on renewable energy, and many transit agencies have built on-site generation such as solar and wind.

The dominant sustainability initiatives put forth in train operations are mostly toward the reduction of electricity. Regenerative braking, coupled with energy storage, provides the greatest potential for noteworthy energy efficiencies. Energy storage systems are destined to be a big part of future sustainability initiatives. In addition to providing energy for train acceleration, energy systems are connecting with the power grid to help make up for voltage loss. There is an infinite number of ways to take advantage of a charged wayside energy storage system. Trains and buses, who have traditionally worked together in planning by connecting train routes and bus lines, can also work together to be more sustainable. As an example, a train wayside energy storage system could be configured to help supply energy for the electric bus vehicle charger for an all-electric bus line.

The public bus transportation industry has several historic sustainability initiatives of note, including numerous types of environmentally friendly buses that reduce diesel consumption considerably. The future should see the growth and proliferation of an all-electric public bus fleet. The continuous improvement of battery technologies will help evolve on-board storage systems in electric or hybrid buses, and light rail or streetcar trains, and wayside energy storage systems will also help. The evolution of the hybrid or all-electric bus battery has played a key role in the past, and the present, and will undoubtedly play a huge future role in the development of the all-electric bus fleet. State-of-the-art bus depots include sustainable initiatives that will save energy, and water, and help prevent pollution.

Mass transit's infrastructure, facilities, and vehicles, have potential significant environmental impacts to manage, including air pollution, greenhouse gas release from energy use, water discharges, hazardous waste removal, contaminated soil, and noise and vibrations. Environmental mitigation measures, such as those that reduce the noise and vibration of track, lead to smoother operation, less friction, a reduced amount of unwanted sound, and help save energy.

Effective and appropriate handling of fuel to prevent waste saves energy use in many ways. Fuel delivery, storage, and dispensing in proper ways helps reduce wasted fuel. Preventing spills, which in addition to losing the usage of the fuel cause valuable energy to be wasted for cleanup activities is important. Avoiding environmental impacts not only prevents violations or fines, but also saves money and energy in the long run. Preventing the spillage of fuel is important both financially and environmentally.

During construction projects, potential environmental impacts on both the natural and built environments, stemming from mass transit rehabilitation projects, must be mitigated to ensure the environment is well protected, while the project's goals are accomplished. A most sustainable construction practice in mass transit infrastructure projects is the recycling of construction and demolition debris. Recycling helps saves landfill space, and can benefit the environment by saving natural resources. Agencies with an Environmental Management System, or EMS, are always seeking new ways to add sustainable elements into operations, maintenance, and design and construction projects.

An EMS is a structured framework under which an entity can best manage environmental impacts. Numerous mass transit agencies have incorporated a structured environmental management system to ensure compliance and help encourage sustainability initiatives. A commitment to the environment is stated when an entity pledges to work under the framework of an EMS. There are numerous environmental regulations to help guide transit agencies toward environmental compliance; however, working under an EMS encourages going beyond environmental compliance. Ultimately, an EMS is a management tool to help measure environmental performance to ensure environmental compliance and authenticate continuous sustainability improvement.

In today's world, the reducing, minimizing or preventing of environmental impacts is more critical than ever. Much environmental damage has already occurred during the last 100 years of rapid development, leaving today's generation in charge of both cleaning up what past generations have inflicted upon the planet, and ensuring a healthy and prosperous future for generations to come. The mass transit industry has been exemplary in fighting for future generations through environmental protection and sustainability. The history, evolution, and progress of mass transit demonstrates continuous improvement through knowledge sharing and advanced technologies. Environmental consciousness has emerged as a major component of sustainable mass transit.

FURTHER READING

epa.gov/earthday.

http://blogs.nicholas.duke.edu/thegreengrok/co2equivalents/.

www.apta.com.

www.apta.com/resources/hottopics/sustainability/Pages/default.aspx.

www.trb.org.

www.transit.dot.gov.

www.transit.dot.gov/regulations-and-guidance/environmental-programs/environmental-management-systems-training-and-assistance.

http://sustainability.ei.columbia.edu/files/2014/05/FTA-EMS-Training-Program-Analysis-FINAL.pdf.

http://sustainability.ei.columbia.edu/files/2017/01/LA-Metro-SROI-Final-Capstone-Report-1.pdf.

www.iso.org.

Case Studies of Mass Transit Agencies

Mass transit systems in the United States including large, mid-sized, or relatively small and unknown public transportation agencies have established sustainability as a core value or pillar of the agency. The case studies are put together to show the most recent sustainability initiatives of some standout mass transit agencies. Most of the sustainability initiatives that will be focused upon were implemented or completed within the past decade. Major US mass transit in Los Angeles, San Francisco, Portland, Chicago, Philadelphia, Boston, New York, and many others, including international transit agencies, has provided strong leadership in the application of sustainability projects.

LOS ANGELES COUNTY METROPOLITAN TRANSIT AUTHORITY, LOS ANGELES, CALIFORNIA

Los Angeles County Metropolitan Transportation Authority (LA Metro) is Los Angeles County's funder, planner, constructor, and operator of transportation systems. Numerous sustainable and environmental projects have been initiated since 2008. The agency created sustainability guidelines to encourage the integration of sustainability into all its programs, projects, planning, design, construction, operations, and maintenance activities, focusing on recycling, water quality, clean fuel, green products, and greenhouse gas emissions reduction strategies. The LA Metro Sustainability Implementation Plan adopted in June 2008, includes an ongoing requirement to report LA Metro's environmental sustainability performance. The data is used to help measure continuous improvement.

Each year the Energy and Resource Report analyzes Metro's sustainability and environmental performance, and the economic cost of its operational activities. The annual report compares that year's environmental performance to the previous year's environmental performance, comparing trends and increases or decreases in environmental metrics. A trend analysis is used to study the effectiveness of the global program and individual metrics. Overall, from 2012 to 2015 the greenhouse gas emission reduction was 3.61%, depicting a downward trend and continuous improvement. Water use in 2013 peaked at 415,000,000 gal, and reduced to 265,000,000 gal in 2015, almost a 36% reduction.

In the past decade, LA Metro has invested in numerous renewable energy projects since 2005, and as of 2016 the installed capacity of solar is 2.4 MW, with the largest being the agency's Services Support Center. Los Angeles Metro supports a training course on photovoltaic (PV) preventative maintenance, including theory and safety, developed specifically for crews and electricians who maintain the PV. Los Angeles Metro has adopted the ISO 14001 Environmental Management System as a framework to help manage impacts on the environment. The Red and Purple Line Rail Maintenance Shop received certification for its EMS in 2011, and LA Metro has an organizational goal to achieve certification for all its maintenance shops.

The Red and Purple Line is the largest consumer of rail propulsion, and recent overall reduction is being significantly attributed to the installation of the Wayside Energy Storage Substation energy recovery system on the Red Line. Five buildings have achieved Leadership in Energy and Environmental Design (LEED) certification, including several maintenance buildings, with a commitment that all new buildings 10,000 ft^2 or larger attain LEED Silver certification or better. Los Angeles Metro's Division 13 Bus Maintenance and Operations facility is a Gold certified LEED building. The building includes solar panels, and a rainwater collection system with an underground tank of 275,000 gal. The building also includes a green roof.

References and more information about LA Metro:

https://www.metro.net/

https://www.metro.net/projects/sustainability/

http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2015.pdf

BAY AREA RAPID TRANSIT, SAN FRANCISCO

San Francisco's BART or Bay Area Rapid Transit's Fleet of the Future includes extremely energy efficient train cars with numerous sustainability elements. Sustainability is an intrinsic value for Bay Area residents, and BART is a major part of fulfilling this ideology. The new trains include self-adjusting Light Emitting Diode (LED) interior lighting which automatically dim in outside environments, and LED exterior lighting including headlights. Energy reducing features include "microplug" doors which provide a tighter seal to aid climate control features, and help reduce wasted energy lost through tiny openings. The microplug doors also minimize exterior track noise from penetrating into the train car for a quieter passenger experience. The tops of the cars reflect more sunlight, which helps reduce heat loads on each train.

The material used for the exterior of the train car is a lighter weight aluminum material, saving energy. The aluminum will be able to be recycled when the useful life of the train car is over. Each BART Fleet of the Future vehicle is equipped with regenerative braking. BART is interested in "direct procurement of renewable energy" for all their future energy contracts. Included in BART's website is a carbon calculator to estimate how much carbon dioxide is being saved when taking public transportation. The average daily commuter using BART saves over 300 gal of gas, and 6277 pounds of CO_2 in a year, as per BART's carbon calculator.

References and more information about BART:

http://www.bart.gov/

http://www.bart.gov/news/articles/2016/news20160824

SANTA CLARA VALLEY TRANSPORTATION AUTHORITY, NORTHERN CALIFORNIA

The Santa Clara Valley Transportation Authority (VTA) provides bus and light rail services to numerous counties in Northern California. The Santa Clara VTA includes 3 light rail lines, with 62 stations, and 70 bus routes serving numerous counties including San Jose and Palo Alto. Through its sustainability program, VTA is committed to a greener Santa Clara Valley, with an emphasis on the reduction of greenhouse gases, the prevention of pollution, and the use of renewable energy.

Since December 2011, VTA facilities have included solar installations at three Bus Maintenance Shops, the Cerone, Chaboya, and North Divisions, with excess electricity generated fed back into the power grid. More than half the electricity consumed at all three bus facilities is provided by solar energy. At the River Oaks campus, four electric bicycles are available for use by employees, with the battery chargers connected to small solar panels. At numerous light rail stations, VTA has replaced fluorescent light fixtures with LED fixtures.

Mandatory water reductions placed a restriction on irrigating outdoor landscapes with potable water, and in response VTA implemented water conservation strategies, including several landscapes that were replaced with drought tolerant species. Trees that were affected by drought conditions were replaced with native trees, and cuttings from the trees were reused on-site as mulch. In addition, the bus wash at Chaboya Division uses recycled water to reduce potable water consumption.

The design of VTA's BART Silicon Valley Berryessa Extension project includes sustainable features such as LED lights, skylights, variable speed escalators, and solar panels on parking structures. The design of the new tracks includes shredded tires installed underneath the track bed to reduce vibration. Sustainable design features for the Santa Clara Alum Rock Bus Rapid Transit (BRT) project include the use of cold in-place recycling, which is a method of recycling the existing asphalt for pavement rehabilitation. The recycling on-site eliminates the transportation of old asphalt to a recycling plant and back again, thus eliminating transportation related emissions.

References and more information about VTA:

http://www.vta.org/

http://www.vta.org/projects-and-programs/Programs/VTA-Helps-Keep-the-Valley-Green

FOOTHILL TRANSIT, SOUTHERN CALIFORNIA

Foothill Transit operates 39 bus lines, serving over 14,000,000 passengers in Southern California's San Gabriel and Pomona Valleys, from Downtown Los Angeles to San Bernardino County, including an express bus to Pasadena, California. Foothill Transit has been a leader in embracing an Environmental Management System approach. Foothill Transit is the first mass transit agency in the United States to use a fast-charging electric bus, and operate an exclusive all-electric bus line, Line 291. The electric buses are lightweight 35-ft transit buses, with a range of 35 miles on a single charge, and the ability to recharge in 10 minutes. Foothill Transit, which has been ISO 14001 certified since 2013, has an objective to replace all fossil fuel burning buses with electric buses, and a target of a bus fleet that is 100% all-electric by the year 2030.

