VISION 2050

A 21st Century Transportation System for Wisconsin

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About 1000 Friends of Wisconsin

1000 Friends of Wisconsin was created in 1996 by a group of academics and environmentalists with the primary focus of promoting legislation that led to Wisconsin's Smart Growth Comprehensive Planning Law. Over the years we have continued to work to defend the law but also to expand our mission to the many issues that are associated with land use policies and activities that advance healthy communities, positive economic outcomes, and environmental benefits in Wisconsin. We understand that climate change and land use are intrinsically linked. Our goal is to help people make the connection between sound land use and transportation decisions; which lead to a healthier, cleaner environment. We are working to ensure communities across Wisconsin draft and adopt comprehensive climate action plans that focus on: equitably reducing greenhouse gas emissions and a responsible focus on mitigation. We are committed to applying an equity lens to all our programming and operations.

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Chapter 1:
Wisconsin's Existing Transportation System

Wisconsin's transportation system consists of a network of roads and highways, railroads, airports, harbors, bicycle and pedestrian pathways and public transportation services.

Most of these facilities and services come fully or partially under the purview of the Wisconsin Department of Transportation (WisDOT). The Department plans, builds and maintains the state, U.S., and Interstate highways. It manages federal grants. It provides financial support for county and municipal transportation systems, which include county highways, local roads, transit systems and other modes. In addition, WisDOT oversees development of statewide public transportation services.

This chapter describes the existing network of highways and roads, the existing public transportation services and the sources of funds administered by WisDOT.

Overview of the System

The major population centers in Wisconsin are shown in Figure 1.01, which shows cities and metropolitan areas with populations of 50,000 or more. The principal challenge to the system is to facilitate movement of people and freight within and between these densely populated areas. The system also serves residents who live outside these major centers, either in other cities or villages or in towns.

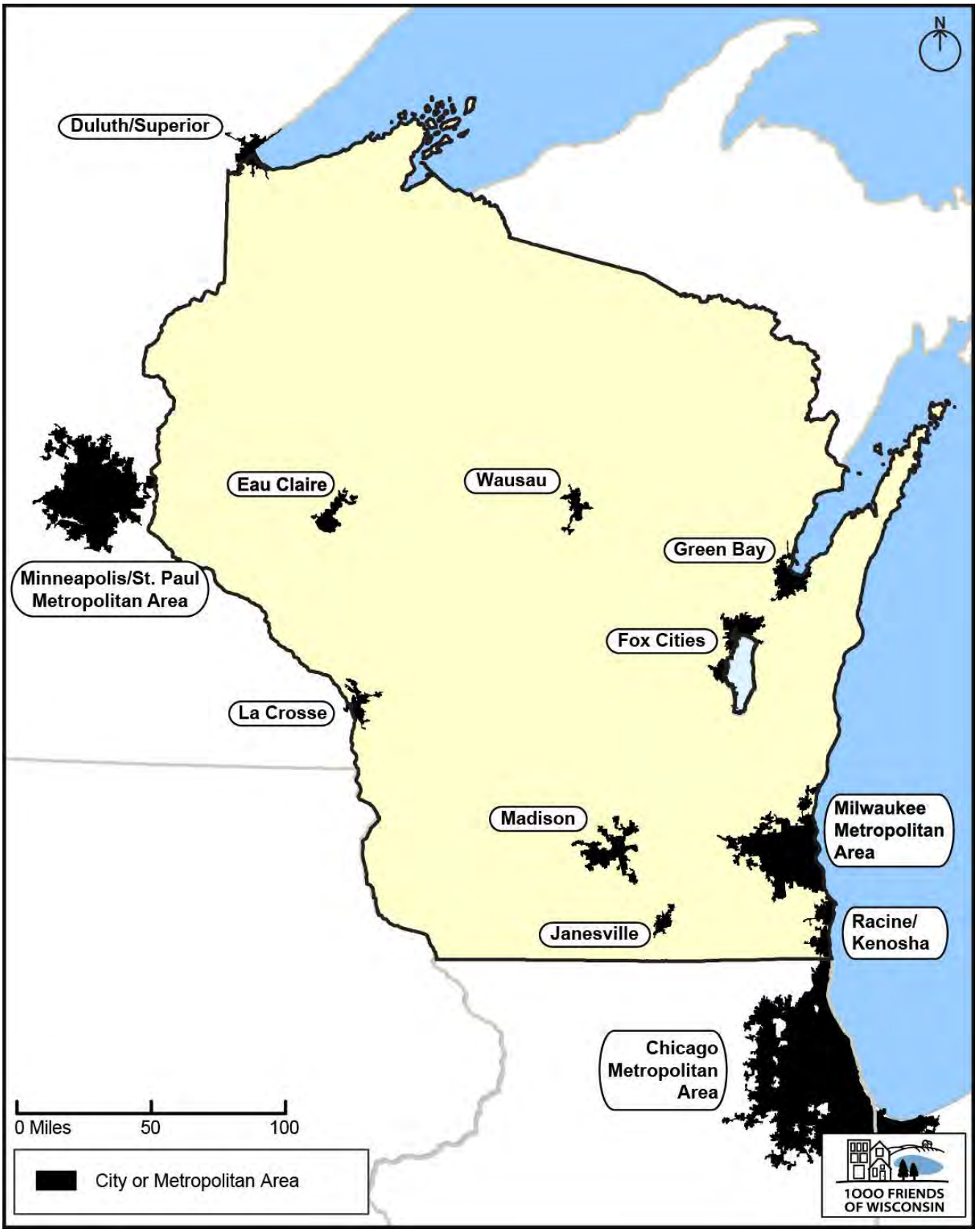


Figure 1.01: Cities and Metropolitan Areas in Wisconsin

Highways and Roads

Statewide highways in Wisconsin include Interstates, U.S. highways and state highways. These connect distinct cities and metropolitan areas, as shown in Figure 1.02. For transportation at a regional level, these major highways are supplemented by county highways. At a local level, roadways include municipal streets and town roads.

Public Transportation Services

Public transportation provides ways for people to get around without driving. There are three levels:

- Local transit (within a city) – typically <10 miles
- Regional intercity transit – typically 10-50 miles
- Statewide intercity public transportation – typically >50 miles

At the local level, many cities have municipal transit systems. The routes offer frequent stops and are generally within the city itself. These cities may contract with suburbs to provide limited service, but these are ad hoc arrangements that do not serve the region as a whole.

The Milwaukee County Transit System (MCTS) is a special case, with characteristics of both local and regional systems. It serves the entire county of Milwaukee, which comprises the City of Milwaukee and 18 other municipalities.[1] The MCTS provides local service with frequent stops but also has regional express routes. Owing to its role as a county-based system, it is able to cross municipal boundaries in a way that municipal systems in Wisconsin cannot. But special arrangements are needed for it to provide routes extending into adjacent counties.[2]

Regional commuter rail service is offered by Metra Rail. Metra, which operates a commuter rail network throughout the Chicago region, has a branch serving Kenosha.

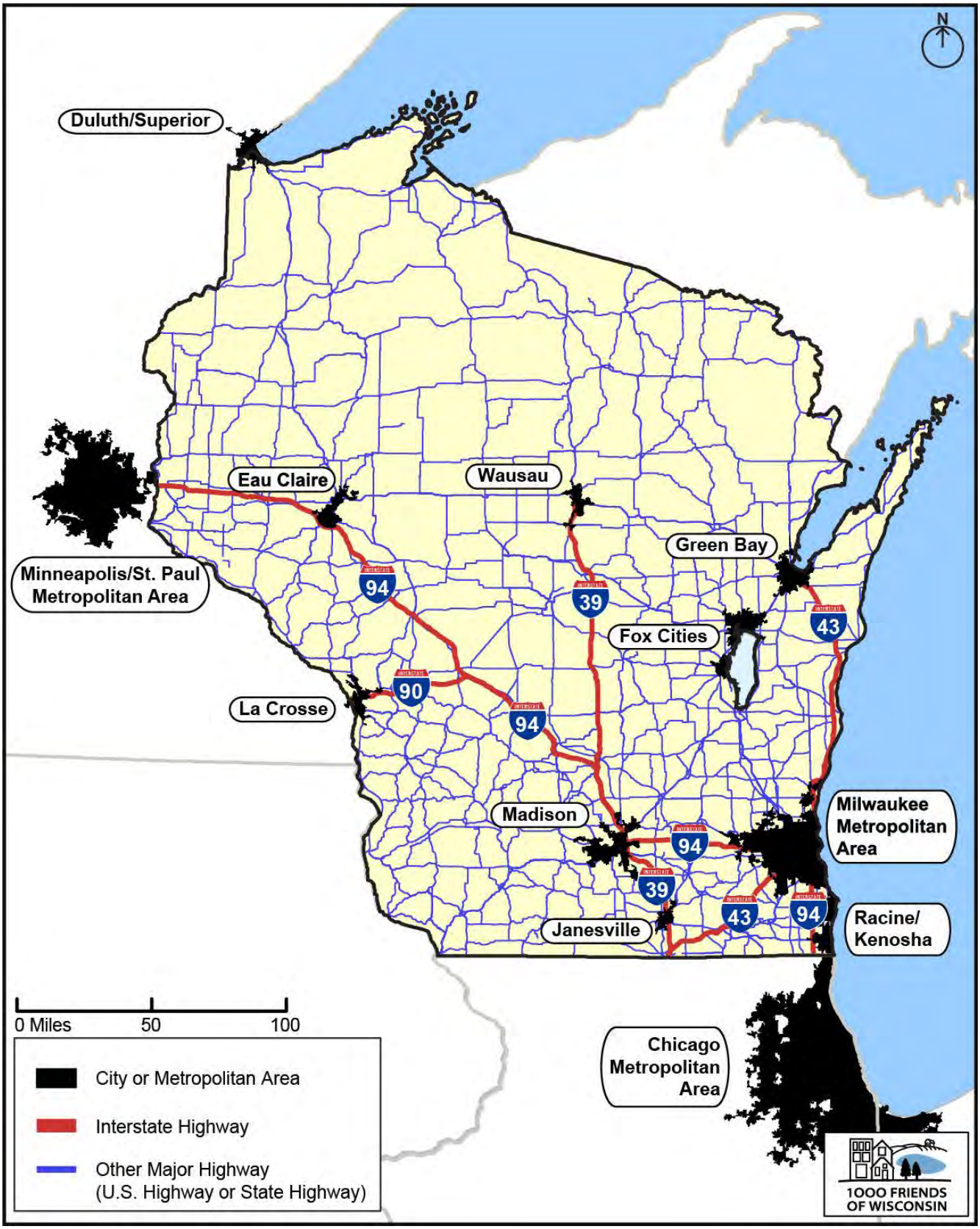


Figure 1.02: Statewide Highways in Wisconsin

Public transportation systems that extend beyond a single region are labeled Statewide. Three forms of statewide public transportation are available in Wisconsin, namely, passenger rail, intercity bus services and airports. The intercity rail and bus routes are shown in Figure 1.21. Wisconsin has two Amtrak passenger rail routes. The once-daily Empire Builder connects Chicago, Milwaukee and Minneapolis on the way to its final destination Seattle. The Hiawatha route between Chicago and Milwaukee offers seven trains daily in each direction. Several companies own and operate the intercity bus routes shown in Figure 1.21.[3] These routes are mostly in southern and central Wisconsin, along with a single route paralleling the Lake Superior shoreline.

Commercial airports, so called because they serve commercial airlines offering regularly scheduled flights, generally are public facilities owned and operated by units of government. The commercial airports in Wisconsin are:

- Appleton International (Appleton)
- Austin Straubel International (Green Bay)
- Central Wisconsin (Wausau)
- Chippewa Valley Regional (Eau Claire)
- Dane County Regional (Madison)
- General Mitchell International (Milwaukee)
- La Crosse Regional (La Crosse)
- Rhinelander-Oneida County (Rhinelander)

The busiest airports are Dane County Regional Airport (Madison) and General Mitchell Airport (Milwaukee). General Mitchell is the largest, with the most domestic and international flights.

