



Guam Transportation Petroleum-Use Reduction Plan

Caley Johnson
National Renewable Energy Laboratory

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Executive Summary

The island of Guam has set a goal to reduce petroleum use 20% by 2020. Because transportation is responsible for one-third of on-island petroleum use, the Guam Energy Task Force (GETF), a collaboration between the U.S. Department of Energy and numerous Guam-based agencies and organizations, devised a specific plan by which to meet the 20% goal within the transportation sector. This report lays out GETF's plan.

The first step to achieving such a goal was to benchmark current fuel use and transportation characteristics. To do this, we (GETF) consolidated key statistics from numerous Guam agencies, surveys, and reports. We found that Guam's on-road transportation used nearly 60 million gallons of petroleum in 2011 and is likely to drop slightly to 56 million gallons per year by 2020. Overall, Guam's transportation system is relatively inefficient, offering much "low-hanging fruit," or relatively easily achievable petroleum-use reductions with many co-benefits. On average, Guam residents take a larger share of their trips in personal vehicles than Hawaiian residents (the closest comparison) do. This can in part be attributed to the facts that bus ridership in Guam is low and walking and biking are inconvenient or dangerous. The vehicles in Guam are less efficient than on the U.S. mainland, and they use no alternative fuels.

We broke down the 20%-by-2020 goal into smaller, more tangible goals correlating to the six main pathways toward reduced on-road petroleum use. These six pathways, and their respective contributions toward the overall goal, are shown in Table A. GETF deems these pathway-specific goals to be achievable. Progress toward these goals will be tracked by GETF, Guam Energy Office (GEO), Guam Department of Revenue and Taxation (DRT), and the Guam Department of Public Works (DPW) through a tool set up by the National Renewable Energy Laboratory (NREL).

Table A. Summary of Petroleum Reduction Sub-Goals

Pathway	2020 Goal	Percent of total reduction
Miles Reduction	Light-duty vehicles (LDVs) travel 10% fewer miles	38.3%
Fuel Economy Improvements	Fuel economy of new LDVs improves 6% per year	36.7%
Idle Time Reduced	Idling reduced by 45 minutes per weekday per heavy-duty vehicle (HDV)	9.5%
Electric Vehicles	10% of new LDVs to be electric	7.7%
Biodiesel	All diesel fuel contains 5% biodiesel	5.4%
Traffic Flow Improvement	Coordinate all 84 traffic signals	2.5%

We identified projects that will help Guam achieve the pathway-specific transportation goals. We then prioritized the projects using a framework based on project cost, potential petroleum savings, anticipated popularity of the project among Guam residents, and time frame of the project. Projects we found to be of highest priority were setting up a rideshare website, supporting a waste-grease to biodiesel refinery, idle reduction initiatives, encouraging more efficient vehicles through a change to the registration fee structure, and development of a central bicycle route. Next steps will be for the prescribed projects to be implemented.

Acknowledgements

This report summarizes the recommendations and work of the Guam Energy Task Force (GETF). The work, time, insight, and creativity of GETF members made this report possible, but any errors herein are the author's responsibility. GETF members come from a diverse set of organizations and backgrounds throughout Guam and provided a well-rounded assessment of strategies to improve the island's transportation. Particularly important contributors include Cyrus Luhr (from Senator Tom Ada's Office), Carl Dominguez (DPW), Tom Renfro and Darryl Taggerty (I Bike), Richard Cruz (Gresco), Ginger Porter (GRTA), Steve Aguon (Department of Revenue and Taxation), Robert Underwood and Carl Swanson (University of Guam), Artemio Perez (GPA), and Ernie Murphy (Toyota).

Fortunately, GETF didn't have to start from scratch in the creation of a plan to reduce Guam's dependence on petroleum-based transportation fuels. Its work builds upon three Parsons Brinckerhoff publications that reflect insight and data achieved after months of research. These publications are the 2030 Guam Transportation Plan (2008), the Guam Transit Business Plan 2009-2015 (2010), and the Guam Transportation Improvement Plan 2012-2015 (2012). The author would like to thank Nora Camacho (Parsons Brinckerhoff) and Cliff Guzman (Galaide Group) for their contributions to these important documents and for helping GETF in its endeavor.

Finally, the author would like to thank Misty Conrad of NREL for the coordination of the Guam Energy Task Force (GETF) and thereby making this report possible. He would also like to thank the University of Guam and Battelle for funding this project.

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Introduction

The island of Guam's economy is almost entirely dependent on imported fossil fuel for its energy. After assessing the risks and costs of this energy portfolio, Guam Governor Eddie Baza Calvo set a goal in 2012 for Guam to reduce its fossil fuel use 20% by 2020 (20X20). The Guam Energy Task Force (GETF) aims to help Guam meet this goal by providing sound technical assistance, analysis, and planning. This plan is part of that overall effort.