References and more information about Foothill Transit:

http://foothilltransit.org

http://foothilltransit.org/news/sustainability/

http://foothilltransit.org/foothill-transit-announces-all-electric-bus-fleet-by-2030/

BIG BLUE BUS IN SANTA MONICA, CALIFORNIA

In the early part of the 20th century, several Jitney lines began to proliferate between downtown Los Angeles and adjacent cities, which soon converted into full-fledged bus networks, and in 1928 Santa Monica began a bus service. Big Blue Bus in Santa Monica, California maintains a complete fleet of renewable natural gas buses. Renewable natural gas is nonfracked methane extracted from waste landfills. Big Blue Bus is also incorporating NO_x reducing emission engines into its fleet. Big Blue Bus's maintenance facility includes: solar panels; reflective "cool roofs"; recycled building materials; recycling tires for street pavements; and recycling 85% of bus wash water.

References and more information about Big Blue Bus:

https://bigbluebus.com/

http://www.bigbluebus.com/About-BBB/About-BBB.aspx

TRI MET, PORTLAND OREGON

Tri Met provides bus, light rail, and commuter rail transit services in the Portland, Oregon, metro area. In November 2015, four new "all-electric hybrids" were put into service. These types of hybrids can run exclusively on battery power for a short period, for up to 2 miles. When the battery runs low it is then recharged by diesel engine and regenerative braking. When these vehicles go slower than 8 mph toward a complete stop, the engine shuts off and uses the battery exclusively. Older hybrid diesel engines do not shut off, no matter how slow or when idling.

Tri Met light rail, street car, and bus will be utilizing the Tilikum Crossing, which is the first bridge in the US exclusive for transit, pedestrians, and bicyclists. The new Tri Met Portland – Milwaukie light rail transit line includes an energy storage unit that receives energy from the regenerative braking of the train. The energy savings are then used for voltage stabilization during peak demand times, to avoid system voltage dropping below critical levels that could result in instances of under voltage tripping in vehicles, potentially disrupting service. The energy storage unit can potentially save up to 500,000 kWh/year, saving cost and carbon dioxide emissions.

References and more information about Tri Met:

https://trimet.org/

http://www.metro-magazine.com/rail/news/290538/siemens-installing-regenerative-battery-on-trimet-train

SOUND TRANSIT, SEATTLE

Sound Transit, Seattle has a most comprehensive organization wide environmental management system, and has formally integrated sustainability into all operations, design, and construction. Sustainability is a central part of the decision-making processes in all aspects of agency business, with a focus on cost effectiveness. One of the cornerstones of Sound Transit is educating the staff about the sustainability plan, with a goal of reaching all employees. From an ecological point of view, Sound Transit ensures environmental protection and includes mitigation measures as part of its expansion projects.

Sound Transit mitigates wetland impacts during construction projects by creating or restoring three acres of wetlands for every acre damaged or affected, and has received the Washington State Department of Ecology's highest award for mitigation by reestablishing 380 acres of vacant land into a salt marsh and salmon habitat, as part of a commuter rail rehabilitation. To reduce pollution, Sound Transit installed power units that use electricity to heat and power diesel locomotives during layover, and implemented a pilot test energy storage system on-board light rail vehicles that enables the capture and reuse of regenerative braking energy.

References and more information about Sound Transit:

http://www.soundtransit.org/

http://www.soundtransit.org/sites/default/files/documents/pdf/about/environment/20150122_sustainabilityplan3yearprogressrpt.pdf

SUN TRAN, TUCSON ARIZONA

Sun Tran in Tucson Arizona originated as the Tucson Rapid Transit Company (TRT). In 1905 it purchased the city's existing horse-drawn streetcar transit system. Within 1 year, it replaced the horse drawn carriage with an electric streetcar system. Twenty years later, bus service was started with two public bus routes. Historically, concerns about air quality led Sun Tran to begin testing alternative fuels. In 1987, Sun Tran converted a diesel bus to use both compressed natural gas (CNG) and diesel fuel, becoming one of the first such buses in the country. Today all 252 buses of Sun Tran's fleet are hybrids, CNG or biodiesel. Recently, Sun Tran introduced the Sun Link streetcar to the public, one of the largest transportation projects in Tucson's history.

References and more information about Sun Tran:

http://suntran.com

http://suntran.com/about_environment.php

UTAH TRANSIT AUTHORITY

Utah Transit Authority (UTA) provides a public mass transportation system for a 1400-square mile service area, serving 75 cities, including Salt Lake

City, and over 2,250,000 residents, representing 75% of the state's population. UTA operates services including BRT, light rail, and commuter rail services. As an initial participant of the FTA EMS Training program in 2003, UTA was the first agency in the program to achieve certification in December 2005.

Under their EMS, significant environmental aspects are deemed "significant" until objective and targets are met, then they are marked "controlled". UTA is committed to the reuse, reduction, and recycling of waste and scrap, and has kept track of and reported the amount of recyclable materials, including oil, antifreeze, metals, and electronic waste. UTA has partnered with GreenBike, a bike sharing program, to include docking stations at 20 stations. Bikes can be used from one station and dropped off at any other station in the system, mostly in the downtown area.

References and more information about UTA:

http://www.rideuta.com

http://www.rideuta.com/-/media/Files/Annual-Reports/2014Sustainbility Report.ashx?la = en

CHAMPAGNE URBANA MASS TRANSIT DISTRICT

Champaign – Urbana, home to the University of Illinois at Urbana–Champaign, is a relatively small metropolitan area approximately 150 miles south of Chicago, in East Central Illinois. Champaign – Urbana Mass Transit District (MTD) provides mostly bus services, with a little over 100 buses, and has been involved with the community with recycling programs and sustainability partnerships. Mass Transit District's bus fleet is over 50% hybrid, all buses use a percentage of soybean biodiesel, and all vehicles are equipped with easy-to-use bike racks. Mass Transit District's Bus Maintenance facility includes a solar panel on the roof, with real time information provided on MTD's website. The solar energy accounts for approximately 25% of the maintenance facilities energy consumption. Mass Transit District has embraced an EMS, and in 2010 bus simulators were added to help train bus drivers, which helps conserve fuel during training exercises.

References and more information about Champaign – Urbana MTD:

https://www.cumtd.com

https://www.cumtd.com/go-green/policy/

CHICAGO TRANSIT AUTHORITY

The Chicago Transit Authority (CTA) takes part in the overall City of Chicago commitment to cleaner air, and has realized large emissions reductions from both rail and bus operations. All new rail cars, known as the 5000 Series, are equipped with regenerative braking. The CTA maintains a fleet of more than 1800 buses, of which approximately 15% are hybrid buses. The

CTA converted to ultra-low sulfur diesel several years before the US Environmental Protection Agency directed its use in 2006. All buses include a front mounted bicycle rack. Bikes are permitted on trains in off-peak hours, and bike parking is available at most stations, with many including shelter for weather protection.

In 2007, the CTA headquarters building was awarded LEED Gold certification, and in 2012 the building was updated to Platinum. The building includes a green roof, and received the Energy Star label from the EPA. The CTA also has an additional green roof on the Clifton Substation on the Red Line. One of the Red Line stations includes a solar panel to power the fare equipment and station lighting. The CTA has installed solar panel powered lubrication houses to reduce noise and vibration along the track right of way.

References and more information about CTA:

http://www.transitchicago.com

http://www.transitchicago.com/goinggreen/lowemissions.aspx

THE KANSAS CITY STREETCAR, KANSAS CITY MISSOURI

The Kansas City Streetcar runs on the existing street corridor, sharing the road with cars and buses. The Kanas City Streetcar runs through the downtown area, and is a completely free streetcar system. It was entirely envisioned to help stimulate growth in downtown Kansas City. It has been extremely successful in stimulating over 1,000,000,000 dollars in economic development in the streetcar district, and plans for expansion are underway. The ridership was greater than 65,000 per day in the initial phase of operation. While people ride free, a 1% sales tax is assessed within the district around the line, and property owners are also paying a small tax.

The project was designed and constructed to use recycled material and minimize waste generated by the project. All 845 tons of steel used for streetcar tracks were made with recycled steel, and 90% of the construction waste at the Singleton Yard was diverted from the landfill. Concrete demolished during construction was crushed and reused as aggregate in the concrete mix for the project construction. Green infrastructure implemented has led to storm water runoff levels that are below prestreetcar implementation. The Kansas City Streetcar earned the Envision Platinum award for sustainable infrastructure from the Institute for Sustainable Infrastructure (ISI), and is the first transit project to receive an ISI Envision sustainable infrastructure rating.

References and more information about Kansas City Streetcar:

http://kcstreetcar.org/

http://kcmo.gov/streetcar/

http://www.hdrinc.com/about-hdr/news-and-events/news-releases/2016-09-07-kansas-city-streetcar-project-receives-envision-p

SOUTHEASTERN PENNSYLVANIA TRANSIT AUTHORITY, PHILADELPHIA

At the Southeastern Pennsylvania Transit Authority (SEPTA), sustainability is institutional, and is all about developing the "ongoing capacity to endure". SEPTA's approach to sustainability is geared toward the triple bottom line, of economic, social, and environmental sustainability opportunities, and is a signatory to American Public Transportation Association (APTA) Sustainability Commitment. SEPTA's historic Bus Loop at 33rd and Dauphin includes a green roof, and at several depots they are building detention basins which will capture rain water, and slowly allow infiltration back into the ground. As a demonstration of its new all-electric buses, SEPTA provided test rides and tours at the Democratic National Convention in Philadelphia in July 2016.

SEPTA installed a wayside energy storage system that captures regenerative braking produced energy, after the initial project was deemed a success, a second battery was installed at another substation, and there are plans for many more storage units to be installed at substations along the Market Line in the future. It has been reported the energy storage systems are reducing energy consumption by almost 10% per substation. In addition to storing energy to be used by oncoming trains, the storage unit is also connected to the grid to help keep the electricity grid in voltage equilibrium, to reduce transmission losses.

References and more information about SEPTA:

http://www.septa.org
http://www.septa.org/sustain/
http://www.septa.org/media/releases/2016/1-21-16.html

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY, BOSTON

Massachusetts Bay Transportation Authority (MBTA) is the fifth-largest transit system in the country, with almost 1,300,000 riders per day, and the MBTA's commitment to sustainability has yielded tremendous environmental benefits. The MBTA is a sustainability leader in the use of renewable energy, with on-site solar PV and wind turbines, and through purchasing a good portion (up to 20%) of the electricity required from renewable energy sources. The MBTA's comprehensive sustainability program seeks to reduce energy usage and greenhouse gas emissions, minimize waste, and conserve water.

The MBTA is vulnerable to increased extreme weather events, including flooding, as much of the MBTA network is built on low-lying areas and near local water bodies. Boston, a northeastern coastal city vulnerable to a rising sea level, was built on "landfill", and is prone to floods during significant rain events. The MBTA recognizes the importance of protecting transit assets, and is addressing the resilience of its infrastructure by developing a comprehensive analysis of all its assets. This Asset Management Program identifies those assets that are threatened by severe weather events, and all capital projects must include a resiliency analysis.