Active Transportation

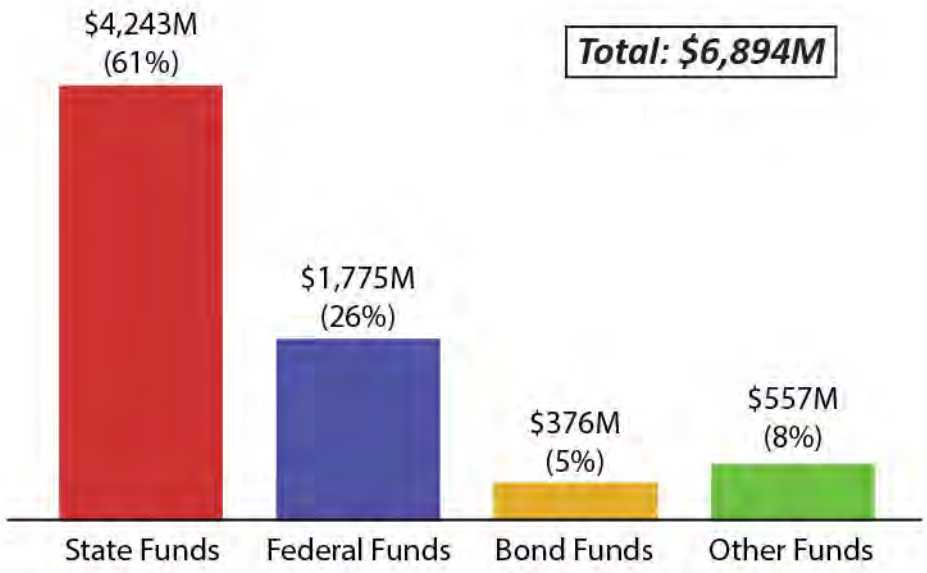
Active transportation is transportation powered by human action such as walking or bicycling. The distances traveled are usually rather short, typically less than one mile for walking and three miles for bicycling. The infrastructure for active transportation is designed to enhance safety.

Figure 1.21: Statewide Rail and Bus Routes in Wisconsin

In urban areas, this includes sidewalks and crosswalks for pedestrians and marked lanes or separated paths for bicyclists. In rural areas, cross-country pathways may be provided for both walkers and bikers. A few highways have special lanes or well separated pathways for bicycles.

Funding of Transportation

Sources of funds for transportation are shown in Figure 1.42. Most of the State funds in this figure come from state transportation revenues, detailed in Figure 1.43. All fees and other revenues from users go into a segregated fund which is constitutionally protected and can be used only for transportation-related purposes administered by WisDOT.



Sources: Wisconsin Department of Transportation: 2018-2019 Transportation Budget Trends, Tables T-6, T-41; Legislative Fiscal Bureau, Informational Paper - 35, Transportation Finance (2019), Tables 9, 10, and 11

Figure 1.42: Sources of Funds for Transportation (2019-2021 Biennium Budget)
State Funds: Mainly State Transportation Revenues (Fig. 1.1). Also includes increments due to transfers from or to other funds. Bond Funds: Proceeds for Transportation Revenue Bonds and State General Obligation (GO) Bonds. Other Funds: Includes $243M transfer from General Purpose Revenues (GPR) to cover cost of debt service for GPR-supported GO Bonds.

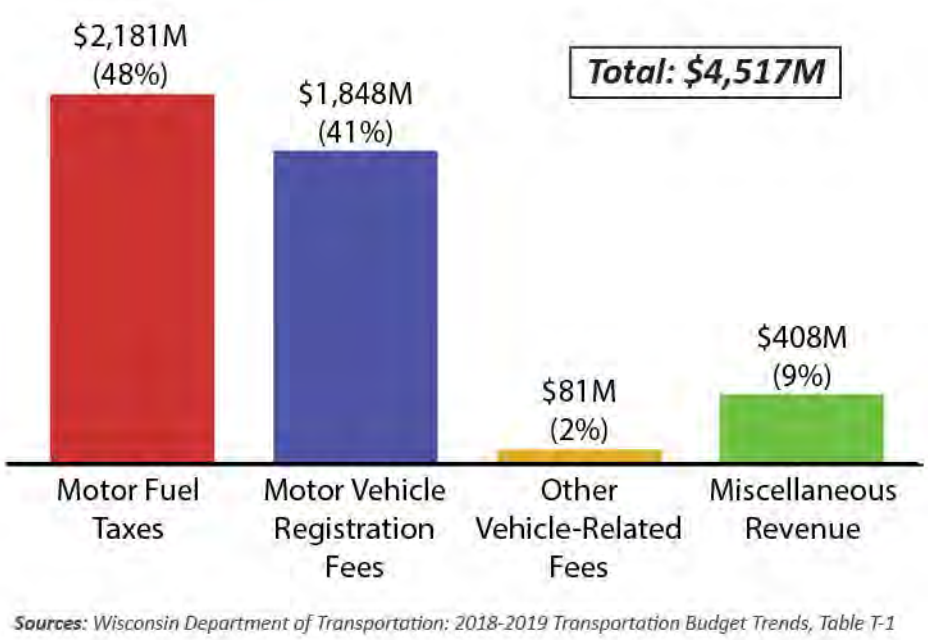


Figure 1.43: Sources of State Transportation Revenues (2019-2021 Biennium Budget)
Other Vehicle-Related Fees: Driver License Fees, Motor Carrier Fees, Other Motor Vehicle Fees. Miscellaneous Revenue: Driver License Fees,Aeronautics Taxes & Fees, Railroad Taxes, Annual Transfer of 0.25% of GPR from General Fund, Miscellaneous Revenue

Summary

The Wisconsin transportation system consists of highways and roads, pathways for pedestrians and bicyclists, railroads, airports, and public transportation services. WisDOT is responsible for the planning, funding, building and maintenance of major highways and provides financial support for regional and local roadways. It oversees and partially supports public transportation services. The system is funded from transportation-related revenues, state appropriations and federal grants.

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Chapter 2:
Why Wisconsin Must Reform Its Transportation System

This chapter examines the numerous shortcomings of Wisconsin's transportation system. The focus on highways and support for gasoline-powered vehicular travel have led to a system that is a major source of emissions that threaten our climate. Inadequate funding of public transportation services has resulted in a system that fails to meet the essential travel needs of many residents and the preferences of an increasing proportion of the population.

The system has inherent inefficiencies that burden the state with high construction and maintenance costs. Expansion of commuter corridors in cities has disrupted neighborhoods, polluting the air and seriously impacting the health and safety of residents. In rural areas, multi-lane highways have degraded farmland, forests and natural habitats.

Greenhouse Gas Emissions

Transportation is now the leading source of GHG emissions in the United States.[1] Eliminating transportation emissions will be critical if we are to avoid the most catastrophic impacts of climate change. States, because of their control of much of our transportation spending, can play a major role in achieving the generally accepted goal of total carbon neutrality by 2050.

The principal greenhouse gases are carbon dioxide (CO_2) and methane (CH_4). These are the most serious because trace

amounts have a powerful greenhouse effect and they are long lived – CO_2 persists in the atmosphere for centuries and CH_4 slowly degrades into CO_2. This persistence means that today's emissions could continue to add to global warming far into the 22nd century.[2]

Figure 2.12 shows GHG emissions for various sectors of the U.S. economy, 2000-2018. Emissions from transportation now exceed those from any other sector and continue to rise while the emissions from the previous major contributor, electric power production, are declining.

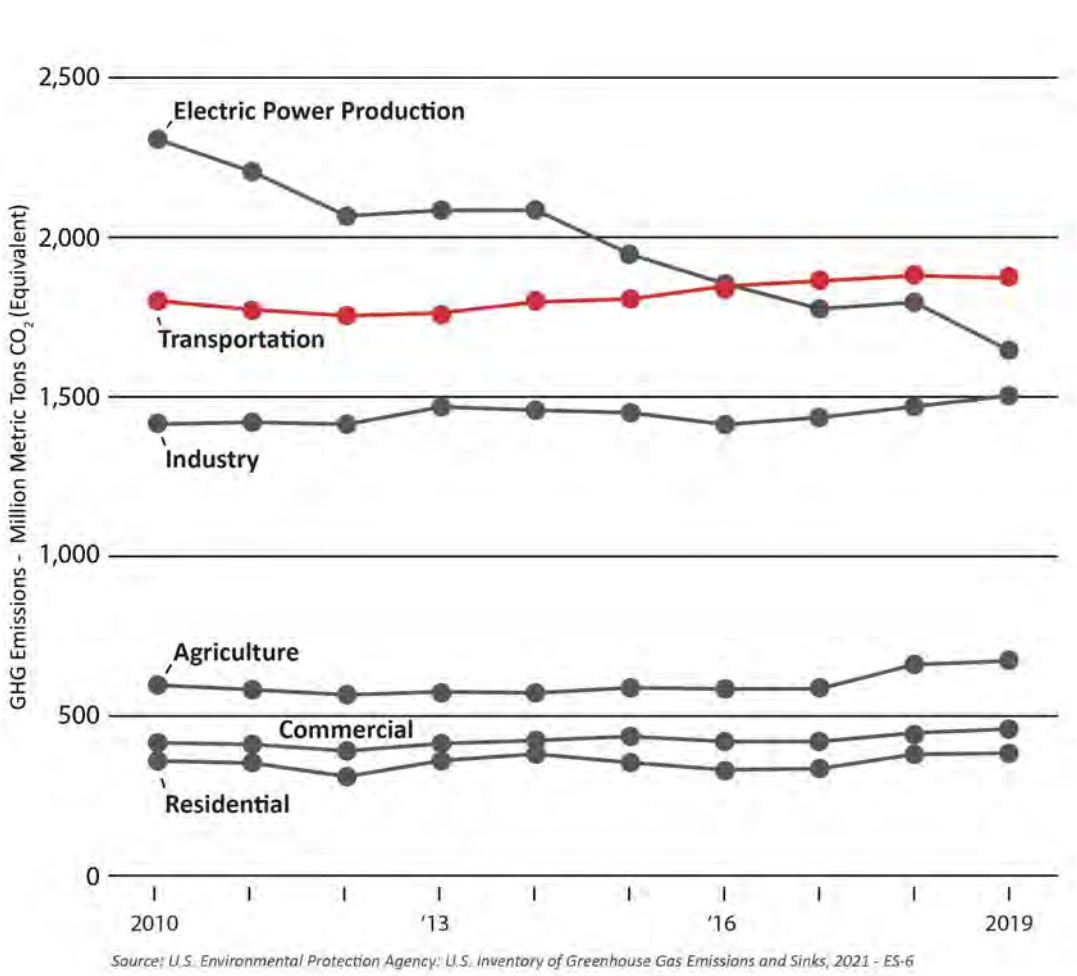


Figure 2.12: U.S. Greenhouse Gas Emissions by Economic Sector (2000-2018)

The breakdown for transportation by vehicle type for the same period appears in Figure 2.13. The category producing the most emissions – passenger cars, small trucks, vans – comprises personally owned vehicles along with commercial vehicles in this size range that carry passengers or light cargo. This category, to which we all contribute as consumers, must be a primary target of reform.