Transportation is responsible for one-third of Guam's on-island fossil fuel consumption (omitting inter-island ships and aircraft), so changes in this sector are therefore key to achieving the 20X20 goal. The purpose of this plan is to assess the current transportation system in Guam, project fuel use patterns into the future, develop a plan to meet the 20X20 goal, and assess projects to help meet that goal. Assessed projects include those currently in use around the world in addition to those previously proposed by various Guam-based organizations.

Baseline Data

All means of petroleum-use reduction from the transportation sector involve altering people's travel and commuting behavior, the vehicles they use for transport, or the fuel(s) used in those vehicles. Therefore, in order to find the best opportunities for transportation petroleum-use reduction projects in Guam, it is important to define baselines for the ways in which people are currently commuting, how their vehicles are performing, and how much fuel is being used.

Petroleum Use

To determine on-road fuel use in Guam, the Guam Energy Office (GEO) provided gasoline and diesel use data for the years 2004 through 2007 through archive files and data for 2010 through August 2012 via its website (GEO 2012). 2004 and 2005 were not good base years due to reporting confusion between on-road diesel and non-road, so we selected 2006 (when Guam consumed 65 million gallons of petroleum) as the base year. According to the data we obtained, on-road gasoline use has increased 0.54% per year between 2006 and 2012, while on-road diesel has decreased 6.1% per year. We extrapolated fuel use at these growth rates to the year 2020, as shown in Figure 1 below. It is worth noting that this does not include any assumptions about potential military buildups, since those are mostly conjecture at this point. The overall transportation fuel use is projected to decline nearly 6% by 2020, making the goal easier to reach. This projection is deemed realistic because Guam's high petroleum prices are already incentivizing people to purchase more efficient vehicles, and the new corporate average fuel economy (CAFE) standards incentivize automotive manufacturers to sell increasingly efficient vehicles in Guam.

According to our projections, diesel fuel use will decline to 16% of Guam's total transportation petroleum use by 2020. This diesel-gasoline ratio is similar to that of Hawaii in 2011. Guam's declining diesel use could pose an economic risk if it further erodes economies of scale for the long delivery from Malaysia. However, such a loss of economies of scale would make the diesel displacement projects listed later in this report much more economically favorable than they would be at current diesel prices.

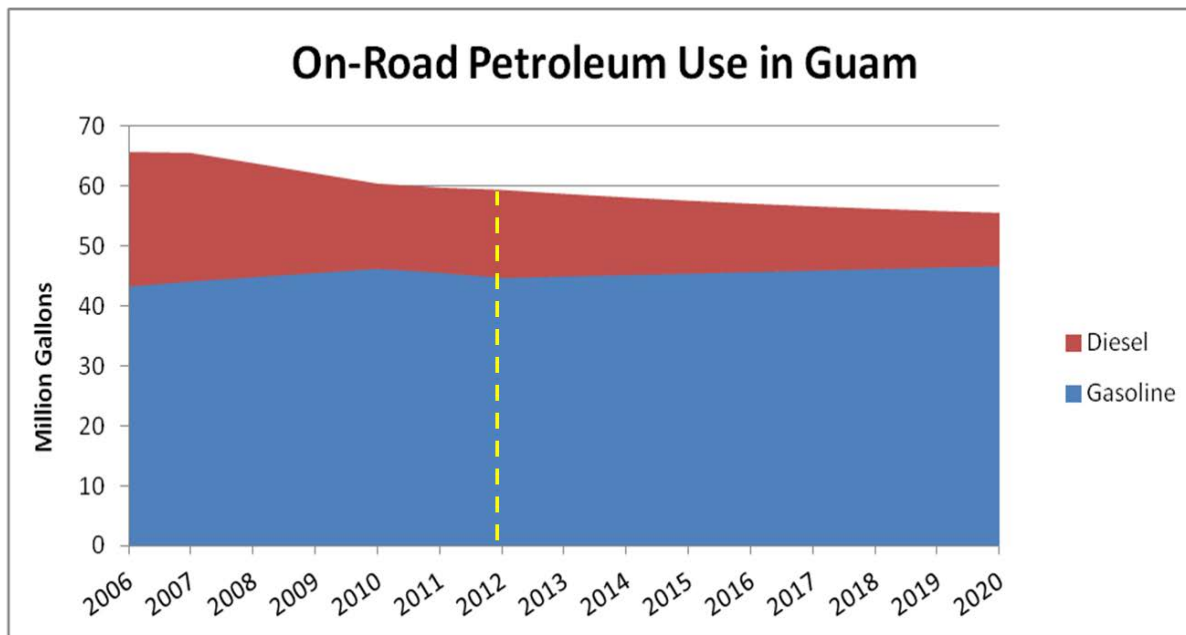


Figure 1. Recorded (2006-2011) and projected (2012-2020) on-road petroleum use in Guam

Vehicles, Miles, and Fuel Economy

Guam’s Department of Revenue and Taxation (DRT) tracks the number of registered vehicles by year, as shown in Figure 2. Two adjustments had to be made to its data for our purposes. First, its “truck” category had to be divided into light trucks and heavy trucks. To do this, we assumed that 74% of registered trucks were light duty, which is the same fraction as in the mainland United States (FHWA 2010). Second, we added federally owned military vehicles since they are not tracked in the DRT database. These adjustments resulted in the vehicle tallies that comprise the first four rows of Table 1.