The MBTA put into service new electric − hybrid buses, which have the ability, when the system permits, to be driven on battery power. The MBTA utilizes regenerative braking that allows the trains to store regen into an energy storage unit, and reuse it for an upcoming train. In June 2015, the MBTA installed a wayside energy storage battery on the Blue Line adjacent to the Airport Station. The initial results include a savings of an estimated $20,000 per year. Regenerative braking also helps increase the useful life of the mechanical brakes, saving maintenance costs. The MBTA is looking for further expansion of their wayside energy storage systems to other lines.

In 2016, the newly built 8400 ft^2 Hingham Intermodal Center is the new terminal for MBTA ferries that run from Hingham to downtown Boston, and was designed to attain LEED Gold certification. The facility includes a green roof, low-flow plumbing, LED fixtures, natural lighting, and a geothermal heat exchange. The MBTA is saving energy and money on projects initiated since 2010, with projects including energy efficient lighting, switch heaters, and third rail heaters, as well as many other improvements.

References and more information about MBTA:

http://www.mbta.com

http://www.mbta.com/about_the_mbta/environment/

METROPOLITAN TRANSPORTATION AUTHORITY NEW YORK CITY TRANSIT, NEW YORK CITY

Metropolitan Transportation Authority—New York City Transit (MTA NYCT), in the last decade, incorporated PV or solar panels onto above ground elevated station canopies. The design and reconstruction of elevated infrastructure projects, specifically the Stillwell Terminal in Brooklyn, and the 74th Street/Roosevelt Avenue Complex in Queens, all included solar panels integrated into platform canopies. Solar panel equipped lubrication houses are also located wayside on the Culver Line, and on other curved track areas throughout the system. The entire NYCT signal light system of approximately 65,000 incandescent signal lights was converted to LED signal lights by 2005.

The Corona Subway Maintenance Shop became the first LEED certified public transportation facility in 2007. The building incorporated several energy-efficient and environmental features, including a white roof, heat recovery units, an array of skylights, solar panels, and natural ventilation. A rooftop rain water collection system saves water, as rain water is stored in a buried 60,000 gal tank for use in the adjacent subway car washer, which also includes a carwash reclamation system. The NYCT facilities include an additional three bus depots which also include rooftop rain water collection for bus washing. The E180th Street Yard Signal Crew Quarter includes MTA NYCT's first green roof, installed in 2009.

The new Mother Clara Hale Bus Depot, which opened in November of 2014, attained Gold level LEED certification in May 2015. This state-of-the-art facility includes a green roof, solar heat wall, heat recovery units, rain water collection, a bus wash water reclamation system, water efficient fixtures, planting of new trees, and was built with recycled and regional materials. The new depot was the topic of a community design charrette, where concerned citizens could provide feedback, suggest improvements, and be an integral part of the design of the project. The former depot on the same site was demolished, and the recycling rate of concrete, brick, and steel reached over 99%. Old concrete was crushed off-site and returned as backfill.

The tracking of Construction and Demolition Debris Recycling from all MTA NYCT construction projects, under the auspices of their Capital Program Management (CPM) Department, since 2009 shows that construction projects diverted over 90% of construction and demolition debris from landfills through recycling and beneficial reuse efforts. The MTA New York City Transit's Department of CPM, has organized its efforts under the structure of ISO 14001 certified EMS since 1999. CPM is the design and construction department of New York City Transit. The MTA NYCT became the first public transit agency in North America to have some part of its organization ISO 14001 certified, and paved the way for more agencies to follow suit.

References and more information about MTA NYCT:
www.mta.info

INTERNATIONAL MASS TRANSPORT AGENCIES AND ACCOMPLISHMENTS

Metrolinx, Toronto, Canada

Metrolinx was created in 2006 as an agency for all modes of transportation in the Greater Toronto and Hamilton Area (GTHA). Sustainability is a major part of operation, design, and construction. Metrolinx has established a "Green Team" of over 200 transportation and sustainability professionals to lead the effort. Sustainability initiatives include LED parking lot lighting at 23 transit stations, 4 solar panel installations at 3 stations and 1 bus maintenance shop, and 1 on-site wind turbine. Metrolinx began a major construction sustainability program to move excess soil from one capital project's excavation to another project that requires fill material, which saves on the amount of backfill.

References and more information about Metrolinx:
http://www.metrolinx.com
http://www.metrolinx.com/en/aboutus/publications/Annual_Report_2014-2015_EN.pdf

Metrobus, Mexico City

Mexico City is in an unusual geographical landscape, as it sits in a high-altitude valley. Air pollution from vehicles, some very old without modern pollution control devices, release pollution that sits within the valley, and hovers above a very crowded city, creating health issues related to poor air quality. The mass transit of Mexico City includes the Metro System, Light Rail System (Tren Ligero), Electric Streetcars (Trolebús), and BRT (Metrobús), which have all helped to reduce pollution in Mexico City over the last decade. Metrobús, as of 2016, includes 6 BRT lines, with dedicated bus lanes, off-board fare collection, and dedicated stations specifically for BRT.

A 2012 study reported reductions in air pollution, greenhouse gas emissions, and fuel consumption, in addition to passenger travel time savings. Ridership increased due to many who switched from using an automobile. Fifteen percent of Metrobus users formerly traveled by car. A reliable global positioning system provides real time information to riders, to ascertain accurate departure and arrival times at bus stations. In 2012, Metrobus carried 187,000,000 passengers annually, and the fleet includes several hybrid diesel – electric buses.

References and more information about Metrobus:
http://mexicometro.org/
http://www.nyc.gov/html/ia/gprb/downloads/pdf/Mexico%20City_Metrobus.pdf

Metro de Santiago, Chile

The subway system in Santiago, Chile, is moving toward using dedicated renewable energy. Santiago's metro is the second-longest metro system in Latin America, and Metro de Santiago has two contracts, with both a solar energy provider, and a wind power company. The El Pelícano Solar Project, a 100-MW facility, is expected to supply 42% of Metro's annual energy needs, and the 185-MW San Juan wind project will supply 18% of its energy needs. The solar and wind farms will be dedicated to Metro de Santiago, and supply the metro for 15 years, starting in 2018.

References and more information about Metro de Santiago:
http://www.metroeasy.com/santiago-metro.html
http://ecowatch.com/2016/05/31/santiago-metro-system-solar-wind/

Guangzhou Metro, China

Guangzhou Metro is one of the busiest mass transit systems in the world, with 164 stations, over 250 km of tracks, and growing. The New Tram or Streetcar system in Guangzhou includes on-board supercapacitors, which have the capacity to charge extremely fast, and are automatically charged from a ground-level power supply at station stops. When the tram pulls into a station, it will take up to 30 seconds to charge the supercapacitor. The trams, when fully charged, can run up to 4 km. The trains also include regenerative braking to help supply the on-board energy system.

The Guangzhou BRT opened its BRT in 2010, and has a daily ridership exceeding 850,000 passengers, an average of 25,000 riders per hour in one direction, on a par with many heavy rail and most light rail lines worldwide. The Guangzhou BRT has won numerous sustainable awards, is considered the role model for all BRTs worldwide, and is inspiring additional BRT implementation in China. The Guangzhou BRT has spurred development along Zhongshan Avenue, since its inception, including additional public spaces included as part of the project.

The Guangzhou BRT system was planned, designed, and constructed together with bicycle parking, and bike sharing at stations. The bike sharing system is located at 113 stations, and includes 5000 bikes. Usually located within nearby commercial areas and residential areas, bike sharing was implemented to help augment BRT usage and ridership. Station architecture has contributed to positive visual impacts along the developed line, and it has been estimated that land values have increased positively along the BRT. Guangzhou is the second highest capacity BRT, with TransMilenio BRT in Bogota the highest.

References and more information about Guangzhou Metro:

http://www.gzbrt.org/

https://www.itdp.org/where-we-work/china/guangzhou/

http://greatergreaterwashington.org/post/23307/china-may-have-figured-out-wireless-trams/

http://www.railwaygazette.com/news/urban/single-view/view/guangzhou-supercapacitor-tram-unveiled.html

Nanjing Wireless Tram, China

Nanjing China's new light rail trams are mostly catenary-free trains powered by lithium – ion batteries, operating without overhead cables on 90% of two lines. As opposed to the Guangzhou Tram, which is charged from beneath the tram, the on-board batteries are charged via a pantograph at the tram stops. Each five-car tram is equipped with two battery systems. Nanjing's new Hexi and Qilin tram lines both feature steep sections, and elevated structure over a highway. During normal stops, the batteries will be given a quick charge to be able to continue the wireless route, until the next stop. At the end points charging stations can fully charge the battery.

References and more information about Nanjing Wireless Tram:

http://primove.bombardier.com/projects/asia-pacific/china-nanjing-primove-tram.html

THE SELECTED CASE STUDIES

These 20 case studies together are a shining example of the exemplary mass transit sustainability movement of the past 20 years. The countless sustainability initiatives that public mass transportation entities have included in projects, programs, and operations, save pollution, reduce greenhouse gas release, protect the environment, and enhance quality of life. In addition to implementing these sustainability projects, each agency has been willing to share information about these projects in various conferences, seminars, and websites, and in their own sustainability reporting. The information sharing of these projects, by the many dedicated and willing transportation professionals involved, has benefitted the knowledge base of an entire industry. The selected case studies are only a portion of the many projects that have been implemented nationally and internationally. There has been great momentum built over the last 20 years by the mass transit industry, led by transportation, engineering, and sustainability professionals.

Appendix A

Glossary of Terms

Air Pollution Air pollution is any solid particles, liquid droplets, or gases directly produced, such as the exhaust from a bus that compromises air quality with toxic or hazardous constituents. Air pollutants can be either primary or secondary. Primary pollutants are directly emitted into the air, and secondary ones are formed in the air when pollutants react with the air or with each other. Major air pollutants include: fine particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, ozone, methane, and volatile organic compounds. Severe air pollution may affect individuals who have difficulty in breathing, or with the onset of heart disease. Air pollution can worsen many health conditions, including respiratory infections, and stroke, and can contribute to lung cancer. Poor air quality can lead to increased spending on health care.

All-Electric Bus An all-electric bus is powered by an electric motor which is fed electricity from a rechargeable type battery or an energy storage system. The energy storage system most often will receive its initial charge by plugging into an electrical power source, and from regenerative braking energy derived when the brakes are applied. An all-electric bus fleet would most likely require the necessary charging stations to be built into both the bus way and within a bus depot or parking facility. The fast charging capabilities of the charging station will differ depending on the battery system in the vehicle. There are several small-scale examples of all-electric bus lines in the US.

Asbestos Asbestos is a naturally occurring mineral that has many material strengths, most particularly resistance to fire and heat. It is also a nonconductor, so it has been widely used in the electricity generating and distribution industry. It was also widely used in buildings for insulation, including roof materials, floor materials, and piping. Asbestos was commonly used, starting in the 19th century up until more recent times, when the health hazards of being exposed became widely known. It was discovered that inhalation of asbestos fibers could cause fatal illnesses, including lung cancer, mesothelioma, and asbestosis.

Asbestos Abatement Asbestos is a danger when materials containing asbestos become airborne due to deterioration, damage, or disturbance, and most often requires abatement. Abatement includes enclosure, encapsulation, and most commonly removal and disposal. Asbestos abatement is strictly regulated, and requires fully adopted safety procedures to ensure worker protection. Asbestos fibers are light and float in air. They are also so minute in size that they cannot be seen by the naked eye. Asbestos abatement most often consists of air-tight containment under negative pressure, to ensure no emissions leave the work zone, and workers must be appropriately protected during abatement, including by wearing respirators.