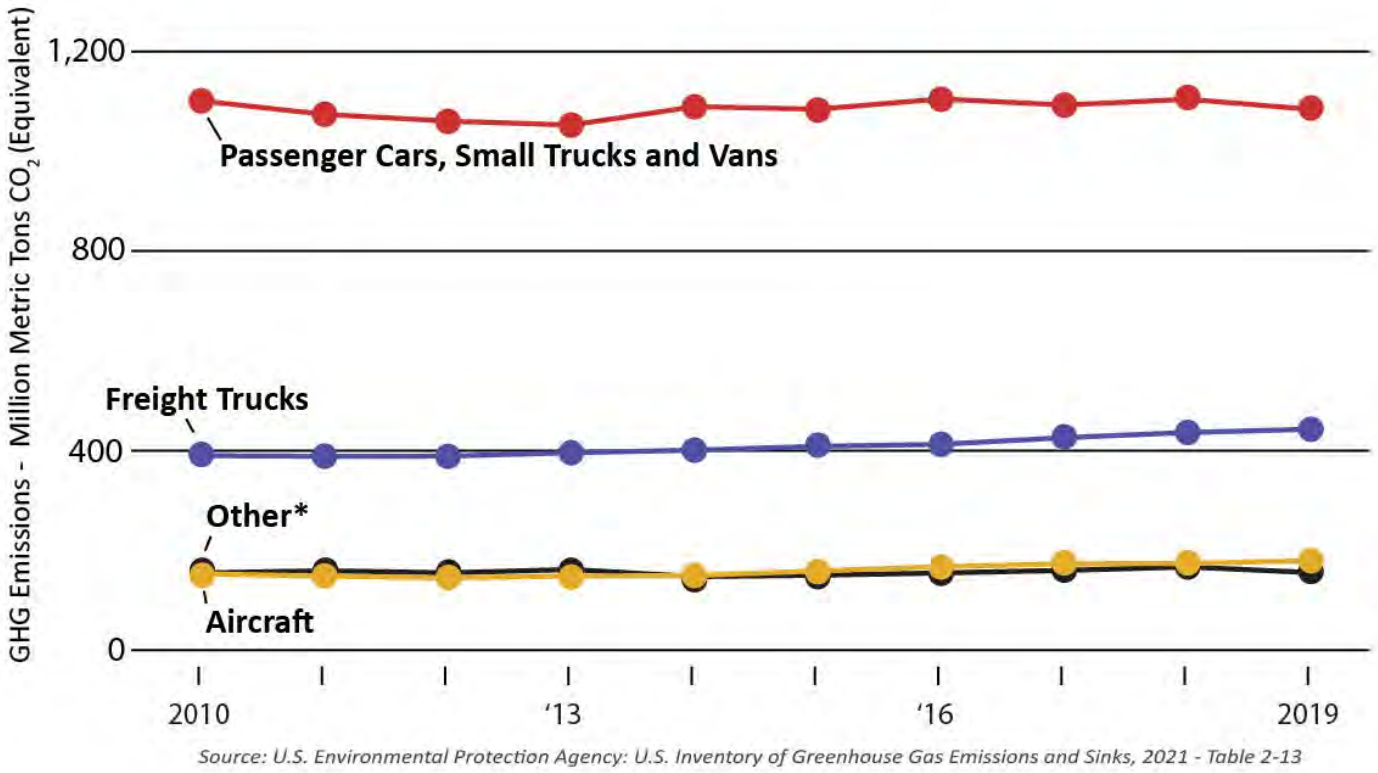
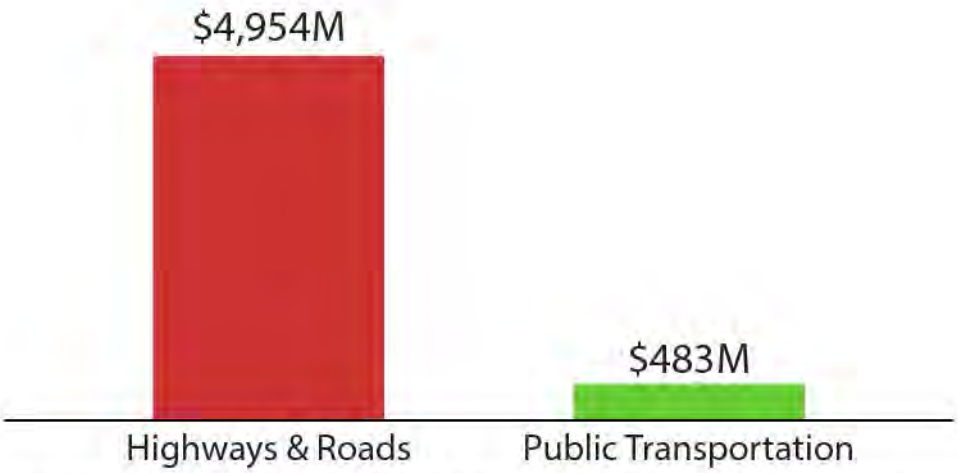


Figure 2.13 U.S. Transportation Emissions by Vehicle Type (2000-2019)
Passenger Cars, Small Trucks and Vans: includes all vehicles weighing 8,500 lbs or less (sedans, trucks, SUV's, and vans). This includes personal and commercial vehicles. *Other: includes motorcycles, ships and boats, rail, buses, pipelines, and lubricants.

Inadequate Funding of Public Transportation

Expenditures for public transportation are compared with those for highways and roads in Figure 2.31. The ratio for the biennium shown, 2017-19, is nearly 10:1, one favoring highways and roads. This ratio was about 7.5:1, two decades ago and has grown steadily since then.

Of the spending for public transportation, most goes to local transit and relatively little to statewide or regional public transportation, as shown in Figure 2.33. Intercity passenger rail receives miniscule support (0.2% of the transportation budget) and intercity bus receives no state support.



Sources: *Wisconsin Department of Transportation: 2020-2021 Budget Trends, Tables T-TR1, T-3, T-23 (Passenger Rail column only); Legislative Fiscal Bureau, Informational Paper - 37, Transportation Aid (2021), Informational Paper - 42, Local Transportation Assistance Programs (2021); Private Communication on County Highways and Local Roads, Division of Transportation Investment Management, WisDOT*

Figure 2.31 Allocation of Transportation Funds: Highways and Roads vs. Public Transportation, 2019-2021 Biennium

Sources: *Wisconsin Department of Transportation: 2020-2021 Budget Trends, Tables T-TR1, T-3, T-23 (Passenger Rail column only); Private Communication on Regional Services, Division of Transportation Investment Management, WisDOT*

Figure 2.33 Allocation of Public Transportation Funds According to Typical Travel Distance, 2019-2021 Biennium

Public transportation is important for reducing GHG emissions, especially for statewide travel. Beyond this, it offers efficient ways of dealing with many of the other shortcomings detailed in this chapter.

GHG emissions from aircraft shown in Figure 2.13 are about 9% of the total and the trend is a slight decline. Emissions at high altitudes are especially serious because water vapor is a greenhouse gas and persists for long periods where the concentration is too low for it to precipitate. Furthermore, as electrification and related technologies reduce emissions from ground vehicles, it is not clear that comparable gains can be achieved for aircraft.

An important step states can take to reduce aircraft emissions is to provide attractive alternatives to air travel. The highest emissions per passenger mile for aircraft are for short flights, 50-500 miles. For distances in this range, fast rail or express bus services would be more convenient and far less costly but are only sporadically available in Wisconsin (see below). Indeed, rail travel should be competitive for even much longer distances but existing Amtrak service is limited in scope and not dependable.[3]

Large Populations Poorly Served or Not Served at All

Wisconsin's public transportation system fails to meet the needs of a large and increasing population, namely, those who cannot drive or who might prefer to use public transportation. Those unable to drive include many who are disabled, many seniors, and all children who are too young to drive.[4]

Many others, though able to drive, would prefer to use public transportation for some or all of their needs if convenient services were available. Ownership of a car is expensive, with an annual cost nationwide of $9,561 in 2019.[5] For residents of a congested city, owning and using a car may be inconvenient and even more costly. Young adults like to live in areas where good public transportation services make it unnecessary to own a car.[6] Suburban residents who work in a city may tire of wasting time commuting in gridlock. People who find it convenient to drive for local trips might prefer to take a train for long trips if fast, dependable rail options were available.

It is useful to consider local and regional transit together as both are involved in metropolitan areas. Individual cities may have local transit systems but the need is for a regional system that crosses municipal boundaries. The efficient way of doing this is for the municipalities involved to form a Regional Transit Authority (RTA) – an agency empowered to plan, fund and operate a transit system. However, in 2011 the State Legislature and Governor Walker banned the creation of RTAs and dissolved existing RTAs in Dane County and Southeast Wisconsin.[7]

As an illustration, consider the Madison Metro routes shown in Figure 1.03. Most routes are confined to the city itself. The few routes that extend into suburbs are made possible by special arrangements between Madison and individual suburbs, often to facilitate travel to a major employer. Only an RTA could provide good service to the region as a whole.

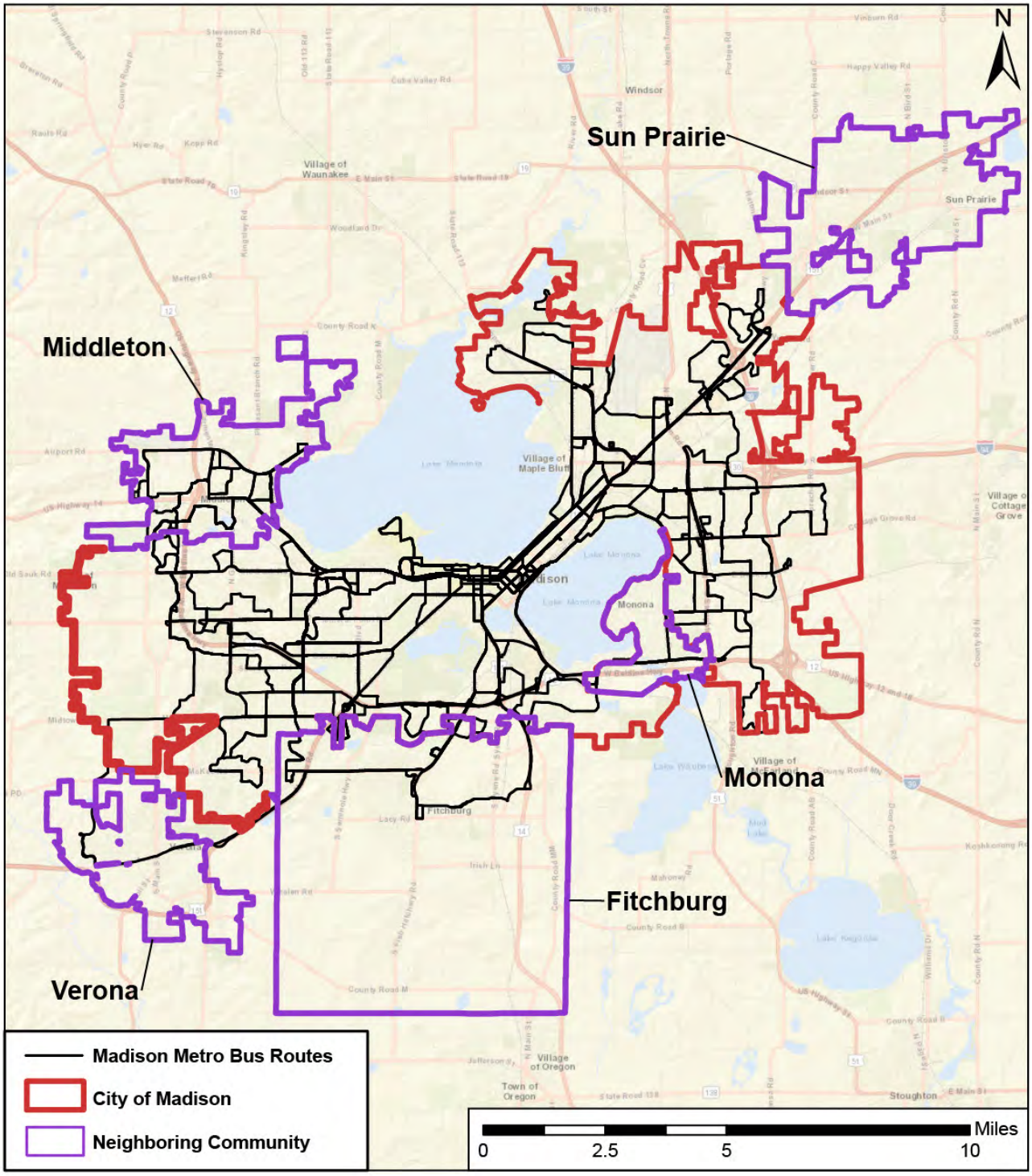


Figure 1.03: Madison Metro Routes

The Milwaukee County Transit System (MCTS), described in Chapter 1, presents a somewhat different case. As a countywide system, it routinely crosses municipal lines. However, to extend routes into adjacent counties, perhaps to reach major employers, it needs to make special arrangements. The region as a whole does not have anything like the kind of transit service it could have with an RTA.

These shortcomings are replicated throughout Wisconsin. A 2014 study of transportation in nine Wisconsin cities and metropolitan areas found a common theme. Public transportation services between residential areas and major employers are often nonexistent or severely limited in frequency and service hours. Interviews with workers showed that many have to choose between living in high-cost areas or bearing the expense of owning a car.[4]

Statewide ground-level public transportation consists of intercity passenger rail and intercity bus services. Figure 2.41 shows existing passenger rail routes. The only statewide intercity rail service is along the Chicago-Milwaukee-Minneapolis corridor. There is no service to Green Bay, the Fox Valley, or to popular tourist destinations such as Door County, Ashland or Bayfield, or north-central Wisconsin with its lakes, rivers, parks and forests. Twenty-two cities in Wisconsin with populations over 25,000 are not served by intercity passenger rail. Even Madison is not served by rail despite being Wisconsin's fastest growing city, the site of the State Capitol and home to the main campus of the University of Wisconsin.

Tourism is a major and growing feature of Wisconsin's economy but most tourist destinations are a long drive from population centers such as Chicago, southeast Wisconsin and Minneapolis. Congestion of highways on summer weekends tells us that fast passenger rail service could bring a significant boost in business along with a major reduction in GHG emissions.