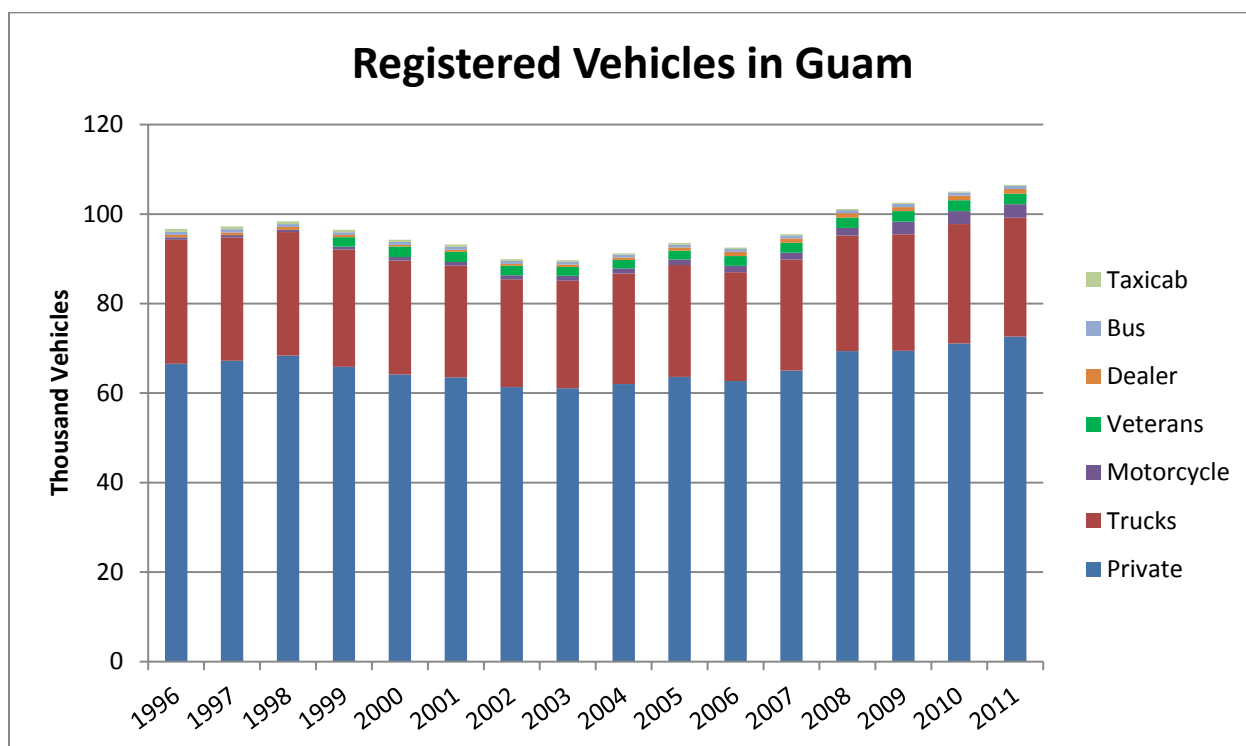


Figure 2. Registered vehicles in Guam, 1997-2011

Source: DR&T 2012

Table 1. Guam's Vehicle, Miles, and Fuel Economy Statistics (Reported and Calculated)