Asbestos Containing Material Asbestos containing material (ACM) was extensively utilized in materials for all kinds of insulation. Asbestos containing material was most notably used for piping, floor tiles, roof material, shingles, electrical circuit boards and wiring, gaskets, and seals, all heavily used in mass transit infrastructure. Over time, the condition of the material begins to deteriorate, especially in harsh physical environments. Material containing asbestos which becomes disturbed or damaged may cause the release of deadly fibers into the air, requiring the need for asbestos abatement, including encapsulation or complete removal.

Aspect and Impact Analysis An aspect and impact analysis is an internal self-evaluation process, and is at the forefront of an Environmental Management System (EMS). The analysis is necessary to bring to attention the most significant environmental aspects of an organization, facility, or department. An "environmental aspect" is an aspect of an activity that can lead to an environmental impact. An aspect and impact analysis leads an organization to discover the most significant environmental aspects of any proposed projects. In an EMS, determining an organization's significant environmental aspects helps decide where to utilize resources or develop programs for the benefit of the environment.

Batteries A battery is an energy storage device that relies on a chemical reaction to generate voltage. In a normal battery, once the charge is expended, the battery becomes unusable. Rechargeable batteries can be recharged and reused when provided with an electrical supply. Rechargeable batteries can reverse the chemical reaction to restore the charge. The battery cell contains three parts: a positive cathode, a negative anode, and the electrolyte. Over time and much use, a rechargeable battery will lose its effectiveness, and will require maintenance or recycling.

Beneficial Reuse of Soil The removal of soil from an excavation site can provide material for a wide variety of reuses, including backfill on-site. The potential reuse of the soil will be determined by the level of contamination in the soil, and the less contaminated the soil the greater the opportunities to beneficially reuse the soil on an outside project in a completely different manner. There are many possible reuses of soil, even if it is compromised by petroleum contamination, including use in an asphalt manufacturing facility or to a landfill to help separate layers to prevent other contamination from spreading.

Biodiesel Biodiesel is a renewable energy source which can be made from vegetable oils, recycled cooking oil, and animal fats. Biodiesel is a renewable and cleaner burning diesel fuel replacement. Biodiesel can be used directly in an existing diesel engine. Biodiesel is made from a chemical reaction called transesterification, where glycerin is removed from oil, yielding a long chain fatty acid or methyl ester. Blends of biodiesel and regular diesel have been used to reduce environmental impacts. Pure biodiesel is referred to as B100, and the most common used blend is a 20% blend referred to as B20.

Building Management Systems A Building Management System (BMS) is a computer-based system which can be installed to monitor and control a building's services, including heating, ventilation, air conditioning, and lighting. A BMS can help manage a building's system, including energy and water demand. This can help to monitor consumption to ensure energy or water is not being wasted. Other systems, which can be included in the BMS, include motion detectors, fire alarm systems, and elevators. Sensors, timers, and monitors can be utilized in many applications to maximize energy efficiency, and in many cases, be internet enabled.

Bus Depot A bus depot is the regular home to a fleet of buses. Bus depots include fueling infrastructure, bus washing apparatus, maintenance bays, parts and equipment storage, and most importantly, bus parking when a bus is not out on the road fulfilling its route. Bus depots normally include maintenance areas required for inspections, engine or transmission repair, tire replacement, oil and fluid changes, and areas for minor defect repairs or touch up painting. In many instances, office space, locker rooms, and other employee amenities are also included.

A bus depot typically includes light maintenance, and the work areas or bays are commonly equipped with tailpipe exhaust removal systems so bus maintainers are not exposed to harmful exhaust when inspecting or fixing bus engines which may have to be running to complete the inspection or maintenance task. The conventional bus depots, especially those in the inner city, include these prime functions, traditionally in one single large transportation building or facility.

Bus Rapid Transit Bus rapid transit (BRT) is a bus only based mass transit system that has a dedicated right-of-way, specific street grade, or highway infrastructure that only allows buses. This removes the major source of a bus delay, other traffic. The aim of Bus Rapid Transit (BRT) is to combine the volume and speed of train or light rail with the flexibility and lower cost of a bus system. A true Bus Rapid Transit system includes off-board paying, bus stations, or platforms, and, most importantly, signal prioritization to allow a bus to hold a green light, to allow the bus to move through city streets unimpeded.

Capacitors A capacitor is an energy storage system similar to a battery with some specific differences. The capacitor and the super capacitor use two conductive plates separated by a dielectric fluid or, in the case of a super capacitor, an electrolyte. When being charged, energy is stored in an electric field between the plates. Batteries and capacitors both are constructed to store and release energy, although in many cases a capacitor charges much more quickly than a battery.

Carbon Dioxide Carbon dioxide is a naturally occurring chemical compound, composed of a carbon atom and two oxygen atoms. Carbon dioxide (CO_2) is produced by all humans and animals when they exhale. Carbon dioxide is also produced during the decay of organic materials, and is produced by the combustion of fossil fuels such as coal, petroleum, and natural gas. Carbon dioxide is the main greenhouse gas which is leading to global warming, climate changes, and ocean acidification. It is a scientific certainty that increasing greenhouse gas concentrations in the atmosphere warm the planet, and that the increase in greenhouse gas over the last two centuries is related to human activities is the consensus scientific conclusion.

Compressed Natural Gas Bus Compressed natural gas has been used as a replacement for diesel fuel in buses. Numerous bus agencies added compressed natural gas (CNG) vehicles to their bus fleet, and some converted their entire fleet to CNG. Compared to diesel, natural gas burns much cleaner with lower emissions of particulate matter than other petroleum fuels. Although the compressed natural gas internal combustion engine produces air pollution and greenhouse gas, it is at a lower level than the comparable diesel engine exhaust. A major issue is that compressed natural gas fuel storage tanks require a special fueling infrastructure. Special care must be taken when fueling buses with natural gas under high pressure.

Clean Buses A Clean Bus is a term of endearment, usually associated with a replacement bus using alternative fuels, such as compressed natural gas or biodiesel, or a bus with hybrid technology, that has significantly reduced emissions compared to a diesel bus. None of these are really a "clean" bus, as there will be some level of emissions. However, an all-electric bus or fuel cell bus comes the closest to being a real clean bus, at least during operation, as there is no toxic exhaust from an electric or fuel cell bus.

Climate Adaptation Climate adaptation is the necessary changes to infrastructure planning, design, and construction that considers the scientifically explained phenomenon of global warming, and that the earth's climate has begun to change. Scientifically, when there are more greenhouse gases in the atmosphere, the planet warms, and this leads to the earth's temperature rising. Among many other consequences, there is more moisture in the atmosphere, polar ice caps melt, and sea levels begin to rise. Global warming leads to extreme precipitation, as warming causes more moisture in the air which leads to more voluminous precipitation events, requiring methods that take this into consideration when planning new or rehabilitating existing infrastructure.

Construction and Demolition Debris Construction and demolition debris is the end-product waste due to rehabilitation or reconstruction of an infrastructure project, and is normally made up of concrete, bricks, iron, steel, copper, cinder block, rock, stone, soil, dirt, asphalt, wood, sheetrock material, glass, plastics, and numerous other materials. If there is no comingled contamination, generally these materials that make up much of construction and demolition debris can be recycled or reused. Also, these waste materials can be recycled if they are not mixed with or do not contain any hazardous waste or asbestos. Construction and demolition debris should avoid being used as landfill if possible, and should be reused as practical.

Construction Staging Construction staging is the necessary space and land, usually adjacent to a construction project, which could include equipment storage, truck parking and loading, crane access, etc. During construction, staging areas are more often adjacent to or near the work area; however, some large projects which may require large staging areas, can be some distance away from the site, depending on many factors of the overall construction project. Some projects can maintain a remote staging area for equipment, excavation material, or parking.

Dedicated Renewable Energy A dedicated renewable energy generating power facility built specifically to provide electricity for mass transit systems, is what some cities are planning. Some transit agencies are working with electricity generating companies to have new renewable energy sources *dedicated* for a mass transit system. A new solar or wind farm, or a hydroelectric dam, could conceivably produce much of the electric power for a moderately-sized mass transit system such as light rail, or easily provide electric charging stations to power the batteries in the bus of an all-electric bus line or fleet.

Diesel Fuels Diesel fuel is refined from crude oil and works very well with heavy vehicles such as buses, trucks, ships, construction vehicles, agricultural equipment, military vehicles such as tanks, and train locomotives in railroad or commuter rail. When crude oil is processed, it is separated into several different kinds of fuels, including gasoline. Diesel fuel is heavier than gasoline and has a higher boiling point, and has an energy density higher than gasoline. Many facilities, including bus depots and train maintenance shops, use diesel fuel for emergency back-up generators.

Dust Control Dust control is necessary in construction, specifically those construction sites adjacent to residential neighborhoods. Any visible emission of dust can be a potential hazard, in addition, particles that are not visible can be much more problematic. Concrete demolition can cause tremendous amounts of dust particles. Containment with tarpaulins, both horizontal and vertical, rigid barriers, vacuum attached equipment, and the use of water mist to wet down the work area can minimize dust spreading off-site.

Electrical Generating Power Plants Electrical generating power plants produce electricity, and supply it the power grid. The US electrical generating power plants produce electricity generated from fossil fuels such as natural gas, coal, and petroleum. They also produce electricity from nuclear power plants and renewable energy sources such as hydropower, wind, biomass, and solar. Electricity from power plants is transmitted through a series of sub-stations and transmission lines, and provides electricity for residential and commercial establishments.

Electrification of Train Infrastructure The electrification of train infrastructure begins with electric power that is supplied to trains through a continuous conductor in two basic types: one type of train power is received by the train from a rail running alongside the track referred to as the third rail, and the other type is an overhead line or catenary wire suspended above the track. Trains get power from a third rail mounted at track level from contact with a train shoe, which sticks out beneath the train car and contacts the third rail. Pantographs on the roofs of the train contact the overhead or catenary contact wire to receive electricity.

Elevated Train Railway Elevated train railway is a transit infrastructure with the track bed elevated above the street level on a steel, concrete, or brick structure. In inner cities, the tracks of elevated railways can be adjacent to commercial establishments and residences, and can be seen and heard from street level. Above ground elevated structures allow street traffic to pass underneath, while trains pass overhead. Design of elevated trains must consider local climate, specifically hot and cold weather, to ensure allowance for the expansion and contraction of steel rails, in extreme outside temperatures both hot or cold.

EMS Fence Line The EMS fence line is the theoretical boundary around which an entity will apply its structured format to operate under an EMS. The EMS fence line can encompass a complete transit agency and the entire footprint of the operation. Alternately, the EMS fence line can be placed around a specific component of an organization, or a single facility or department. For example, a specific train line including its associated maintenance shop can be within an EMS fence line, with other lines and shops not included. A design and construction division or department can have its own EMS fence line, with complete operations not included in that fence line.

Energy Star Equipment Energy star equipment are products which have the energy star label. Energy star equipment runs with less power consumption, and devices with the Energy Star label commonly use 20–30% less energy than is required by basic standards. The Energy Star program was developed by the EPA and Department of Energy, initially as a labeling program to promote energy efficient products, starting with computers, and it then expanded to air conditioners and major appliances.