Figure 2.41: Statewide Intercity Passenger Rail Service in Wisconsin

The sparsity of passenger rail is only half the story. The Empire Builder, between Minneapolis and Chicago, has an average speed of only 50 mph. At times it may experience serious delays sitting on a sidetrack waiting for a freight train to go by.[8] This is because the tracks are leased from two companies, BNSF and Canadian Pacific Railways, whose freight trains have priority. The other major intercity passenger route, the Hiawatha, between Milwaukee and Chicago, has better access to tracks and offers much better service, but this service is still a far cry from what could be offered with electrification, dedicated tracks and rerouting or fencing to allow higher speeds through populated areas.

These shortcomings of passenger rail are a direct result of indifference of state leaders toward public transportation. In 2010, the incoming state administration rejected a federal grant – after it had been awarded – that would have fully funded infrastructure upgrades for a Madison to Milwaukee high-speed rail corridor. This included rail upgrades, new locomotives and passenger cars and all of the costs associated with design and construction.[9] Until state leaders become more supportive, passenger rail will continue to languish.

Intercity bus lines offer service to many areas of the state not served by passenger rail, as shown in Figure 1.21. These services are valuable, as they may offer the only way for people who do not have a car to reach these areas and fares are modest. But long bus trips are time-consuming and offer few amenities. Given the shortcomings of intercity bus service, people with a car will prefer to drive and many others will not travel long distances to these areas at all.

In short, for fast statewide travel with good amenities and no GHG emissions, there is no substitute for fast electrified rail.

Further enhancement of statewide public transportation would be achieved if intercity train and bus schedules were coordinated so that a trip could be planned making use of both modes. The uncertainty of Amtrak arrival times makes such

planning impossible now. If the state were to commit funds to support improvement of Amtrak service in Wisconsin, especially that of the Empire Builder, so as to facilitate coordination of schedules, intermodal travel would come as an additional benefit.

Infrastructure for walking and biking is also lacking in many communities. Major barriers include an absence of funding and the removal of eminent domain power to build walking and biking infrastructure. Active transportation has the capacity to greatly reduce emissions while promoting positive health outcomes. 21% of car trips travel one mile, a distance than can be walked in 20 minutes. Another 24% of car trips travel one to three miles, a distance that can be biked in 20 minutes.[10] If these trips could be replaced, it would greatly reduce our transportation emissions. In order to get people to take active transportation over their car, infrastructure must be designed to enhance safety. In urban areas, this includes sidewalks and cross-walks for pedestrians and marked lanes or separated paths for bicyclists. More active transportation infrastructure needs to be developed to help cross major barriers like highways.

Impacts on Health and Safety

Beyond emitting GHGs, fossil fuels are notorious for producing pollutants such as nitrogen oxides (NO_X), sulfur oxides (SO_X) and arsenic. These can cause serious health effects, including damage to neurological, cardiovascular, respiratory, reproductive and immune systems.[11] Human suffering from such health effects – not to mention their dollar costs – is so great that it alone makes a strong case for reforming the system.

Health impacts are particularly serious for communities of color, which are exposed, at times, to 75% more vehicle emissions than are predominately white neighborhoods. This is a result of the tendency to route commuting corridors through low-cost areas.[12] Residents of these neighborhoods also make up a disproportionate number of pedestrian deaths, as shown in Milwaukee County data.[13]

Inherent Inefficiency of the System

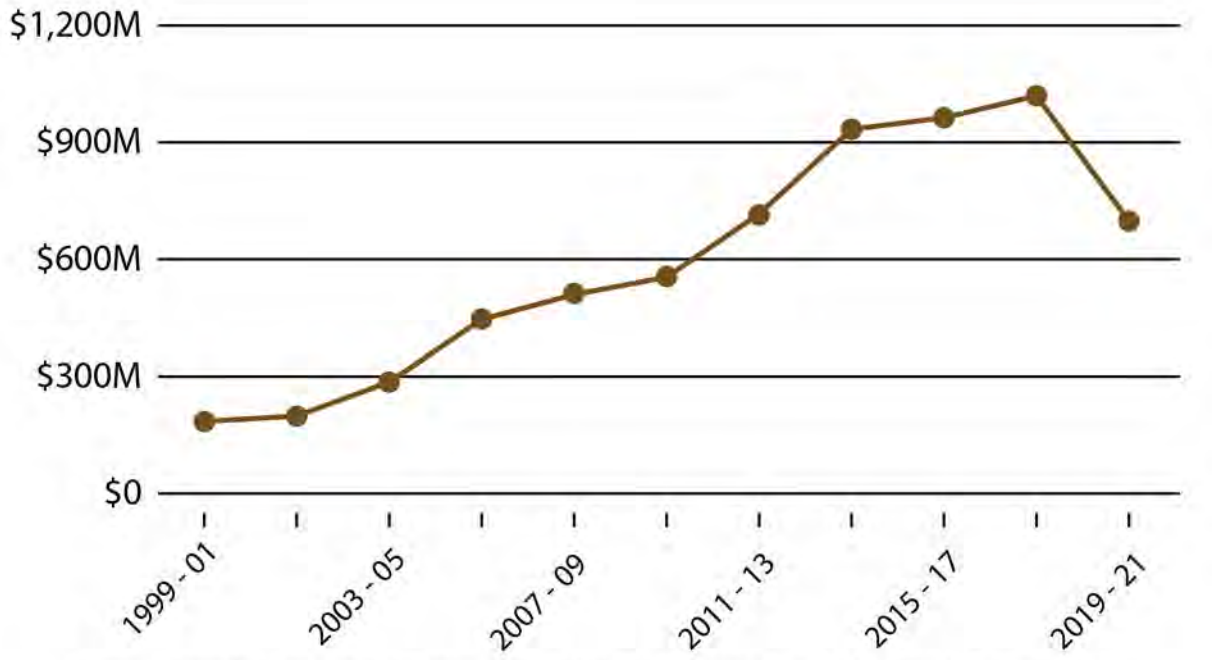
Any transportation system will be challenged by the rhythm of demands. Large numbers of people need to commute from residential areas to employment centers and back. On holidays and weekends, many will travel longer distances to visit family and friends, or to enjoy recreational attractions. For most of the time, traffic is well below these peaks. Our current system is ill suited for accommodating such changes in demand. Building commuter routes and major highways with peak demands in mind is inefficient and costly.

Public transportation offers a far more efficient solution to the problem posed by large fluctuations in demand. The capital and operating costs of bringing additional buses into service, or of adding passenger cars to a train, are much lower than costs associated with widening commuter corridors or major highways.

The high cost of building and maintaining our current network of highways and commuting roads is becoming unsustainable. One sign of this is the increasing use of debt to finance new highways, as shown by the rising debt service costs, Figure 2.51. Another sign is the increased use of General Fund revenues to cover transportation costs, as shown in Table 2.55.

Poor Land Use

Another cost of our inefficient transportation system is the impact on land use. In cities, it is hard to find space for further expansion of commuting corridors in a vain effort to satisfy rush-hour demand. In Milwaukee, urban freeways have disrupted minority communities, displacing residents and businesses to accommodate freeways that bring vehicle emissions and noise while isolating the remaining neighborhoods from the larger city.[14] In rural areas, unnecessary paving of agricultural and forested lands is poor use of land and disfigures the landscape of the state.



Source: Wisconsin Department of Transportation: 2020-2021 Transportation Budget Trends, Tables T-8, T-41

Figure 2.51: Cost of Transportation Debt Service (1999—2021 Biennia)

Biennium	Amount
2011-13	$275M
2013-15	$406M
2015-17	$235M
2017-19	$341M
2019-21	$177M

Source: Legislative Fiscal Bureau, 2021 Informational Paper #37, Transportation Finance - Table 7

Table 2.55: Use of General Funds to Cover Transportation Costs (2013-2019)

Conclusion

The shortcomings of our transportation system present a powerful case for reform. Add to this the imperative of getting to zero net carbon emissions by 2050 to avoid the danger of catastrophic climate change and the need for action becomes urgent.

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Chapter 3:
Available and Emerging Technologies

The purpose of this Chapter is to summarize the available and emerging technologies that are likely to be most useful for transforming Wisconsin's transportation system from one that relies on fossil fuels for energy to one that uses no fossil fuels and produces no net emissions of greenhouse gases.

The central feature of the transition will be replacing internal combustion engines (ICEs) with electric motors. Electrical vehicles (EVs) offer many advantages and their share of the market is rapidly expanding, with a projection to reach two-thirds of all global vehicle sales by 2040.[1] EVs are quieter than ICE-powered vehicles and are more energy-efficient, requiring only about a third as much energy input for the same vehicle travel (see footnote A)*. A further advantage of EVs is "regenerative braking", which allows recovery of up to half the energy otherwise lost by frictional braking. The energy recovered is stored as electrical energy, further reducing the net energy required for vehicle propulsion.[5]

**Footnote A: There are theoretical and practical considerations. Thermodynamics allows complete conversions between electrical and mechanical energy, as in an electric motor or electric generator. In practice, there are frictional losses in the rotors and resistive losses in the wiring, but the efficiency is still typically 80% or better.[2] For ICEs, the input energy comes from combustion of the fuel, and there is a thermodynamic limit on the fraction of the input energy that can be converted into mechanical work. For automotive ICEs, this is about 67%.[3] In practice, friction and other imperfections in operations mean that, at best, only about 30% of the input energy is converted into mechanical work propelling the vehicle.[4]*

The Importance of Decarbonizing the Electrical Grid

Much of the power for electric vehicles will come, directly or indirectly, from the electrical grid. Steps taken to reduce GHG emissions by electrifying transportation will not be effective if power plants feeding the grid continue to produce such emissions. The generally accepted target date for decarbonizing the grid is 2030.[6]

The transition to electric vehicles will create new demand for electrical power. With increases in demand from other sectors of the economy, there could be a doubling of demand by 2030. Wisconsin is not on track for meeting this timetable, yet doing this is fundamental to achieving a zero-carbon transportation system by 2050.

The pathway for moving from fossil fuels to renewable energy sources for generating electrical power is clear. The state of Wisconsin should join the growing list of states committed to doing that by 2030 or soon thereafter.

Providing Electrical Power to Vehicles

Whether we're talking about cars, trucks, buses, trains, boats, or bicycles, electrification means replacing an existing method of propulsion with electrically powered motors. To provide the electric power, various methods can be used.

For trains, since the early 1900's, this has been done with overhead wires, which allow speeds of up to 220 miles per hour.[7] For commuter rail, power is often provided through the rails. Many electrified bus systems use overhead wires. These methods amount to extending the electrical grid along the route in an accessible manner.

For electrification and expansion of its statewide passenger rail service, Wisconsin will have to coordinate plans with Amtrak and with neighboring states, especially Illinois. The long-term goal is complete electrification. It may be that new technologies will make efficient onboard sources of electrical power available (see following pages). Otherwise, it is expected that power will be provided through overhead wires.

If overhead wires are to be used, there will be times, while the necessary infrastructure is being constructed, when this source of electrical power is available for only parts of an entire route. During this period, locomotives should be equipped to use this source of electrical power where it is available and to generate electrical power on board where it is not. This requirement is met well by "dual-mode" locomotives, already common in the U.S.[8]

Dual-mode locomotives have an electric motor and can either take power from an external source or generate electric power on board. Currently, the generator is powered by a diesel engine but in a fossil-free system an alternative source would be employed, perhaps a fuel cell using a non-carbon fuel (see next page).

Electrically powered automobiles have electric motors to propel the vehicle and need an onboard source of electrical power for the motor. Today, most of these vehicles use batteries, but alternatives such as fuel cells are being developed, as discussed in the following section. The required infrastructure is charging or refueling stations along well-traveled routes.

Batteries, Fuel Cells, and Supercapacitors

The lithium-ion battery generally used in electric automobiles today performs well but the limited energy capacity, Figure 3.1, constrains the full-charge driving range. Charging stations may not be conveniently located and recharging en route can be time consuming. Battery technology is continually improving, but these limitations are inherent, so there is an interest in developing alternative sources of onboard electrical power.