Metric	Value	Unit	Source/Verification
Number of LDVs	96,631	vehicles	Guam DR&T 2011*
Number of Trucks (Heavy and Medium Duty)	7,086	vehicles	Guam DR&T 2011*
Number of Buses	720	vehicles	Guam DR&T 2011
Number of Motorcycles	2,987	vehicles	Guam DR&T 2011
Average VMT (All Vehicles)	9,478	miles/vehicl e-year	Derived from Parsons Brinckerhoff, Inc. 2008 and 2008 vehicle registrations
VMT of LDVs	9,667	miles/vehicl e-year	Multiplied average Guam VMT times the fraction of VMT that LDVs account for in U.S. (FHWA 2010)
VMT of Trucks	11,332	miles/vehicl e-year	Multiplied average Guam VMT times the fraction of VMT that trucks account for in U.S. (FHWA 2010)
VMT of Buses	13,712	miles/vehicl e-year	Multiplied average Guam VMT times the fraction of VMT that buses account for in U.S. (FHWA 2010)
VMT of Motorcycles	1,891	miles/vehicl e-year	Multiplied average VMT times the fraction of VMT that motorcycles account for in U.S. (FHWA 2010)
LDV Fuel Economy	20.5	mpg	Calculated Vehicle Miles/Gallons Gasoline remaining after motorcycles gasoline subtracted out. This is lower than U.S. Average of 21.6 (FHWA 2012)
Fuel Economy Trucks	6.3	mpg	Calculated Vehicle Miles/Gallons diesel remaining after buses diesel is subtracted out. This is lower than U.S. Average of 6.4 mpg (FHWA 2012)
Fuel Economy Buses	7.2	mpg	U.S. Average (FHWA 2012)
Fuel Economy Motorcycles	43.4	mpg	U.S. Average (FHWA 2012)
LDV Annual Fuel Use	45,490,373	gals gasoline	(#LDV*VMT of LDV)/FE of LDV
Truck Annual Fuel Use	12,705,045	gals diesel	(#Trucks*VMT of Trucks)/FE of Trucks
Bus Annual Fuel Use	1,377,255	gals diesel	(#Buses*VMT of Buses)/FE of Buses
Motorcycle Annual Fuel Use	130,227	gals gasoline	(#Motorcycles*VMT of Motorcycles)/FE of Motorcycles
Total Gasoline Use	45,620,600	gals gasoline	Guam Energy Office 2012, also derived by adding LDV and motorcycle annual fuel use
Total Diesel Use	14,082,300	gals diesel	Guam Energy Office 2012, also derived by adding truck and bus annual fuel use
Average LDV Lifetime	17.5	years	HI Clean Energy Initiative 2011
Annual LDV Scrappage Rate	5.7%	of LDVs	100% divided by 17.5 years

*Light trucks separated from general truck pool by applying ratios from FHWA 2012.

The other primary data input to Table 1 is the total vehicle miles traveled (VMT) in Guam. According to traffic counts conducted by Parsons Brinckerhoff, an estimated 967 million vehicle miles were traveled in 2008 (Parsons Brinckerhoff, Inc., 2008). Dividing this figure by the total number of vehicles in 2008 equates to an average of nearly 9,500 miles per vehicle per year. Mileage ratios by vehicle type in the mainland U.S. were then applied to this average VMT to estimate the average VMT by vehicle category in Guam. The fuel economy of motorcycles and buses was assumed to be the same as in the mainland U.S. The assumed gasoline use by motorcycles was subtracted from the total amount of gasoline sold in Guam (shown in Figure 1), and the remaining gasoline was assumed to all be used by light-duty vehicles (LDVs). The total VMT of LDVs was then divided by the total gallons of gasoline used to estimate the average fuel economy of LDVs. The assumed diesel use by buses was subtracted from the total amount of diesel sold in Guam (shown in Figure 1), and the remaining diesel fuel was assumed to all be used by heavy-duty and medium-duty trucks. The total VMT of trucks was then divided by the total gallons of diesel fuel used to estimate the average fuel economy of the trucks.

One last important trait of the vehicle population is the scrappage rate, or the number of vehicles replaced each year. This allows us to set boundaries for the rates at which new vehicles can penetrate the vehicle population. Guam doesn't track scrappage, so we assumed it to be the same as in Hawaii. In Hawaii, the average vehicle life (regardless of how many owners it has) is 17.5 years (Braccio and Finch, 2011). Dividing 100% of the vehicle population by 17.5 years tells us that 7.5% of the vehicle population will be scrapped and replaced each year.

Commuter Behavior

Means of commuting have a large impact on the number of vehicle-miles traveled in an area, and therefore, how much petroleum is used. Table 2 shows estimates of the portion of Guam's workforce that commutes by each of a number of different means, as reported in the U.S. Census Bureau's 2000 Insular Area Profiles. We multiplied those percentages by the current number of workers in Guam (60,183) to estimate the current numbers of people commuting by each means. Because the source data is from 2000, we ran various verifications in order to ensure that the estimates match current data. Foremost among these was a comparison to Biggs (2012) findings of a smaller sample size. Biggs' findings weren't taken as the definitive source because the sample size was small and categories were more granular. Finally, we made a comparison to 2010 Hawaii commuting data. The purpose of this is twofold: to benchmark the commuter choices in a similar island environment so that any anomalies in the Guam estimates will become apparent; and to identify potential opportunities for Guam to increase the proportions of workers using low-petroleum commuting means that Hawaii may be successfully implementing.