Environmental Impacts Environmental impacts are direct effects inflicted on either the natural or built environments, which can cause change leading to adverse consequences. Environmental impacts can affect the air, water, or soil with contaminated substances. Environmental impacts can affect people's health, and quality of life, such as noise or light pollution, or can affect the built environment with severe vibrations, or corrosives which can damage infrastructure. Environmental impacts can also affect fish and wildlife, and endangered species.

Environmental Management Systems An Environmental Management System or EMS, is a structured and specially organized framework under which an entity can manage environmental impacts, by ensuring compliance and helping to continually measure and improve environmental performance. At the foundation of an environmental management system is compliance with environmental laws and regulations. The utilization of an environmental management system provides a foundation and a framework for managing environmental impacts and ensures environmental compliance.

Environmental Policy An environmental policy is an organizational ideology that helps set the tone for an organization, facility, or department regarding environmental protection and sustainability, and the overall welfare of the planet. It is best when a policy is clearly articulated from the top, which helps it to permeate throughout an organization, facility, or department's structure. The environmental policy speaks for an entire organization, and pronounces what is of utmost importance to an organization, beyond financial and budgetary concerns. An Environmental Management System (EMS) begins with an environmental policy.

Envision Rating System The Envision rating system evaluates and assesses transformational and collaborative approaches of infrastructure projects, with an eye toward reaching a more sustainable future. It is designed for many types of infrastructure, and is very suitable and appropriate for application to a subway, light rail, elevated train line, or bus rapid transit infrastructure project. The Envision rating system is designed to be used during any phase of a project, including planning, conceptual engineering, scope development, design, and construction. It is a collaboration of the Institute for Sustainable Infrastructure (ISI), the America Society of Civil Engineers (ASCE), and the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design.

Fossil Fuels Fossil fuels are the organic matter of ancient decomposed flora and fauna found deep under layers of the earth. Crude oil, coal, and natural gas are the major fossil fuels found beneath the earth's surface. Petroleum products are refined from crude oil. Refineries distill crude oil into fuel used for transportation, including gasoline, diesel, and jet fuel or kerosene.

Fuel Cell Bus A fuel cell bus uses power from the electricity generated by the reaction of hydrogen and oxygen, which produces water vapor. A fuel cell combines hydrogen and the oxygen in air to create water, which produces a small amount of electricity which is captured in a circuit. A fuel cell bus uses a supply of hydrogen, and the generated electricity is used to power a bus engine motor or charge a battery. Utilizing the hydrogen as fuel emits zero emissions while operating the vehicle.

Geothermal Energy Geothermal energy is derived from the earth, specifically just below the surface. Direct geothermal energy is where hot springs or reservoirs, found near the earth's surface, provide natural hot water. Some hot springs can provide steam, which can be used to generate electricity in a power plant, and these geothermal power plants produce clean renewable energy, with very little carbon dioxide emissions. The shallow part beneath the earth surface is normally a constant temperature of 55°F or 12°C, and the constant temperature of the earth can be used as the basis for a geothermal heat pump. The shallow constant earth temperature can be used to lower the temperature of a liquid or gas above 55°F, or raise the temperature of a liquid that is below 55°F.

Green Energy Green energy is a nontechnical terminology generally referring to energy that is both renewable and clean burning. *Green energy* typically includes solar, wind, hydro, and tidal power, and the term can also be attached to geothermal energy. In some cases, biomass or biodiesel which is renewable and burns cleaner than diesel, can be referred to as green.

Greenhouse Gas Effect The greenhouse gas effect is essential to all life on earth. When the rays of the sun penetrate the atmosphere, and brighten the earth, they also heat the surface which absorbs the rays, and radiates heat back toward space in the form of heat waves. Greenhouse gases in the atmosphere absorb these waves, gaining heat themselves, and radiate more heat back toward earth. Too much greenhouse gas in the atmosphere creates too much heat, and continuously warms the air, land, and oceans. There is always a quantity of carbon dioxide in the atmosphere; however, an overabundance has resulted in an increase in greenhouse gases, which is leading toward global warming.

Green Infrastructure Green infrastructure, by using vegetation and soil, is an alternative method of managing storm water in an urban environment. Green infrastructure collects and treats storm water in place. Green infrastructure, which can include rain gardens, planters, bio-swales, trees, and green roofs, can also provide flood protection. On a larger scale, engineered wetlands are a form of green infrastructure. Green infrastructure reduces runoff by naturally absorbing rain water, and by filtering contamination before it can get into a water body.

Green Roofs Green roofs, or vegetative roofs, are a type of green infrastructure that is placed on the roof or canopy of a facility. Green roofs can help reduce energy costs by: providing an extra layer of insulation and weather protection to a rooftop, absorbing storm water, sequestering carbon dioxide, helping reduce the heat island effect in urban areas, attenuating noise from rooftop ventilation units and, most importantly, green roofs filter floating particles. Green roofs help filter particles that are in the air, specifically from the combustion of gasoline and diesel engines, that are typically floating in the atmosphere everywhere, especially in urban environments.

Hazardous Waste A hazardous waste is a distinct type of waste because it can be a threat to public health, and cannot be disposed in a typical or common fashion. Usually treatment, solidification, or stabilization is required. A waste is considered hazardous if it has one or more of the following qualities: ignitability, reactivity, corrosivity, or toxicity.

Heat Island Effect The heat island effect, or urban heat island effect, is the reality that cities are much warmer than their surrounding nonpaved areas. Cities, which have many black surfaces including, blacktop asphalt streets, absorb and retain more heat in the summertime, and this keeps a city generally much hotter in the summertime. Pavements and structures generally absorb sunlight, remain hotter, and radiate heat back into the atmosphere, where vegetative surfaces do not hold heat as long, and cool down quicker. Therefore, rural areas outside cities tend to be cooler, especially at nighttime.

Heat Recovery Units Heat recovery units are mechanical ventilation units which can provide the required hot air for heating in the cold weather season, and work as a fresh air heat exchanger, saving a lot of energy in the process. The heat recovery unit is placed on the roof of a facility, and in addition to providing heat, normally through the combustion of natural gas, when fresh cold air comes in through the intake of the unit, it also exchanges heat with outgoing already warmer air from the depot. The heated outgoing air passes heat to the colder incoming air without the two air streams mixing together, warming the cold air coming in, and requiring less energy to heat the building.

Hybrid Electric Buses Hybrid electric buses are vehicles that include a battery to supply electricity to an electric motor, in addition to having a diesel engine. The most dominant diesel hybrid bus is a parallel hybrid, where there is both a diesel engine and an electric motor that can both concurrently supply power through a normal transmission. A parallel hybrid bus can run on the battery-supplied electric motor, or on a blend of battery power and diesel engine, or the bus may run on the diesel engine alone. In series hybrids, the electric motor drives the bus, as a diesel engine works only as a generator to power the electric motor or to recharge the batteries. It is common to both parallel and series hybrids to use regenerative braking to help recharge the batteries.

Hydroelectric Power Hydroelectric power plants produce electricity by using flowing water to turn the propeller like blades in a turbine, which then turns a magnetic shaft in a generator. Natural waterfalls have been utilized as an energy source for years. Man-made dams can be built to harness energy like natural falls. Dams are built on large powerfully flowing rivers, preferably where there is a long drop in elevation, and the dam stores a lot of water behind it in a reservoir. An exit valve is built under the reservoir to allow flow through the dam, which first goes through a turbine, which creates the electricity, then the water flows back into the river.

International Organization for Standardization (ISO) The International Organization for Standardization (ISO) is an independent non-governmental entity that develops and publishes international standards to provide real-world tools for tackling many global challenges. The ISO utilizes international experts to develop voluntary International Standards that help offer solutions to global challenges. The ISO is based in Geneva, Switzerland.

ISO 14001 Environmental Management System Standard The ISO 14001 EMS standard helps an organization committed to continual improvement of environmental performance to utilize a formal procedure that assigns roles and responsibilities, and ensures that environmental impacts are managed, to avoid unintentional impairment. Adhering to the standard, and having a third-party auditor evaluate whether the entity really does commit to environmental sustainability, validates the effort for all to see and emulate, as the ISO 14001 EMS standard includes the demonstration of commitment to foster sustainability through operations, maintenance, design, and construction. A major requirement for adherence to the ISO 14001 EMS standard is to create an organization wide environmental policy that pledges to work to improve environmental performance, and demonstrate how it will be accomplished.

Landfills A landfill is the most prevalent, common, and cheapest form of waste disposal. The disposal of all types of garbage, refuse, or trash in a landfill is the dumping of useless waste into extremely large holes in the ground; however, there are, and always have been, many environmental impacts from landfills including leaching out, which is a toxic leak that could contaminate ground water, space issues, and air emissions. Landfills include mechanisms to capture leachate before it reaches ground water with special liners; however, it is very likely that over time landfill liners leak, allowing the leachate to contaminate the ground water.

Lead based paint Lead based paint is paint that includes an amount of lead, which was intentionally added to industrial paint used to coat steel columns and girders to prevent moisture from causing corrosion. Lead is a hazardous material, and lead poisoning can cause damage to the nervous system, kidneys, and reproductive systems in adults.

More prominently, it is truly dangerous to small children, in that it can severely stunt development. Lead was banned from household paints, toys, and furniture in the US in 1977 to protect children.

Lead Based Paint Disturbance Lead based paint disturbance activities occur during construction activities that may expose construction workers to the hazard of lead paint dust. During a disturbance of a painted surface that contains any amount of lead, the Occupational Safety and Health Organization (OSHA) have regulations which apply and outline effective procedures to avoid being exposed to the health hazards of lead. Containment during lead disturbance activities such as paint scrapping, demolition, or rivet busting, is usually configured with tarpaulins or plastic sheets, and must prevent paint chips from getting into the environment.

Leadership in Energy and Environmental Design (LEED) The US Green Building Council's Leadership in Energy and Environmental Design or LEED rating system measures the sustainable elements of buildings, and has quickly, within the last decade or so, become the world leader in determining the effectiveness of sustainability initiatives incorporated in buildings. Sustainable elements include physical elements used to reduce energy, collect rain water, or the material used. Elements of the rating system also include a site's proximity to mass transit in an effort to reduce car usage.

Light Emitting Diodes (LED) Light emitting diodes, or LEDs, are a series of small bulbs that last longer, and have energy requirements that are less than incandescent or fluorescent bulbs by a substantial amount. Light emitting diodes have a longer lifespan than that of an incandescent bulb, in some cases by a factor of eight. A diode is a semiconductor, which is a material with the ability to conduct an electrical current. Light emitting diodes are made of different materials, with different gaps between the higher and the lower orbitals, with gap size determining color.

Light Pollution Light pollution is unnecessary, unpleasant, or misdirected artificial light positioned into the environment. Light that shines in an obtrusive way toward residences can be disruptive. Lighting must be positioned to provide optimum illumination directed toward only the intended area. Lights that become misdirected waste lighting. Excessive indoor lighting can become misdirected off-site and could lead to discomfort to adjacent neighborhoods, commonly referred to as light trespass.

Light Rail Transit Light rail systems, trams, or streetcars are an increasingly popular transportation choice for cities to integrate reliable and convenient transit services. Light rail systems usually operate with one, two, or short multiple passenger cars, on fixed rails built into a dedicated right-of-way that is most often separated from adjacent car traffic. Some light rail systems can also operate in rights-of-way above or below the surface, and are typically powered from an overhead electric line via a pantograph, although some use third rail electrification. Light rail systems have grown in many small and large cities. Light rail is essentially the evolution of the electric street car system of the past. Light rail is prevalent all around the world, and the evolution of the electric streetcar has been recently increasing in popularity in the US.