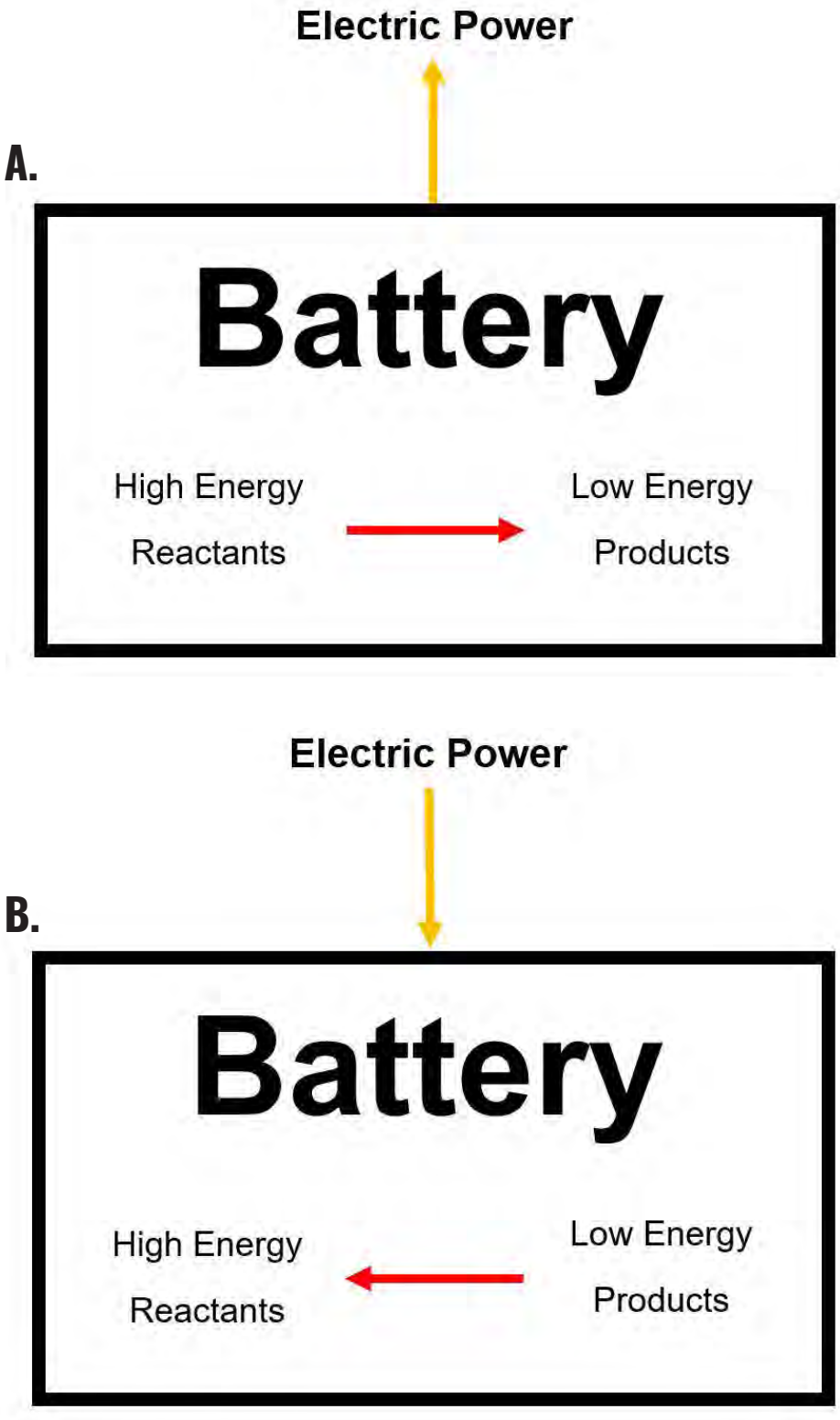

Figure 3.1: Battery operation (a) delivering power, (b) being recharged.
Note: The energy capacity (energy available when fully charged) is fixed and limits the full-charge driving range.

Fuel cells (FCs) offer an attractive alternative to batteries. Like batteries, fuel cells get their energy from a chemical reaction. The difference is that, in the case of FCs, fuel and oxygen (from air) are fed into the cell continuously and the products of the reaction are expelled, as illustrated in Figure 3.2. Electrical power is produced for as long as the fuel supply lasts.[9]
FC-powered models of cars are under development by several manufacturers

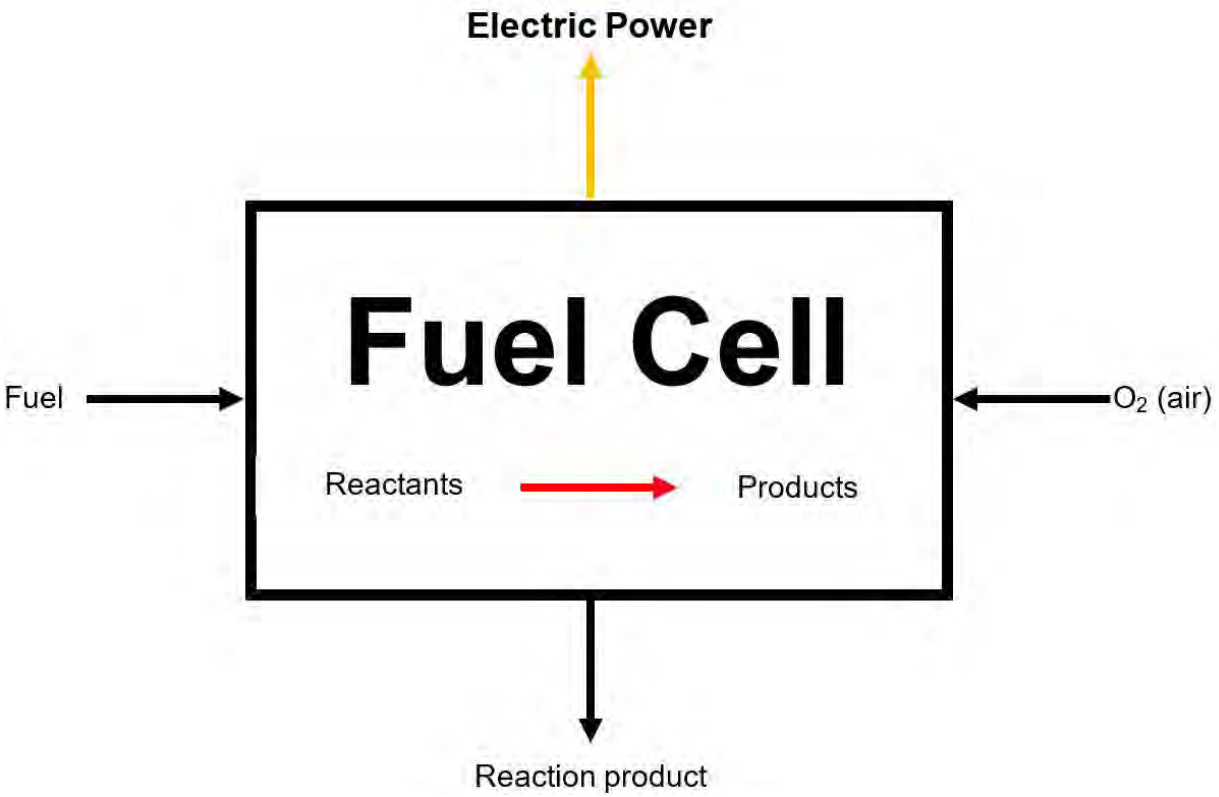

Figure 3.2: Fuel cell operation, showing chemical reaction, inputs and outputs
Note: The cell delivers power for as long as the fuel supply lasts.

and there is little reason to doubt that FCs will have a major role in powering electrical automobiles in the future. It should be feasible to develop FCs to power larger vehicles such as marine vessels and locomotives.[10,11] If FCs could power locomotives, the need for overhead wires or electrified rails would be eliminated.

Supplementary devices can help overcome limitations of batteries and fuel cells. The supercapacitor (SC) is such a device. Like a battery, it can be used to store electrical energy reversibly in an EV. The energy capacity of an SC is much less than that of a battery, but it can deliver a pulse of power faster and the recharge is also faster.[12] SCs are likely to be used in conjunction with a battery or fuel cell to provide surge power when needed or to facilitate regenerative braking. As the technology evolves, SCs may have enough capacity to propel electric buses between charging stations. The name comes from the fact that the SC has some of the electrical characteristics of an ordinary capacitor but its capacity for energy storage is orders of magnitude larger.

Fuels for Fuel Cells

The essential characteristics of a fuel for a fuel cell are that 1) the fuel should be produced from readily available, non-fossil materials 2) the products of the cell reaction should be non-polluting and 3) the overall process should constitute an economically feasible cycle. Much current research is devoted to developing and refining potential fuels to optimize performance. Two promising examples, hydrogen and ammonia, follow.

Hydrogen (H_2)

The inputs and outputs of an H_2-based fuel cell are shown in Figure 3.3. The energy released by the chemical reaction within the cell produces electrical power.

In a decarbonized economy, H_2 would be produced by splitting of water using electricity from solar power, hydro power, or other renewable sources.[13]

From an environmental standpoint, H_2 is an ideal fuel, since the only reaction product is water.[14] The problem is that storage and distribution are difficult because H_2 is very reactive and the energy density is low. Storage as a liquid requires cryogenic temperatures. To overcome these problems, the gas can be stored in special containers that are resistant to corrosion and can sustain pressures as high as 1000 bar[15] (See footnote B)*. At such high pressures, special precautions must be taken. If the gas leaks into a poorly ventilated space, an explosive mixture with air can be formed.

**Footnote B: The unit of pressure, bar, is the standard barometric pressure, approximately 14.7 lb./sq in., so even 700 bar is over 10,000 lb./sq in.*

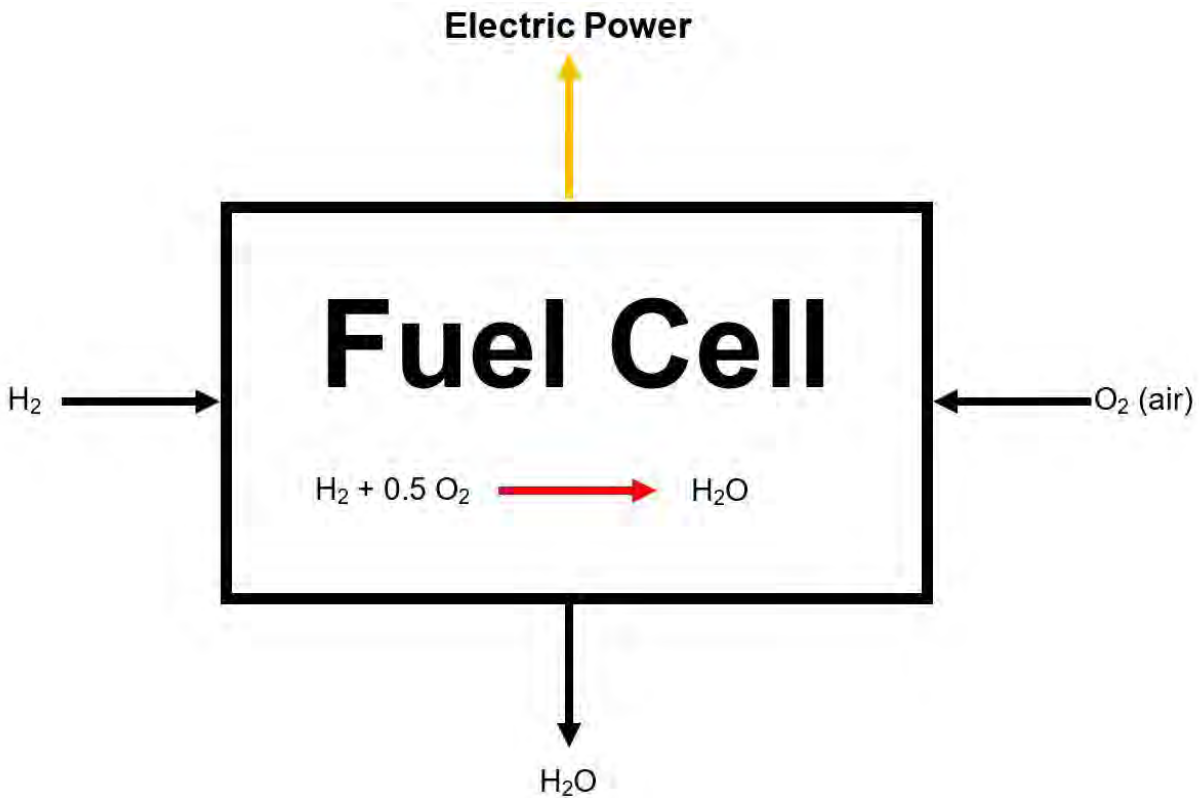

Figure 3.3: H_2 fuel cell operation, showing overall chemical reaction, inputs and outputs

An alternative to storing and distributing H_2 as a liquid or gas is to use "hydrogen carriers" -- liquid or solid substances that contain hydrogen and release H_2 on demand.[15] These can be stored at EV refueling stations.