Table 2. Means of Commuting in Guam and Comparisons to Hawaii

Metric	Percent of Workers (Guam, 2000)*	Commuters	Verification/Source	Percent of workers (Hawaii, 2010)**
Workers in Guam		60,183	Guam Bureau of Labor Statistics***	
Drove Alone to Work	69.8%	42,032	Checked against miles in 2030 plan. Biggs 2012 shows 83%.	66.6%
Carpooled to Work	23.2%	13,987	Checked against miles in 2030 plan. Biggs 2012 shows 14%.	13.8%
Walked to Work	2.5%	1,474	Biggs 2012 shows 0%.	4.5%
Other	2.0%	1,198		3.4%
Worked at Home	1.3%	782	Likely higher now that technology has improved. Biggs 2012 shows 0%.	5.1%
Public Transit	0.5%	277	276 of the 296 are reflected in GRTA Fixed-Route bus stats. Biggs 2012 shows 0%.	6.6%
Bike to Work	0.3%	199	Biggs 2012 shows 0%.	Included in "Other"
Taxi to Work	0.2%	120		Included in "Other"
Motorcycle	0.1%	84	Motorcycles are 3.1% of registered vehicles	Included in "Alone"
Mean Travel Time to Work	19.2 minutes			25.5 mins

*2000 Insular Areas Profiles, U.S. Census Bureau.

**2010 American Community Survey, U.S. Census Bureau

***Guam Department of Labor's Bureau of Labor Statistics. Average of most recent four quarters from Current Employment Statistics Historical Summary: 1993 - 2012.

Gasoline Prices

Gasoline prices are another regional attribute that can help shape a transportation petroleum-use reduction plan. Figure 3 reveals two patterns for gasoline prices in Guam:

- Gasoline prices are consistently substantially higher than those in the mainland United States. Basic economics tells us that this is a motivating factor for gasoline-use reduction and makes behavioral change and up-front investments more likely. Indeed, this is probably one of the reasons why annual transportation petroleum consumption is only 322 gallons per person in Guam while it is 575 gallons per person in the mainland United States and 380 gallons per person in Hawaii, where gasoline prices are also above the U.S. average.
- Gasoline prices are less volatile in Guam than in the U.S. or Hawaii. This is likely due to the fact that fewer gasoline shipments are made, so prices get locked in at the time of arrival. The lack of sudden and drastic price drops reduces uncertainty for potential investments in petroleum-saving technologies.

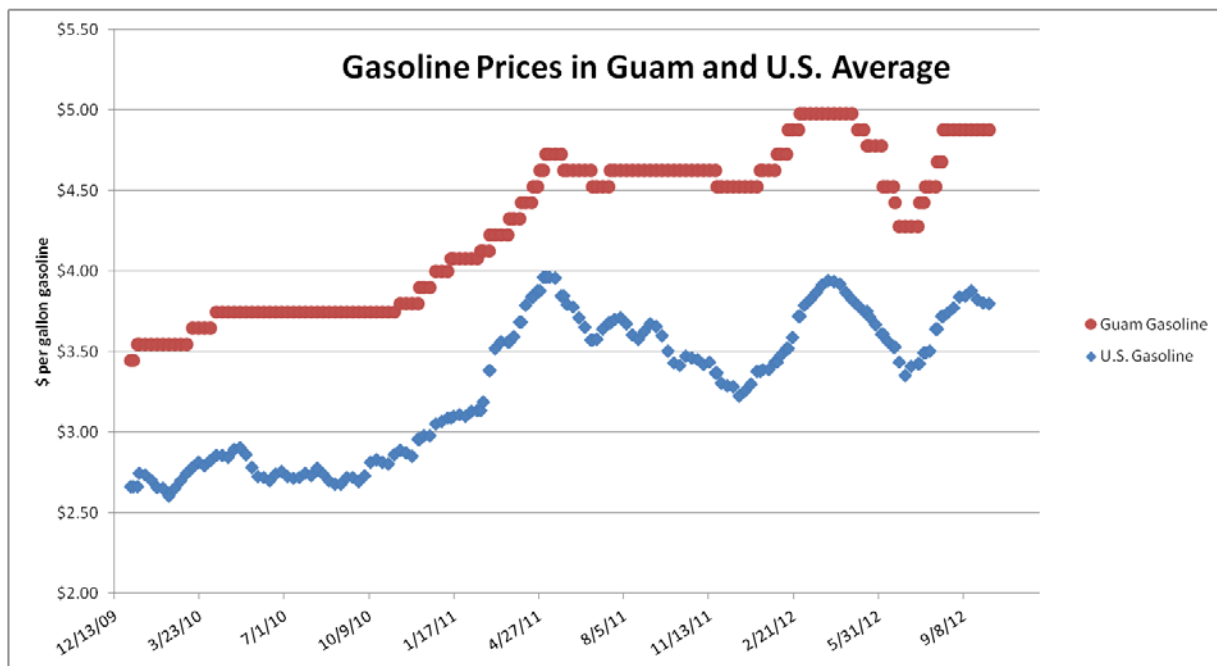


Figure 3. Average gasoline prices in Guam and mainland United States

Source: Guam Energy Office and U.S. EIA

Planning for Petroleum-Use Reduction

This section of the report lays out the general framework for the Guam petroleum-use reduction plan.