Lithium – Ion Battery The lithium – ion is a rechargeable type of battery which has many applications, including the electric or hybrid bus battery energy storage system. The best advantage of the lithium – ion battery is the lightweight nature of the battery. Lithium is the lightest metal, and has an efficient electrochemical potential. Compared to most other metals, it has a larger energy density per weight, which is preferred in hybrid or all-electric buses.

Mass Transit Mass transit is public transportation systems including subway or elevated train lines, light rail systems, commuter rail, and bus services including bus rapid transit, which rapidly move millions of people each day, back and forth to work, school, or recreational activities. Ferry services, depending on passenger count, can also be considered in the mass transit definition. Mass transit is often referred to as "mass transport" outside the US.

Material with a Recycled Content Material with a recycled content is a material which includes a component that has been previously used. This helps to save natural resources. Major construction material, such as concrete and steel with a recycled content, provide benefits to the environment, as material with recycled content normally requires less energy and water for processing an equal amount of virgin material.

Monitoring and Measuring Monitoring and measuring is a way to assess actual performance. In environmental management, a big key to continuous improvement of environmental performance relies on monitoring and measuring environmental metrics. Environmental metrics are statistics utilized that measure environmental performance. Monitoring and measuring is a key part of the plan-do-check-act cycle.

National Environmental Policy Act The National Environmental Policy Act, or NEPA, is the leading environmental regulation in the US. The act was adopted in 1970, the year of the first official earth day, and was put in place to protect the environment. The law was established to allow humans and nature to coexist, without compromising future generations, and to find a balance between rapid development and environmental protection. Major construction projects, such as new highways and new transit lines, were a leading activity that influenced the adoption of NEPA.

Natural Gas Natural gas is a fossil fuel which is mostly extracted from beneath the earth's surface, sometimes deep in underground bedrock, or in shallow swamplands. Natural gas may also be collected from landfills, sewage, or waste water treatment plants. Natural gas has a low density and tends to rise to the surface of the earth through loose, shale type rock, and other material. Natural gas is predominantly methane, but it can also be in forms such as ethane, propane, butane, and pentane.

Methane is also a greenhouse gas, so any unintentional leakage contributes to global warming. Natural gas burns cleaner than diesel fuel, emitting far less fine particulate matter upon combustion. Natural gas or methane is extensively used through utilities to provide gas for homes, including heat, hot water, and for cooking. Natural gas is used to generate electricity, and is replacing coal as the leading electricity generator in the US.

Natural Lighting Natural lighting is the ability to allow sunlight to enter an establishment to provide the required lighting for a specific space. Natural lighting is incorporated into traditional architectural design, and windows and skylights allow sunlight into large centralized areas and reduce the amount of artificial energy lights consume. Skylights can also be covered to reduce heat gain with a Low-E coating, to reduce heat flow through the glass, and can use special glazing to reduce glare. Daylight, in combination with automatic light sensing controls, can maximize energy savings.

Natural Ventilation Natural ventilation is the process that allows fresh air to permeate through a building or facility, reducing the need for mechanical energy, using wind to ventilate and cool a building, thereby creating a comfortable and productive indoor climate. A mass transit maintenance shop, with its large shop floor, is very suitable for natural ventilation. Through openings from the windward side of the building, such as louvers or grills, and openings on the leeward side or the roof, fresh air will permeate through a maintenance shop, without the use of mechanical fans.

Noise and Vibration Noise and vibration from operating trains is always a significant environmental concern, as unwanted sound can disturb the quality of life of everyday living. Sound is created by the train, specifically at the steel rail and steel wheel interface. Any defect or abnormality can produce unwanted sound or noise. Vibration concerns are of critical importance in subway services, as the subway tunnel fundamentally may allow only an infinitesimal amount of movement as heavy trains pass through, build up speed, and then come to a complete stop.

In construction, noise and vibration impacts are byproducts of operating heavy equipment. Construction equipment generates various levels of noise, depending on the specific activity. Large construction projects produce noise and vibration levels due to the use of equipment, and the construction related vehicles that regularly travel on- and off-site, including trucks, bulldozers, and cranes.

Noise Pollution Noise pollution is the excessive sound level that can disturb human or animal life. Cars, trucks, airplanes, and construction activity, as well as mass transit operations, all contribute to ambient noise levels in cities. Noise pollution can affect human health. Noise can induce hearing loss, contribute to cardiovascular effects, and can cause hypertension or high blood pressure, stress, tinnitus, or ringing in the ears, and mostly can disturb people trying to sleep. Noise is basically considered unwanted sound.

Oil—Water Separator Oil—water separators help prevent oil from entering the sewer system using the fact that oil floats on water. Often installed below ground, oil is separated from water as the level of the oil—water mix enters the separator, and the oil is skimmed off the top, preventing oil from entering the sewer. Drainage from all parking or maintenance areas must be connected to oil—water separators, to prevent spills of gasoline, diesel, motor oil, or other fluids from entering the sewer system. As sludge builds up in an oil—water separator, it needs to be pumped out often to avoid clogging.

On-Board Energy Storage On-board energy storage systems are batteries or capacitors built into the train or bus, which allow the vehicle to operate without external electrical energy, or in case of a bus, without the consumption of fuel. With an on-board battery, if the vehicle is equipped with regenerative braking, the energy produced (regen) can be supplied to the battery system on board the train or bus. Light rail systems, using an on-board energy storage system that complements the energy supplied by the pantograph from an overhead contact wire, can operate wireless during portions of their run.

Piezoelectricity The piezoelectric effect is the capability of certain materials to generate electricity, when subject to vibrations. Material that exhibits the piezoelectric effect, such as quartz, can be placed between two metal plates, and when the material is subject to vibrations, it produces electricity.

Polychlorinated Biphenyls (PCBs) Polychlorinated biphenyls (PCBs) were most widely used as dielectric fluids in electrical equipment, specifically electrical transformers. Polychlorinated biphenyls were commonly used as insulating fluid for transformers, and capacitors in light ballasts. Other applications include use in paints, sealants, calking, adhesives, electrical cables, and electronic components. Polychlorinated biphenyls are toxic and potentially carcinogenic, and production was banned by the US in 1979.

Rain Water Collection System Rain water collection systems drain water, mostly from rooftops or canopies, into water storage tanks to be used later. Rain water collected can be used as water for landscaping, or gray water use in buildings. Storage tanks can be either above ground or underground, and rain water can be used for washing either trains or buses in a subway car washer or bus depot. Supplementing the water used to clean, wash, and rinse transit vehicles with collected rain water will save potable water.

Recycling Recycling is the process to reuse material or products over again, and thus avoid landfilling or incinerating old material. Recycling reduces the impact on the environment by utilizing waste material in a productive way. Recycling saves on decreasing landfill space. Recycling is an important part of modern waste reduction.

Recycle Bus Washers Recycle Bus Washers use recycled wash water, often within a continuous loop recycling system. After water is used in a bus washer system, it drains into a collection unit which is designed to remove oils, filter particles, and remove organic material, to allow reuse of previously used water. Activated carbon is used to adsorb organic compounds in water treatment processes.

Regenerative Braking Regenerative braking is a supplemental braking system that converts a train car or bus's kinetic energy when a train slows down, and changes it into usable electrical energy. It is a prolific sustainability initiative in the mass transit industry. When the train or bus is in full motion, and the motorman or driver applies the brakes, the vehicle's electric motor is prompted to run in reverse, which provides a resistance to the moving wheels, helping to slow down the train or bus. As soon as a train's electric motor is changed to run in the opposite direction, it temporarily becomes an electric generator, allowing it to produce electricity while braking.

Renewable Energy Renewable energy includes the natural continuously supplied energy extracted from the sun, air, water, or the land. Renewable energy is indefinite, it never runs out of supply or potential, and it has the ability to sustain itself. Energy produced includes solar, wind, hydroelectric, and biomass. Much renewable energy does not directly emit pollution or greenhouse gases during generation of electricity, except for biomass electricity generation, which uses the combustion process.

Renewable Energy Certificates Renewable energy certificates or RECs can be bought and sold. The renewable energy certificates or green credits represent energy that has been produced in an environmentally sustainable way. Many states have mandatory requirements for the level of renewable energy they must produce each year. Mass transit agencies can invest in solar, wind, biomass, or hydroelectric power by purchasing green energy credits or renewable energy certificates.

Significant Environmental Aspects Significant environmental aspects are the aspects that require preventative mitigation measures to reduce environmental impacts, or enhancements to help accentuate positive outcomes, under the framework of an Environmental Management System. An aspect and impact analysis determines an organization's significant environmental aspects, and these aspects are where resources and programs are established to help mitigate any negative impacts or accentuate positive impacts.

Sleep-mode Escalator Sleep mode escalators are equipped with sensors that make escalators slow down when no one is using them, and increase to normal speed when an approaching customer is detected by the sensor. These sleep mode escalators consume less energy, during inactive periods, and have been popular in mass transit systems in Europe and Asia for many years.

Solar Energy Solar energy is derived from sunlight, to create electricity or heat. Solar or photovoltaic panels transform sunlight into an electric current with materials made from semi-conductors. Solar panels can be mounted on rooftops to provide electricity derived from the sun into a facility. Solar power plants can consist of individual solar panels in rows in solar farms, or concentrated solar thermal plants, using solar thermal energy to make steam for a turbine to make electricity.

Solar Thermal Solar thermal processes use sunlight to heat water or another liquid, sometimes a synthetic oil, to transfer heat for heating or hot water. Solar thermal heat energy systems are mounted on rooftops, and can generate heat or hot water, without fossil fuel combustion. There are a few basic types, but most utilize mirrors to reflect and concentrate sunlight on a medium such as water or oil that runs through a tube that can transfer heat, and convert it into heat for a building or hot water.

Solar Heat Walls A solar heat wall is a metal wall, which is mounted in front of a masonry wall of a building. The metal wall, with tiny holes, is placed on the south side of the building, facing the equator in the northern hemisphere (and facing north in the southern hemisphere), and when sunshine falls on the wall during wintertime, air is sucked through the holes of the wall. The air is heated as it goes through tiny holes in the wall, and supplements the heat being produced inside.

Stations Stations are the entry points to a subway, elevated train, or bus rapid transit operations. Stations usually include pay areas, turnstiles, and include the platforms for passengers to wait for the oncoming train or bus. Stations can be elaborate building like structures, or simple modest platform and canopy amalgamations. Stations can be situated within a variety of cityscape locations. Cities can see stations come up from the sidewalk or street, within park properties, in large plaza areas, and as part of a large building, or directly interconnected with an arena or large theater venue.

Storm Water Runoff Storm water runoff is rain water that hits the pavement, does not drain into a sewer basin, and has the potential to run off into the nearest water body. In many cases, runoff carries with it any debris or pollution that is in its path. Storm water running off impervious surfaces can pick up remnants of gasoline, motor oil, and trash, and debris such as plastic bottles that do not make it into a garbage or recycling container.

Sub-stations Sub-stations receive electricity from the power grid, and supply electricity for the third rail or overhead catenary, that provides the train with the required energy to run. The mass transit sub-station converts and transforms voltage from alternating current to direct current for traction power. Sub-stations are generally located adjacent to transit infrastructure, and are spaced out to provide maximum efficiency.