Several auto manufacturers are marketing H_2 fuel-cell powered models in the United States.[15] There are H_2 fueling stations throughout the developed world.

Ammonia (NH_3)

In a direct ammonia fuel cell (DAFC), the inputs are NH_3 and oxygen from air and the output is nitrogen and water, as shown in Fig. 3.4.[16] Ammonia is a versatile fuel and can also be used as a hydrogen carrier and as a fuel in internal combustion engines.[15]

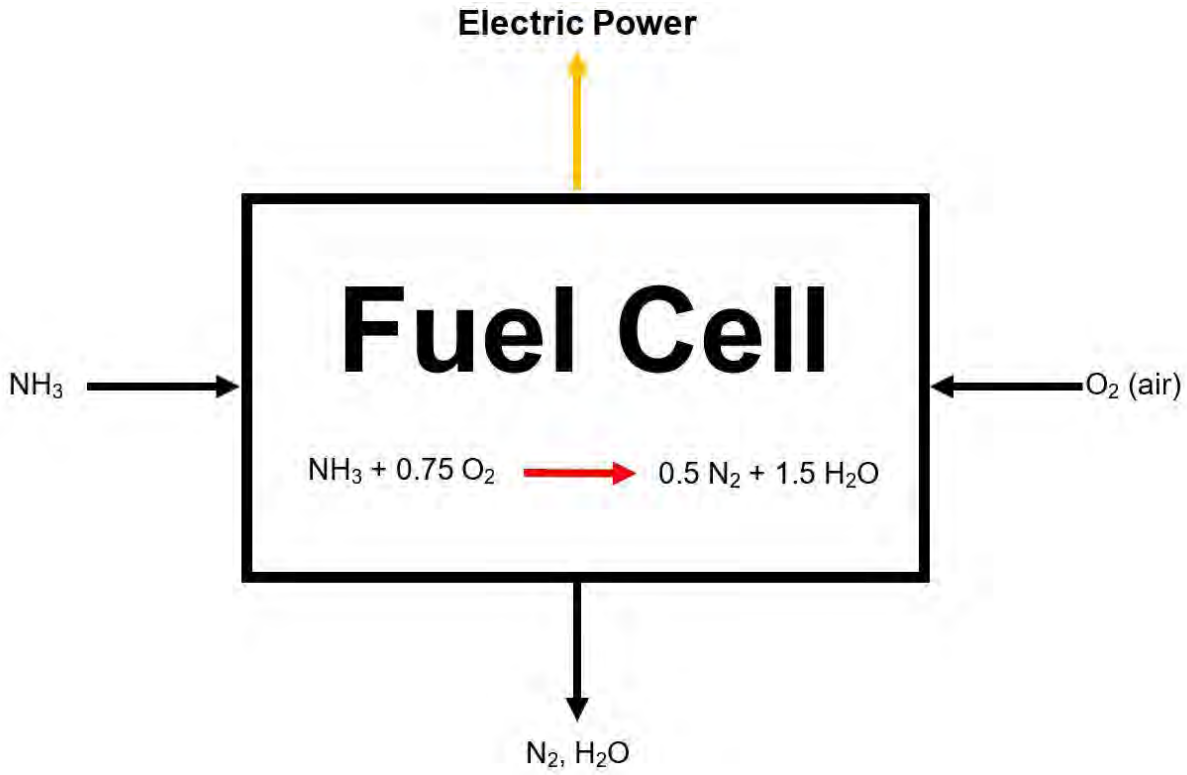

Figure 3.4: Direct Ammonia Fuel Cell (DAFC), showing overall chemical reaction, inputs and outputs

Ammonia is readily available. For a century, it has been a huge part of the agricultural economy, making fertilizers available to farmers and gardeners. It is produced from nitrogen from air and fossil chemicals. Within the past decade or so, it has come into serious consideration as an alternative, non-carbon fuel.[17] Fortunately, it can be produced from nitrogen and water, without use of fossil chemicals.[18]

Autonomous Vehicles

Autonomous Vehicles (AVs) are automotive vehicles that navigate with no human attention. Given a map, navigating from Point A to Point B is relatively easy. The challenge is to sense the environment, including weather conditions, road irregularities, other vehicles and pedestrians, to anticipate what other vehicles and pedestrians may do, and to respond appropriately. There is much discussion of the use of dedicated lanes, i.e., lanes restricted to AVs only or to human driven vehicles (HDVs) only. Model calculations indicate that good lane management by traffic authorities can improve traffic flow and reduce congestion.[19] With all these challenges to operation of AVs, it must be noted that they do not exhibit common shortcomings of human drivers, such as drowsiness, speeding, and following too closely.

Decarbonizing Aviation

The airline industry has done much to decrease emissions per passenger-flight, through improved efficiency of engines and operations. But these gains have been overwhelmed by the growth in air travel, so that the industry's contribution to global warming is increasing significantly.[20] The most serious drivers are emissions of CO_2 at all altitudes and of water vapor at high altitudes, water being a greenhouse gas which persists when the concentration is too low for precipitation. Much research has gone into finding alternatives to the aircraft fuel most commonly used today, kerosene.[21,22] Ammonia and hydrogen are the most likely non- carbon alternatives. Either of these could be burned as a fuel or could feed a fuel cell. Especially promising is a blend of ammonia and hydrogen which can serve as fuel for jets as well as for propeller-driven aircraft.[23] There is also the prospect that, as various technologies evolve, entirely new methods of propelling aircraft may emerge.

Capture of CO_2 From the Atmosphere

Capture of CO_2 from the atmosphere can compensate for emission of an equivalent amount of CO_2. Several methods for doing this on a large scale have been proposed.[24,25] The recovered CO_2 can be used to prepare numerous useful chemicals rather than being sequestered as a gas.

Summary

The key to eliminating GHG emissions from ground-level and marine transportation is electrification. Power for trains or for local transit systems can be provided through overhead wires or through the rails. For surface vehicles which cannot access these sources, electrical power can be provided by onboard devices such as batteries, fuel cells, or supercapacitors. All of these strategies for eliminating GHG emissions hinge on decarbonization of the electrical grid.

The future for air transportation is less clear. Replacing fossil fuels with alternatives, especially hydrogen and ammonia, can eliminate emissions of CO2 but emissions of H2O at high altitudes, which also contribute to global warming, remain a problem. Development of fuel cells for aircraft and other technologies can facilitate the transition to alternative fuels.

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Chapter 4:
Pathways for the Transformation

In this chapter, we describe pathways that can take us from a fossil fuel dependent transportation system that leaves much of our population poorly served to a transportation system that has zero-net carbon emissions and works for everyone. These pathways are defined by long-term strategies that we call Solutions. A variety of policies will enable us to achieve these solutions. Most of the policy recommendations outlined below can be implemented immediately, but policies will evolve over time as the landscape changes.

The solutions we propose are as follows:
1. Decarbonize Electric Power Generation in Wisconsin
2. Rebalance Priorities for State Funding of Transportation
3. Expedite Electrification of Public Transportation
4. Enhance Infrastructure for Private Electric Vehicles (EVs)
5. Support Active Transportation
6. Encourage Smart Growth and Compact Development of Communities
7. Identify Emerging Technologies and Prepare to Use Them

Solution: Decarbonize Electric Power Generation in Wisconsin

Wisconsin should set a goal of having a 100% carbon-free electrical grid by 2030 so that EVs can operate carbon-free. This can be achieved by working with utilities to decommission existing coal and natural gas plants and to use wind and solar energy to produce electrical power. The combination of a carbon-free electrical grid and increased EV usage will remove a significant amount of greenhouse gas emissions.

To help speed the transition, the Public Service Commission (PSC) when approving construction or acquisition of new power plants or upgrades, should take environmental impacts into account along with the cost to rate

payers. The PSC should minimize long-term costs to rate-payers subject to the constraint that production of electrical power in Wisconsin be carbon-free by 2030. Also, PSC review and approval should be required for power plant construction by third parties.

Solution: Rebalance Priorities for State Funding of Transportation

State spending for transportation should be shifted to provide more support for public transportation and less support for highways and drivers of personal automobiles. At the local and regional level, the focus should be on expanding transit service that helps people get from home to their jobs, medical care, school, recreation, and other basic services. Special consideration should be given to service that supports low-to-moderate-income communities. To reduce statewide emissions, there should be a major shift away from funding highway construction to improving statewide passenger rail and intercity bus services. Statewide passenger rail must be made faster, with dependable arrival times. There is also a need to provide intercity bus service to many areas of the state that currently lack service.

State Funding Policy: Require WisDOT to perform carbon audits for all projects to show the environmental impacts and ensure these are consistent with long-term climate change goals.

When considering transportation projects, WisDOT should perform climate and environmental justice impact analyses to help determine the value of the project. When making a final decision about a project, WisDOT must consider the carbon and environmental justice impacts as top criteria.

State Funding Policy: Require WisDOT, when proposing a new roadway or expansion of an existing roadway, to also offer an alternative that would address the same problem but would do so by expansion of public transportation or active transportation alternative.

When considering transportation projects, WisDOT should explore alternatives that address safety, operational, and congestion problem outside of highway expansion and share them with the broader public. The inclusion of public transportation and active transportation elements instead of expansion projects would reduce overall emissions, address congestion issues, and potentially cost less than expansion.

Statewide Transit Policy: Invest in new passenger rail routes that add frequency and expand statewide access. Explore opportunities for high speed rail.

Improved state-wide passenger rail will efficiently move a large number of people while reducing carbon emissions. Wisconsin should invest in passenger rail lines, separate from freight, to allow fast, dependable service with reliable arrival times. These lines should be designed with the long term goal of full electrification and speeds up to 220 mph. This additional rail capacity could be safer and more convenient than driving, while helping to integrate our transportation network and economy with neighboring states. Wisconsin should reach out to Amtrak to support more service similar to the agreement between Amtrak, Illinois, and Wisconsin on the Hiawatha line. WisDOT should fund further studies that make the case for rail improvements. A new route between Green Bay and Milwaukee that services the Fox Valley would be a good place to start. See Figure 4.2 – Future Passenger Rail Service in Wisconsin for more potential routes. Many passenger rail expansions could be achieved with minimal incremental costs by using existing freight railways and adding sidetracks to reduce delays.

Route	Date
1. Chicago, Milwaukee, Madison, Minneapolis	2025
2. Milwaukee, Fond du Lac, Oshkosh, Appleton, Green Bay	2030
3. Tomah, Eau Claire, Minneapolis	2030
4. Madison, Janesville, Beloit, Rockford	2030
5. Green Bay, Appleton, Stevens Point, Marshfield, Chippewa Falls, Eau Claire, Minneapolis	2030
6. Milwaukee, Sheboygan, Manitowoc, Green Bay	2030
7. Madison, Mt. Horeb, Dodgeville, Platteville, Dubuque	2050
8. Green Bay, Oconto, Marinette, Northern Michigan	2050
9. Green Bay, Sturgeon Bay, Sister Bay	2050
10. Eau Claire, Chippewa Falls, Rice Lake, Superior, Duluth	2050
11. Madison, Wisconsin Rapids, Stevens Point, Wausau, Rhinelander, Ashland, Superior, Duluth	2050