Wedge Analysis Approach

The goal of reducing transportation petroleum use 20% by 2020 is quite achievable if approached systematically. To do so, we break this basic goal down into achievable steps through a “wedge analysis.”

The wedge analysis uses a baseline of the most recent 12 months’ fuel use and projects it forward to 2020. Notably, this baseline is not the projected fuel use shown in Figure 1, because the goal is not pegged to a “business as usual” scenario. The analysis then subtracts fuel use by “wedges,” or strategy groups, until the goal is reached. Wedges are shaped as such, because the fuel displacement resulting

from each strategy grows as projects progress. For example, improvements to bicycle routes may initially result in modest petroleum displacement but then grow more substantial over time as the number of commuters using the routes increases. This analysis tool allows the user to assess the potential of various scenarios to reach the goal and to then formulate a plan of action. The wedge analysis representing the Guam scenario is shown in Figure 4, followed by a description of each wedge. To avoid overlapping claims, petroleum use reduction is accounted for from the bottom of Figure 4 to the top.

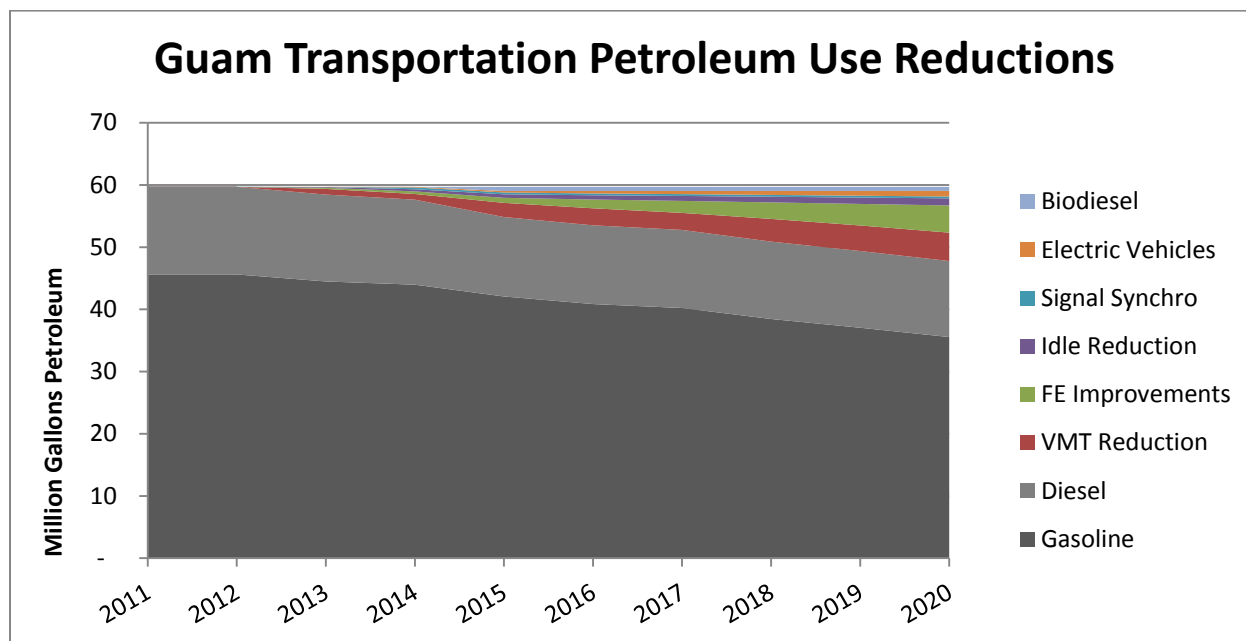


Figure 4. Reduction wedges to meet the 20% petroleum-use reduction goal by 2020

Wedge Analysis Categories

We selected the wedges, or sub-goals, charted in Figure 4 because they align with Guam’s resources and potential. Furthermore, these groupings, as listed below, are a natural way to categorize petroleum-reduction projects.