Subway The subway is a below ground or subsurface infrastructure, made of massive amounts of concrete and steel, which carries a train service. The subway tunnel is the ideal mass transit infrastructure, in that it is below ground, it can travel unimpeded and very rapidly underground, and it doesn't take up valuable real estate or room above the surface.

Sustainability Sustainability, in the modern lexicon pertaining to the environment, is described as not compromising the needs of future generations with the needs of the present. Sustainability can also be described as having three pillars: environmental, economic, and social with environmental sustainability the most critical in terms of a healthy planet. Sustainability denotes a responsibility that lessens negative environmental impact, and seeks to maintain a balance between economic prosperity, social growth, and a planet where all humans and animals can survive now and in the future.

Third rail The third rail is the source of electricity from which heavy rail trains receive their power. The third rail is mounted at track level on either side of the running rails, and provides electricity from contact with a train shoe, which sticks out from beneath the train car. Third rail is made up of either all steel or a composite of steel and aluminum, to minimize resistance and maximize efficiency.

Ties Ties are cross pieces constructed perpendicular to the rails of the track bed. Ties are traditionally made from wood. Ties often rest on ballast, which are very small pieces of broken up rock that are packed together, allow for proper drainage, and hold the railway tracks in place.

Track Track is what trains run on, and the track bed includes a set of two parallel rows of steel, which make up the running rail that is used as the fixed guideway used by trains. The steel rails are supported by ties at consistent intervals, which spreads the pressure load forced by the train wheels into the ground or the foundation of the structure.

Train Infrastructure Train infrastructure consists of subway tunnels, elevated railways, or at grade-level surface rail. The elementary construction materials of most subway tunnels consist of concrete and steel, with steel framing and columns, and concrete foundations and footings. Infrastructure also includes line equipment such as substations, ventilation facilities, circuit breaker houses, pump rooms, and tunnel lighting.

Transit Oriented Development Transit oriented development (TOD) is when new public transit in cities helps to stimulate major residential and commercial development. A new transit system can help generate new housing, restaurants, supermarkets, and many additional small businesses, along and around the transportation route. New transit expansion in a city can help stimulate economic growth that comes with people settling in cities, and people who live in cities are generally more sustainable.

Turnstile Energy Turnstile energy is the potential electrical energy that may be derived from the spinning motion of the turnstile. A device that includes an object that spins can be conformed to work as a generator, by spinning a coil of wire around a magnet to produce current and/or store generated energy. Similarly, hand-powered generators working under the same premise were originally used by the military to generate electrical power in the battle field.

Ultra-Low Sulfur Diesel Ultra-low sulfur diesel (ULSD) fuel is defined as diesel fuel with a sulfur content below 15 parts per million. Crude oil, which diesel fuel is refined from, includes considerable amounts of sulfur. Removing the sulfur in diesel during refinement helps reduce particles generated when burning diesel fuel, because less sulfur means more efficient combustion. The initial advance of cleaner burning diesel began with the use low sulfur diesel, defined as less than 500 parts per million, which led to an even more refined process which produced ultra-low sulfur diesel.

Underground Storage Tanks Underground storage tanks (UST) are buried storage tanks usually for fuel dispensing purposes. As part of the bus depot infrastructure, fueling stations are an integral part of the facility. Traditionally, underground diesel fueling systems have left a pool of contaminated sites through corroded tanks, spilling oil into the ground, and in many instances, contaminating the ground water. Modern underground storage tanks are equipped with secondary containment and leak detection systems.

Vertical Axis Wind Turbines Vertical axis wind turbines are electricity-generating turbines that are generally smaller than giant horizontal turbines that are the traditional large turbines utilized in both on-shore and off-shore wind farms. The main rotation shaft of a vertical axis wind turbine is vertical like a helicopter, rather than horizontal, and can catch wind from any angle. Vertical axis wind turbines can work in very turbulent or gusty winds. Vertical axis wind turbines work better in urban settings on top of buildings or facilities.

Visual Impacts Visual impacts are those stemming from the appearance of an infrastructure on the cityscape. Visual impacts, either positive or negative, are quite subjective.

An elevated train, subway, or train station or terminals may affect the urban environment, as they are part of the neighborhood landscape. To avoid negative visual impacts, infrastructure design should be true to area esthetics and be in step with any district motif. Light rail or streetcar services, and bus rapid transit infrastructure design should also blend into the existing urban landscape to attempt to be esthetically pleasing and simpatico with neighborhood architecture.

Wayside Energy Storage Wayside energy storage systems, which are typically made up of a battery or capacitor, are systems which store energy for future use, and are located on an adjacent area to the train infrastructure. Wayside energy storage can capture and store regenerative braking energy, to maximize efficiency. The regenerative braking energy, the electricity created by braking trains (regen), can be stored in a wayside energy storage system, and then reused for acceleration of the next train. Wayside energy storage systems can help supply voltage to help reduce losses in the power grid.

Wetlands Wetlands are one of nature's most valuable natural assets in the environment. Wetlands, which are characterized as the areas between the land and the water, and are where the water table meets the surface, are usually covered by shallow water. Wetlands absorb water, cleanse and filter contamination, and include plants that live in water. Wetlands are well protected by federal and state environmental regulations, with strict guidance and enforcement.

White Roofs A white or reflective roof reflects the rays of the sun, will not absorb as much of the sunlight as a black or dark colored roof, and will keep a building cooler. Hotter rooftops, due to a blacktop or non-reflective roof, will require a building to use more energy for cooling. Albedo, or reflectivity, is the percentage of light that hits a surface that is reflected, and not absorbed. White surfaces reflect light, and black surfaces absorb light.

Wind Power Wind power is electricity produced by wind currents that spin a turbine generator without any emissions of greenhouse gases during operation. Wind turbines use the power of wind to create electricity. Wind farms consist of many individual wind turbines, which are connected to electric power transmission lines. Most wind turbines consist of three blades and sit atop a tubular tower that, in many cases, can rotate into the face of the wind. Wind farms are predominantly on-shore; however, more off-shore capacity is being planned and will be constructed in the future. Off-shore wind farms located in coastal areas have no obstructions, and can generally create more electricity than on-shore farms.

Appendix B

Environmental Acronyms

Environmental Term	Acronym
American Public Transportation Association	APTA
Asbestos containing material	ACM
Aspects and impacts	A & I
Building Management Systems	BMS
Bus Rapid Transit	BRT
Carbon dioxide	CO_2
Categorical exclusion	Cat Ex
Clean Air Act	CAA
Compressed natural gas	CNG
Construction and demolition debris	C & D
Contaminant of concern	COC
Decibel	dB
Department of Energy	DOE
Environmental assessment	EA
Environmental Impact Statement	EIS
Environmental Management Systems	EMS
Environmental Protection Agency	EPA
Envision Specialist	ENV SP
Federal Transit Administration	FTA
Hazardous waste	HW
Hazardous Waste Operations and Emergency Response	HAZWOPER
Health and safety	H & S
International Organization for Standardization	ISO
Lead	Pb
Leadership in Energy and Environmental Design	LEED
LEED Accredited Professional	LEED AP
Light emitting diodes	LED
Light rail transit	LRT
Liquefied natural gas	LNG
Maintenance and protection of traffic	MPT
National Ambient Air Quality Standards	NAAQS
National Emissions Standards for Hazardous Pollutants	NESHAP
National Environmental Policy Act	NEPA
National Oceanographic and Atmospheric Administration	NOAA

(*Continued*)

(Continued)

Environmental Term	Acronym
Nitrous oxides	NOx
Noise and vibration	N & V
Occupational Safety and Health Administration	OSHA
Operation and maintenance	O & M
Particulate matter	PM
Personal protective equipment	PPE
Polychlorinated biphenyls	PCB
Regenerative braking	Regen
Renewable energy certificates	RECs
Renewable natural gas	RNG
Safety data sheet	SDS
Spill Prevention Control and Countermeasure Plan	SPCC
Sulfur dioxide	SO_2
Toxic Substance Control Act	TSCA
Transit oriented development	TOD
Transportation Research Board	TRB
Treatment Storage and Disposal Facility	TSDF
Ultra-low sulfur diesel	ULSD
Underground storage tanks	UST
Waste water treatment plant	WWTP

Appendix C

Photos

FIGURE C.1 Number 1 Train in Upper Manhattan. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/*.

FIGURE C.2 Two (2) Number 7 Trains. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.3 Number 6 Train on elevated track curve over roadway. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.4 Elevated train structure adjacent to Hybrid Bus parking lot (and CitiField) Flushing, Queens. *Photo courtesy of Yekaterina Aglitsky.*

FIGURE C.5 A Train on Jamaica Swing Bridge Flushing Bay. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.6 B Train in archway. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.7 C Train leaving underground subway station. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.8 View beneath elevated train structure. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.9 Two M trains approaching station. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.10 B Train Yard. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/*.

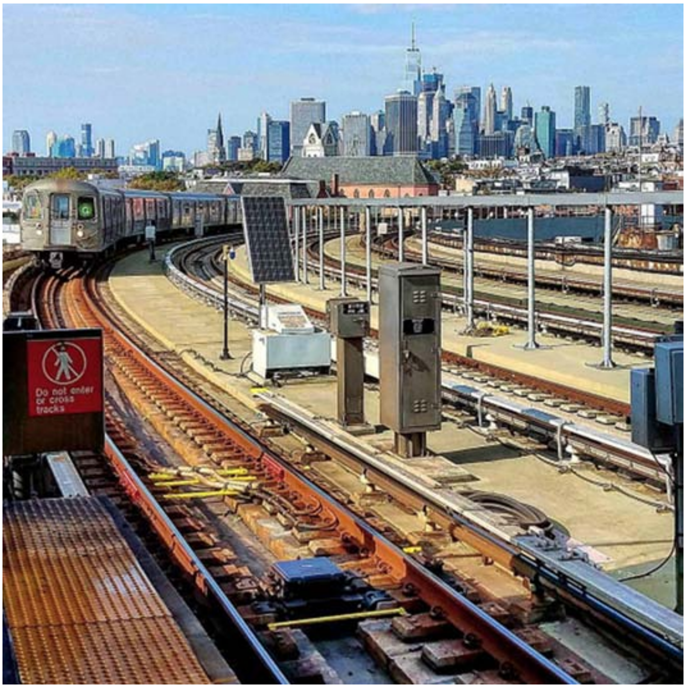

FIGURE C.11 Solar panel powered lubrication house Culver Line Brooklyn (Freedom Tower background). *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/*.