Table 4.1: Timeline for Passenger Rail Expansion in Wisconsin

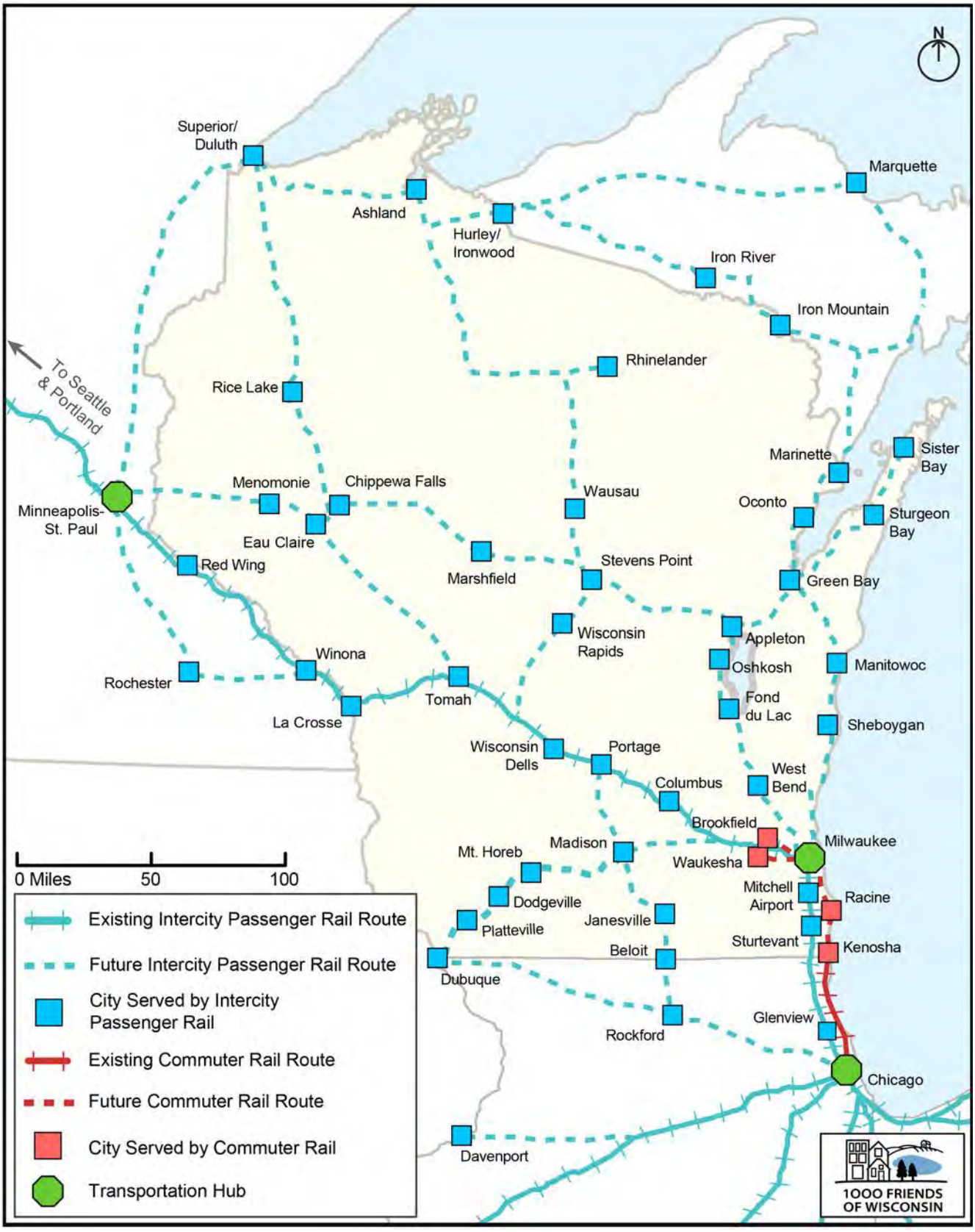

Figure 4.2: Future Passenger Rail Service in Wisconsin

Statewide Transit Policy: Plan a robust rail network in collaboration with Amtrak, Illinois, and Minnesota.

In order to make rail a more attractive travel mode than flying to Minneapolis and Chicago, it will be necessary to collaborate with neighboring states. Planning and constructing a network that connects the region's major metropolitan areas will require the input and coordination with neighboring states and Amtrak. Communication will be key because the political environment of each state is different and Amtrak, a federal entity, will have to overcome unique hurdles.

Wisconsin should dedicate additional staff time to the Midwest Interstate Passenger Rail Commission (MIPRC), an interstate compact that brings together Midwest states to promote and coordinate passenger rail efforts. To ensure that interstate routes between major transportation hubs are built in a timely and efficient manner, Wisconsin should publicly state its goals and take a leading role in the MIPRC.

Statewide Transit Policy: Invest in Intercity Bus Routes

To ensure that small and rural communities have access to statewide public transit, WisDOT should increase funding to the intercity bus program. This will connect every part of the state and provide more flexibility for those making short intercity trips that are impractical on passenger rail. Additional funding should be dedicated to a capital program that buys new, more comfortable buses that feature modern amenities.

Statewide Transit Policy: To facilitate intermodal travel, encourage coordination of schedules for Rail and Intercity Bus Routes.

Pulse-scheduling allows easy transfer between statewide and regional/ local public transportation. Getting the scheduling right will be critical to the success of the zero-carbon transportation system. The state should dedicate funding to a new division, likely at WisDOT, which monitors and administers statewide travel schedules.

This department would coordinate and assist local governments with their schedules to ensure that all forms of transportation are working together to facilitate easy use throughout the state's transportation system.

Regional Transit Policy: Reauthorize "Regional Transit Authorities" (RTAs) to improve regional, commuter, and rural transit.

Throughout Wisconsin, communities are trying to address transportation access issues across municipal boundaries. If communities vote to pass an RTA referendum in their region, it will have limited authority to impose taxes in the region it serves. Still, reauthorizing RTAs will allow cities, villages, and counties to address their unique transit needs.

Regional Transit Policy: Support opportunities for commuter rail, especially in Southeast Wisconsin.

In the Spring of 2011, the State ended plans for a commuter rail line linking Milwaukee and its southern suburbs including Kenosha and Racine. The route planned for fifteen roundtrips a day.[1] If RTAs are reauthorized, the Southeast Wisconsin Regional Transit Authority could restart this commuter rail project. If completed, the KRM commuter line would have improved efficiency in our transportation network, while improving access to jobs and education in Southeast Wisconsin. Other commuter lines should be explored, especially in the Milwaukee metropolitan area.

Local Transit Policy: Make a major investment in local transit by increasing funding to the Mass Transit Assistance Program.

The State should increase state transportation aids to inflationary levels, at a minimum, and allow local transit agencies to raise revenue above their levy limits to address their local transit needs. This should include capital support for bus rapid transit (BRT) projects along major corridors in communities.

Local Transit Policy: Support seniors and individuals with disabilities by increasing Specialized Assistance and County Assistance Programs.

For the next several decades, Wisconsin will see a growing population of seniors and people with disabilities.[2] To support this transition, the State should invest in more specialized transportation assistance, so that electric van and buses can be purchased to move our vulnerable populations around in a carbon-free manner.

Solution: Expedite Electrification of Public Transportation

Policy: Invest in the Electrification of Train Routes
Wisconsin should develop a plan to overhaul the passenger rail system with overhead wires.

Plans should start with the most heavily used routes and then spread throughout the system as new routes develop. In the interim, passenger rail should incorporate dual purpose locomotives that take advantage of electric infrastructure as it is developed and still use non-carbon power where infrastructure is lacking. Wisconsin may not have control over which locomotives Amtrak uses, but the State should push for models that have non-carbon sources of onboard electrical power. An all-electric passenger rail system, built in tandem with our neighboring states will remove greenhouse gas emissions from statewide and regional travel.

Policy: Create a capital assistance grant to help purchase electric buses for both transit operators and school districts.

Electric buses provide a number of significant advantages over traditional diesel buses. At the moment, electric buses have a higher capital cost than traditional buses, but cost less to maintain over the lifetime of the vehicle.[3] These capital costs will come down as the market for electric buses expands. With capital funding support from the state, Wisconsin's local transit networks can build a fully electrified transit fleet and school districts will be able to transition to all-electric buses.

Solution: Infrastructure for Private Electric Vehicles (EVs)

Policy: Build a statewide network of EV charging stations that support major travel corridors.

To support EV adoption, WisDOT should develop an EV infrastructure plan using a collaborative approach at the local and regional level, in partnership with utilities, interested businesses, and EV drivers. This plan should include uniform EV charging infrastructure that is interoperable with all vehicles and minimizes charging gaps. After the plan is complete, WisDOT should provide extensive funding to build charging infrastructure using highway rest-stops and public-private partnerships with existing gas stations and other interested businesses. Figure 4.3 highlights the early priorities for EV infrastructure, which should have a station at least every 25 miles along U.S. and State highways.

The long-term goal is to build a robust network that includes charging infrastructure at every rest stop, national and state park, and most traditional gas stations across Wisconsin. Funding should be provided to ensure that rural communities have equal access and that all charging locations are easily identifiable through road signs, state maps, and interactive websites.

Policy: Build a network of EV charging stations at major tourist attractions to support In- and out-of-state travelers.

If tourists in EVs are unable to access important locations around the state, then local communities will suffer. Locating charging infrastructure at key locations will allow Wisconsin's tourism industry to seamlessly transition. Figure 4.4 highlights some key tourist areas that would benefit from having dedicated EV charging stations.