Vehicle Miles Traveled (VMT) Reduction

This wedge represents gasoline use reduced through reductions in the number of miles vehicles traveled. Common ways to avoid vehicle miles are by “active transit” (bicycling, walking, or wheelchairs) or telecommuting to work or meetings. Two other means of VMT reductions are the use of ride-share (carpooling) and mass transit, because multiple people can be transported by fewer vehicles, leaving more vehicles off the road. In this analysis, all VMT are assumed to be reduced from gasoline-powered LDVs, rather than from heavy-duty vehicles (HDVs). This is because fleet management techniques and systems, which are quite effective at reducing VMT from HDVs in large cities, are deemed less effective in Guam, with its limited routing options that are probably already optimized. However, there are many ways the Guam government can promote these heavy-duty VMT reductions, and a few projects will be outlined in the next section.

We propose a goal to reduce overall LDV VMT 10% by 2020. This means that one in 10 trips taken in a motorized vehicle in 2011 would be taken by carpool, bike, foot, or bus, or replaced by telecommuting, by 2020. We deem this goal to be feasible for four reasons:

1. Guam's high gasoline costs serve as an incentive to use any of these alternative forms of transportation and make any of them financially viable decisions. VMT reductions were the most common way for U.S. commuters to reduce their transportation costs when faced with the petroleum price spike of 2008 (Robert Half International and Careerbuilder.com 2008).
2. As noted above, Guam commuters use public transit at a much lower rate than their Hawaiian counterparts (0.5% vs. 6.6%). Furthermore, Guam has extremely low bus ridership (less than two transit boardings per year per person) for its population density (nearly 800 per square mile) (PB Americas, 2010). This indicates great potential for increased use of public transit. Guam Regional Transit Authority (GRTA) sees this potential and is already positioning itself for expansion to carry more passengers. We will address GRTA measures in greater depth later in this report.
3. The hospitable weather and condensed geography of Guam are similar to those in Hawaii and therefore should lead to a similar level of active transit. However, Guam's workers commute by walking at about half the rate of Hawaii's workers, and though the data can't be compared head-to-head for bikers, it appears there are many more bicycle commuters on Hawaii. This indicates a large potential increase in active transit once key hurdles are addressed.
4. The fact that Guam is a very small economy in one of the most isolated locations in the world is a huge incentive for teleworking. The first wave of teleworkers, and their employers, will likely see significant financial benefit from tapping into distant economies with fewer interisland flights. This could, in turn, accelerate the adoption of teleworking overall.

The VMT reduction wedge is the largest contributor towards the 2020 goal and is expected to provide nearly 38% of the overall petroleum-use reduction needed to achieve it.

Fuel Economy Improvements

This wedge represents gasoline use avoided through the use of more efficient light-duty vehicles. Such vehicles include advanced technologies (such as hybrids and cylinder lockout) as well as simply replacing vehicles with smaller or more efficient models. We propose that the average fuel economy of LDVs purchased in Guam increase 6% per year (compounded), from 20.5 mpg in 2012 to 30.1 mpg in 2020. This goal is realistic because the U.S. Corporate Average Fuel Economy (CAFE) requirements became applicable to Guam in model year 2012, so manufacturers now have the same incentive to sell fuel efficient vehicles in Guam as in any U.S. state. The reason for this change is that 2012 is the first year that CAFE will be harmonized with the Clean Air Act, which applies to Guam (EPA and NHTSA, 2010). The new CAFE standards require a growth rate in fuel economy of nearly 8% (if compounded), so 6% for Guam should be entirely achievable.

Fuel economy improvement projects will provide 37% of the needed petroleum use reduction in order to meet the 2020 goal. Therefore, this category is the second-largest contributor to the goal.

Traffic-Flow Improvements

This wedge depicts petroleum saved by reducing the number of times that vehicles need to stop or substantially slow down, then accelerate back up to traveling speed. Acceleration requires much more energy than traveling at a consistent speed. The potential benefit from traffic-flow improvements can be illustrated by comparing EPA's city and highway drive cycles (as shown in Figure 5). The highway drive cycle has many fewer acceleration events than the city drive cycle and has a higher average speed. The average vehicle in the FuelEconomy.gov database, maintained by EPA and DOE, is 35% more efficient when driving the highway drive cycle than in the city drive cycle.