FIGURE C.12 18th Avenue Station Brooklyn. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.13 Elevated train moving high above overcrowded New York City highways. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.14 Franklin Ave shuttle in Fall with foliage covered track right of way. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.15 Light Rail Train Station New Jersey Transit. *Photo courtesy of Steve Eget, P.E. Dewberry Engineers.*

FIGURE C.16 Long Island Railroad commuter train yard with Empire State Building in background. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.17 Metro-North Commuter Train Station. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

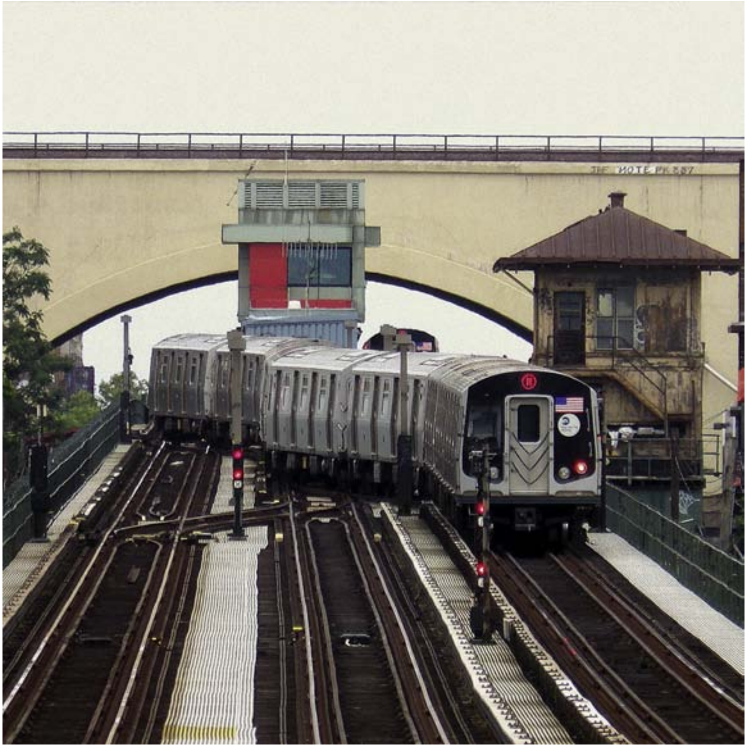

FIGURE C.18 N Train making cross over (switching from one track to another). *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.19 Elevated train adjacent to bicycle path on Williamsburg Bridge. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.20 Train Car Storage Lineup. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

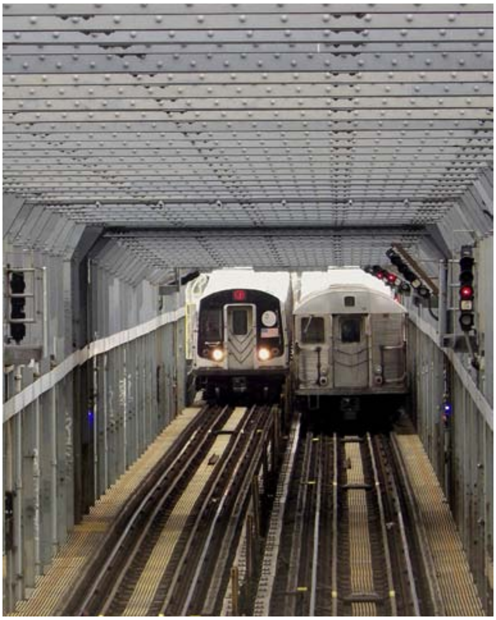

FIGURE C.21 Trains passing each other on Williamsburg Bridge. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.22 Subway track tunnel curve. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.23 Natural Gas Bus Toledo, Spain. *Photo courtesy of Yekaterina Aglitsky.*

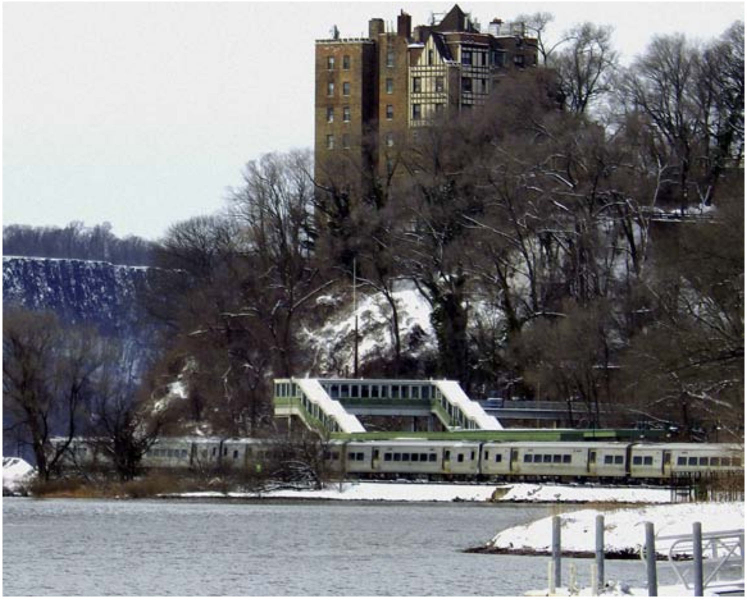

FIGURE C.24 Metro-North station adjacent to snow covered hilltop. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

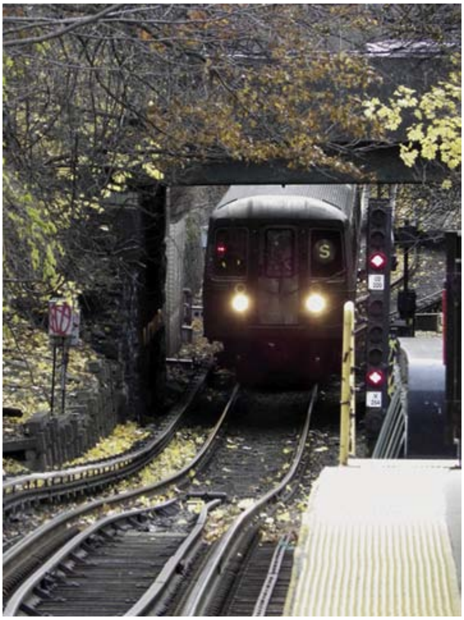

FIGURE C.25 Franklin Ave Shuttle. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.26 Elevated train above bus on snow covered street. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/*.

FIGURE C.27 Corona Train Storage Yard. *Photo courtesy of Yekaterina Aglitsky.*

FIGURE C.28 Construction on elevated track. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/*.

FIGURE C.29 Whitehall Street Station. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/*.

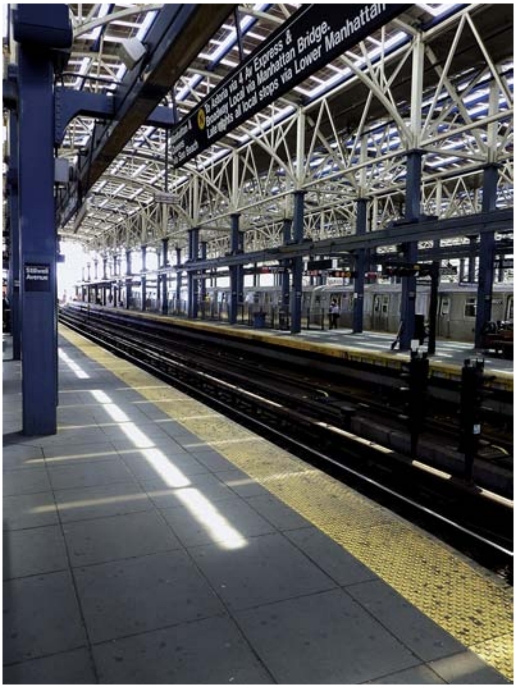

FIGURE C.30 Stillwell Terminal Photovoltaic Roof Canopy with natural lighting Coney Island. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.31 Metro-North Hudson Line station platform with bridge in background. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

FIGURE C.32 Number 6 Train on elevated track curve. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

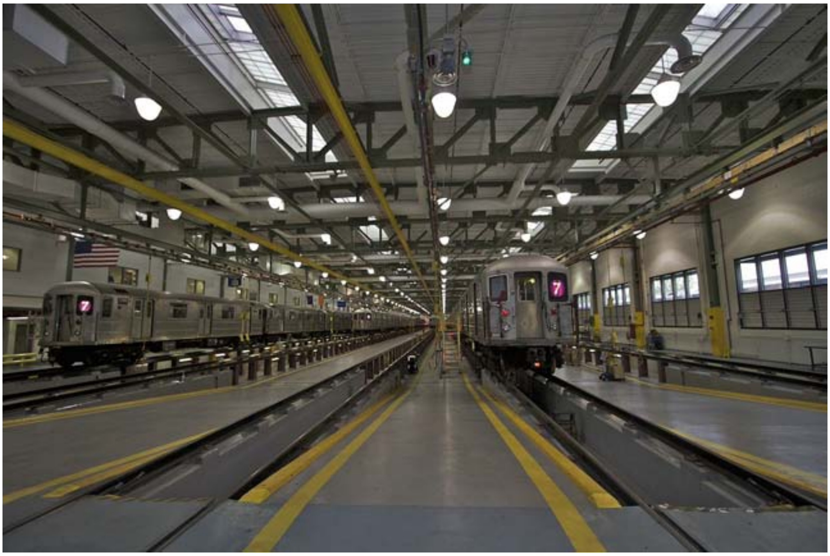

FIGURE C.33 Corona Maintenance Shop. *Photo courtesy of Yekaterina Aglitsky.*

FIGURE C.34 Mother Clara Hale Bus Depot Harlem. *Photo courtesy of Yekaterina Aglitsky.*

FIGURE C.35 Tram (electric streetcar) stop with electric charger above canopy Seville, Spain. *Photo courtesy of Yekaterina Aglitsky.*

FIGURE C.36 Number 7 Train (with Empire State Building in background) at dusk. *Photo courtesy of Joe Raskin, http://wanderingnewyork.tumblr.com/.*

Index

Note: Page numbers followed by "*f*" and "*t*" refer to figures and tables, respectively.

D

E

F

M

N

O

P

Q

R

S

W

Z

SUSTAINABLE MASS TRANSIT

CHALLENGES AND OPPORTUNITIES IN URBAN PUBLIC TRANSPORTATION

THOMAS ABDALLAH

Comprehensive overview on how to make public transportation systems worldwide less reliant on fossil fuels and more energy efficient.

- Explores how Environmental Management System frameworks improve the environmental performance in the operations, maintenance, design, rehabilitation, and expansion of a mass transportation system.
- Shows how teams from different fields, entities, agencies, and cities can work together to solve complex sustainability challenges.
- Numerous case studies from the United States, Canada, Mexico, South America, and Asia, including sustainable influences from Europe.

Sustainable Mass Transit: Challenges and Opportunities in Urban Public Transportation provides a comprehensive overview of how to incorporate sustainable business practices into public transportation systems worldwide.

Every day, millions of people in the cities commute from home to work or school. Most do so though by getting into their own car and driving to where they need to be, causing significant environmental damage to the earth's ecosystem. Cities with subways, train lines, light rail systems, and bus lines, however, contribute less environmental damage overall than cities that do not.

Sustainable Mass Transit: Challenges and Opportunities in Urban Public Transportation examines the numerous types of mass transit systems, looking closely at all their key functions, including operations, maintenance, development, design, building, and retrofitting. It examines the mitigation measures that reduce or eliminate negative environmental impacts, including green infrastructure, materials conservation, ecological conservation, and other sustainable initiatives.

Thomas Abdallah has more than 30 years of experience in the environmental and transportation fields. He is Deputy Vice President and Chief Environmental Engineer for New York City Transit and an Adjunct Professor of Columbia University's Sustainability Management graduate program.

Related titles

- *Sustainable Land Development and Restoration*, Kondi Brown, Butterworth-Heinemann, 9781856177979
- *Sustainable Communities Design Handbook*, Woodrow Clark, Butterworth-Heinemann, 9781856178044
- *Towards Sustainable Road Transport*, Ronald Dell, Academic Press, 9780124046160

ISBN 978-0-12-811299-1

9 780128 112991

ELSEVIER

elsevier.com/books-and-journals