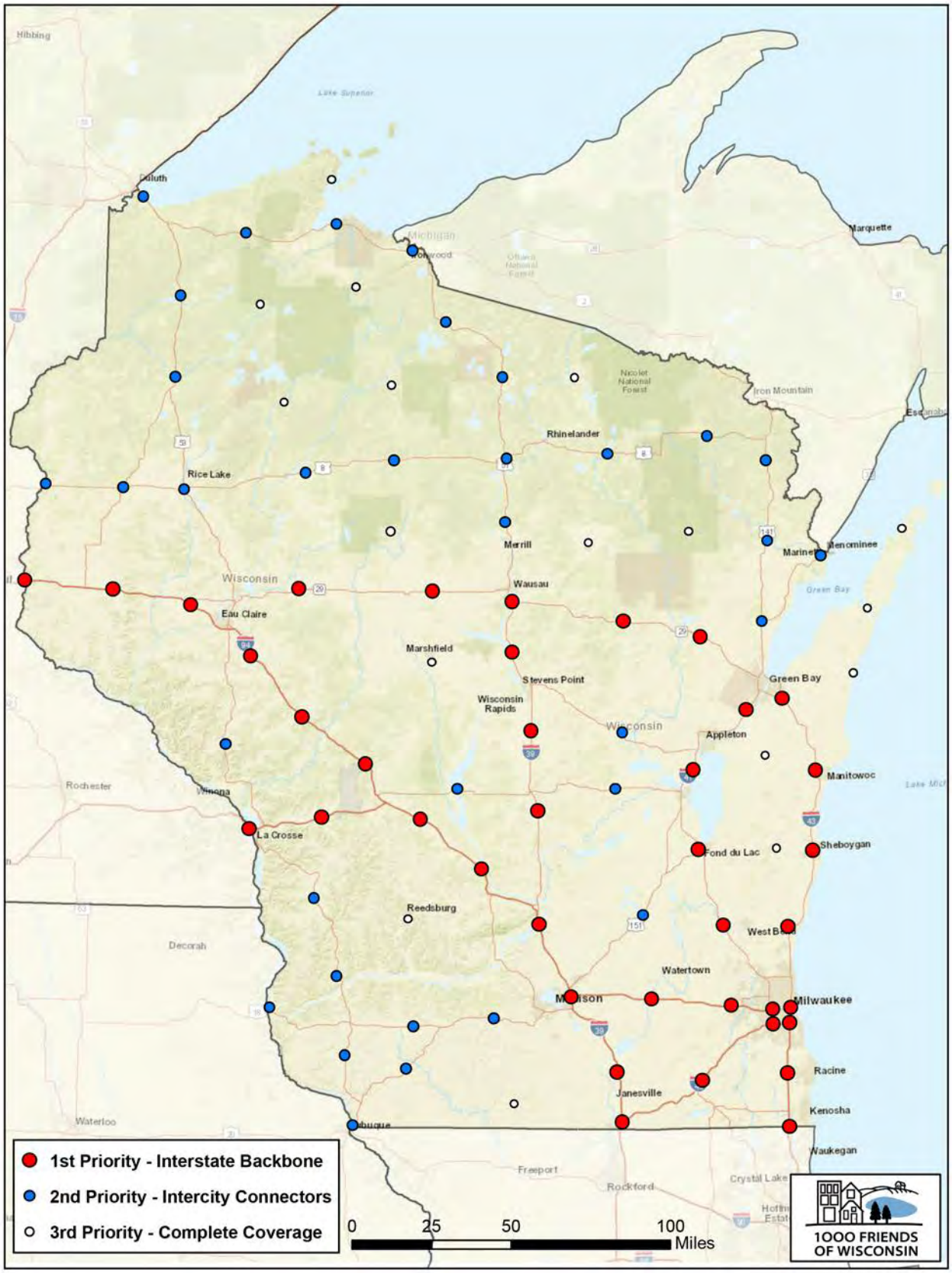

Figure 4.3: Future Wisconsin Electric Vehicle Charging Station Infrastructure

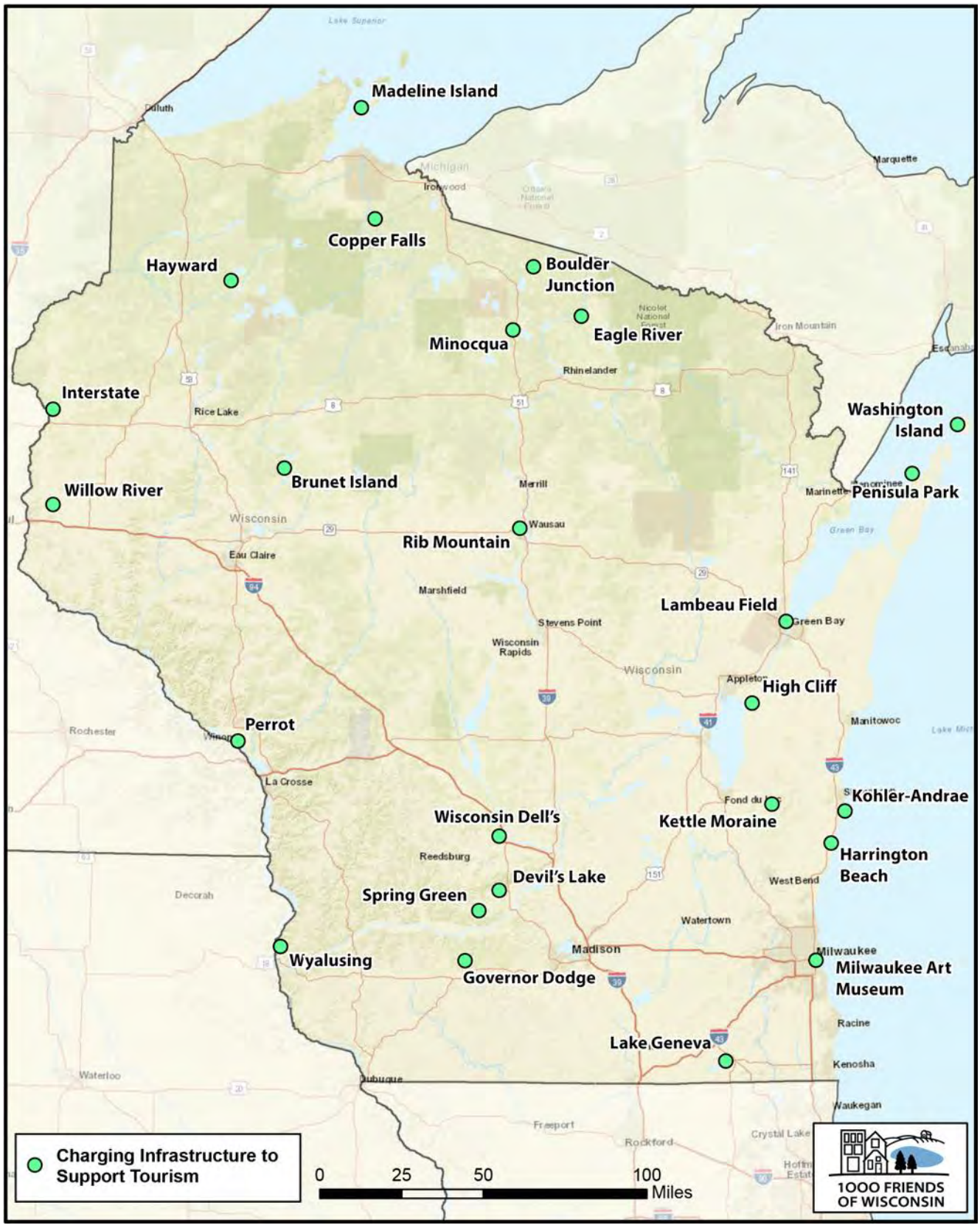

Figure 4.4: Future Wisconsin Electric Vehicle Charging Station Infrastructure - Stations to Serve Tourists

Policy: Create a statewide campaign to educate about the benefits of EVs.

WisDOT should create a Wisconsin-wide EV educational program tailored for residents and dealerships. The program's goal would be to increase exposure to EVs. This educational program will ease the transition by providing consumer buying guides, charging guides for commercial businesses, and by offering the opportunity to test drive EVs to demystify the experience. Many surrounding states have undertaken similar efforts, including Minnesota's "Drive Electric Minnesota."

Solution: Support Active Transportation

Policy: Reinstate Wisconsin "Complete Streets Law" on projects receiving state funding.

Complete street laws encourage the development of active transportation infrastructure by requiring that all modes of transportation be considered when designing a road. In 2015, Wisconsin changed its complete streets policy, removing many of the regulations. WisDOT should return the policy to its original language so that project managers must consider other travel alternatives when reconstructing a road that receives state funding. Reinstating complete streets will help build additional sidewalks, bike lanes, and multi-use paths around the state and will support individuals taking zero-carbon transportation options.

Policy: Restore eminent domain acquisition for pedestrian and bike trails

In 2017, the State of Wisconsin passed a law that prohibited local governments from using their powers of eminent domain to construct pedestrian and bicycle trails.[4] The State should restore this eminent domain power to local governments. If restored, local governments will be able to continue their efforts to build local walking and biking infrastructure including sidewalks, bicycle lanes, and multi-use paths.

Policy: Implement a "Vision Zero" goal statewide.

Vision Zero is a movement to eliminate all life-altering injuries and fatalities in our transportation system. Wisconsin cities and villages should join the pledge. This movement puts a special priority on preventing traffic deaths by recognizing people make mistakes and designing our network to accommodate those mistakes. Local governments can bring together cross-disciplinary groups to review roadway design, speeds, and existing policies to make our network safer for all users. By pledging to Vision Zero, Wisconsin would be committing to a safer, more equitable transportation system.

Solution: Encourage Smart Growth for Wisconsin Communities

Smart growth means accommodating growth of communities in such a way as to reduce distances residents need to travel for employment and for goods and services. Beyond its transportation benefits, smart growth provides numerous societal advantages, including decreases in major illnesses and improvements in upward mobility over their less-dense counterparts.[5]

Policy: Promote smart growth in Wisconsin communities.

State government should work with communities to promote smart growth policies that focus future population growth on amenity-rich areas serviced by transit, walking, and bicycle infrastructure. By focusing growth in areas served by transit there should be a reduction in vehicle traffic. Smart-growth policies that local communities should consider include lowering or removing mandatory parking minimums, prioritizing infill development, and building mixed-use neighborhoods. Zoning codes should also be amended to support new developments along public transit nodes and corridors.

Policy: Provide more funding for comprehensive planning across Wisconsin.

When the Smart Growth Comprehensive Planning Law was passed in 1999, it included one position within the Department of Administration (DOA) to administer a comprehensive planning grant program and one position at UW-extension to educate and provide technical assistance for local policy makers about planning and the grant program. It also allocated $3.5 million in grants for comprehensive planning across the state.[6]

Communities are still required to update their comprehensive plan every 10 years but the lack of funding and technical support makes it far more difficult. The state should restore funding to the grant program and ensure that these comprehensive planning positions are filled.

Solution: Identify Emerging Technologies and Prepare to Use Them

A number of emerging technologies can be expected to mature over the coming years. Among these are onboard devices such as fuel cells and super capacitors, to provide electrical power to EVs. To encourage increased use of EVs, the state should support development of a statewide network of stations for replenishing fuels for fuel cells. Technological developments could have an enormous impact on evolution of passenger rail service in Wisconsin. As autonomous vehicles come into use, state regulation, including allocation of dedicated lanes, will be critical for maximizing safety and efficiency.

Policy: Authorize WisDOT to establish a division tasked with advising policymakers about existing and emerging technology.

Their goal would be to identify and evaluate those technologies which seem to be of use for transportation in Wisconsin within a decade. This new division would also work in consultation with outside experts, to advise the Governor and Legislature of developments in transportation technologies that should be taken into account in drafting legislation or when preparing budgets.

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Chapter 5:
Vision 2050: A Transportation System That is Carbon-Free and Works for Everyone

We envision a transportation system for Wisconsin in 2050 that looks very different from what we have today. In the intervening decades, a major rebalancing of state funding will have shifted funds away from expansion of highways to investment in public transit and low-carbon modes of travel.
key features are:

- Fully electrified, it emits no greenhouse gases.
- Everyone uses the efficient public transportation system.
- Active transportation is well supported.
- Transit corridors replace traffic corridors.
- State transportation funding prioritizes protection of the environment, energy efficiency, and services to the broad public, with special consideration for low-income communities and disadvantaged individuals.

Electrification Using Renewable Energy

By 2050, vehicles will generally be propelled by electric motors and will have onboard sources of electrical power for the motors. These power sources will likely include batteries, fuel cells and physical energy-storage devices. Fuels for fuel cells could be hydrogen (H_2), stored in hydrogen carriers, or ammonia (NH_3). There will be an abundance of recharging and refueling stations at well-marked sites along roadways, at rest stops and at national and state parks.

All of the energy for transportation will come from non-carbon sources. The electric grid, by 2030 or soon thereafter, will have become green. Transportation fuels (e.g., H_2 or NH_3) will be produced from water or N_2 using electrical or solar energy.

Public Transportation

Our public transportation system will comprise:

- Statewide passenger rail
- Intercity bus lines
- Local and regional transit systems
- Airlines.

Statewide Passenger Rail

Passenger railroads will generally have two parallel tracks, one for high-speed travel in each direction. Freight trains will have separate tracks. In the development stage, passenger trains will share tracks with freight, but the preference is for separate tracks. Onbord devices will provide electrical power to the motors, so that overhead wires will not be needed.

Trains with many cars will still be used, but it will also be possible to equip individual passenger cars with motors so they can move independently. Then, instead of a train with six cars once an hour, there could be a car every ten minutes. A further advantage is that individual cars could follow different routes, so a passenger could get to a destination without changing cars. A single computer-dispatcher will monitor all trains and cars in a given region, manage the switching of tracks and, if necessary, take control of speeds.

This passenger rail network will provide dependable high-speed rail service to all parts of the state, with good connections to intercity buses and to local and regional transit. No community or tourist destination will be more than 50 miles from the nearest rail station. Working collaboratively with neighboring states, Wisconsin will be connected to a Midwest rail system that dramatically reduces the need to fly between commercial airports only a few hundred miles apart.

Intercity Bus Lines

With the added rail routes in place, the role of intercity bus lines will change. Currently, they offer the only public transportation available in large areas of the state. Their new role will be to serve the areas between the railroads and to connect rail stations with communities and tourist attractions in those areas. WisDOT will oversee the system, which may be operated by several bus companies, to facilitate coordination between the companies and assure adequacy of service to all parts of the state.

Local and Regional Transit Systems

With RTAs enabled, new and existing regional transit systems will be authorized to plan, fund and operate routes extending throughout metropolitan areas and beyond. With increased funding, local transit systems will be able to add new routes where needed and improve frequency on existing routes. Pulse scheduling and other methods will be used to assure good connectivity with rail and intercity bus services.

Airlines

By 2050, a way of propelling large aircraft at high altitudes without net emission of GHGs may have been found, but the technological path is not at all clear today. The pressure of necessity and growing economic incentives seem likely to yield a solution.

Active Transportation

Investments in infrastructure for active transportation will have made it easier for everyone to walk and bike safely. Non-drivers will be able to access commercial areas with good separation from automotive traffic. Many cities in Wisconsin will have developed “mixed use” neighborhoods, designed to reduce the need for motorized travel.

Transit Corridors

High-traffic corridors now often cut through residential neighborhoods, bringing noise, pollution and hazardous conditions for pedestrians. The worst impacts are typically on communities of color and low-income communities. We expect that by 2050 most traffic corridors will have been replaced by transit corridors. These will have fewer vehicles and these will be EVs, which are clean and quieter. Proximity to a transit corridor will be an asset for residents and businesses. Cities will seek to direct population and commercial growth as infill along these corridors.

Summary

By 2050, we foresee a Wisconsin transportation system that, through electrification and use of alternative fuels, will have eliminated greenhouse gas emissions. With a shift in state funding priorities, Wisconsin will have built a first-class public transportation network that serves everyone. By investing in infrastructure for active transportation, the state will have made walking and biking safer and more convenient. Our transportation system will be fiscally and environmentally sustainable. If we follow the recommendations put forth in this report, we can build a transportation system that future generations will cherish as clean, efficient, and equitable.

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