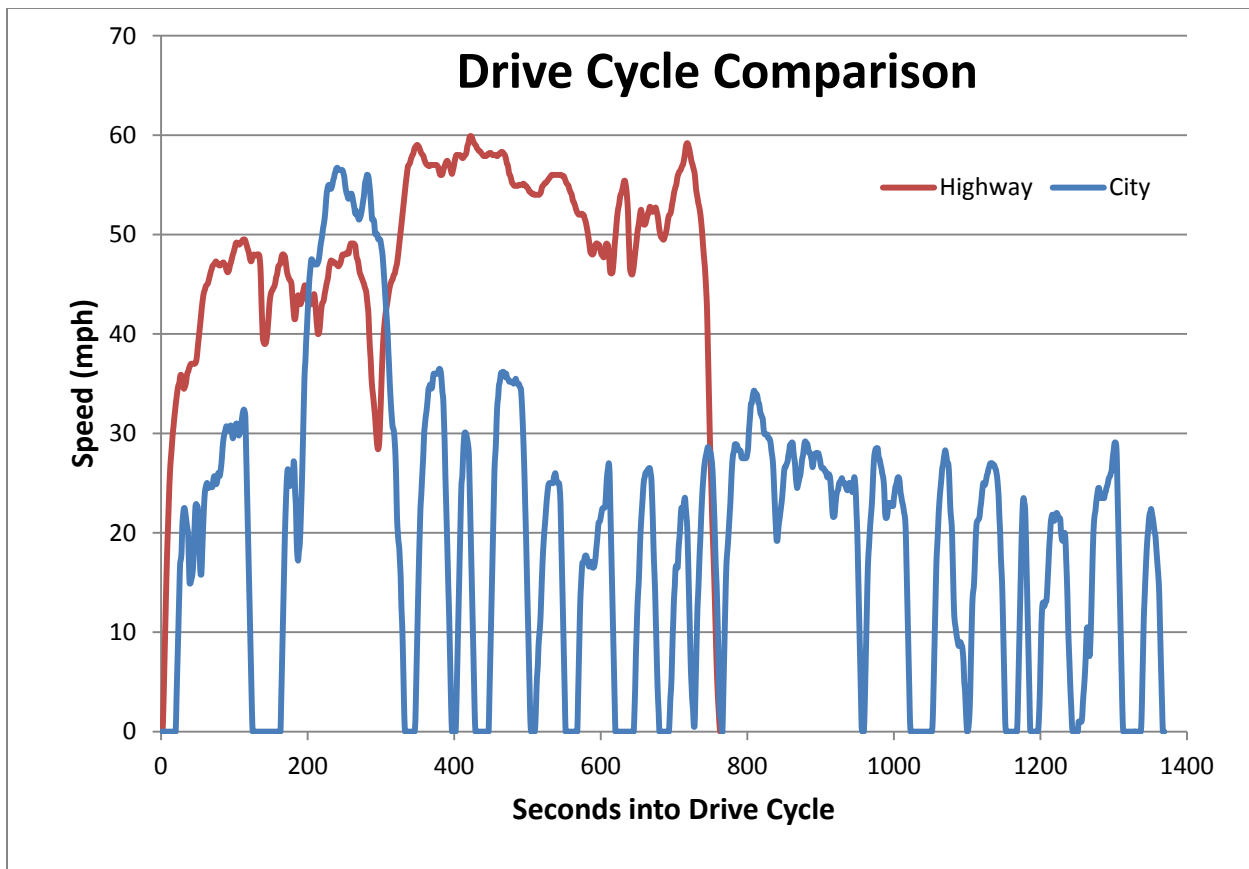


Figure 5. EPA city and highway drive cycles

Source: EPA, 2011

Guam has developed a road system that flows relatively well and has left-hand turn lanes, relatively well-maintained pavement, pull-off spots for buses, and many other features of a well-designed road. However, its 84 traffic signals are not timed, coordinated, or synchronized well, since a hurricane took out the signal control center in 2002. Calculations conducted for Trafficware (one of the leading signal synchronization software companies) show that, in a series of projects, synchronized traffic signals are saving between 3,500 and 8,100 gallons per signal per year (Gerken 2010).

To achieve the fuel use reductions depicted in the Flow Improvements wedge, we set a goal to time and coordinate all 84 traffic signals on the island of Guam. We then conservatively assume that each traffic signal saves 3,500 gallons per year—the amount in the worst-performing Trafficware signal synchronization project. The fuel saved by these signals is split proportionally between gasoline and diesel, and contributes 2.5% of the petroleum savings needed to reach the 2020 goal.

Electric Vehicles (EVs)

This wedge consists of petroleum displaced through the use of vehicles that can be plugged into the electrical grid. To achieve the fuel savings depicted in the wedge, we set a goal for electric vehicles to comprise 10% of LDV sales in Guam by 2020. This wedge also includes plug-in hybrid electric vehicles (like the Chevy Volt), but assumes that they run on electricity a majority of the time since commute distances are so short on Guam.

Electric vehicles can save a substantial amount of petroleum in Guam, despite the fact that the island's electricity is produced by oil. This is largely because the electric drive train of EVs is three times more efficient than the average internal combustion engine (CARB, 2010). Even when taking into account that Guam's electricity generation is 24% efficient (Baring-Gould et. al., 2011) and assume distribution

losses of 5.8% (EIA 2012) and battery storage losses of 13% (Lohse-Busch and Douba, 2012), an EV uses less petroleum than the average conventional LDV. We calculate that the Nissan Leaf uses 54% less petroleum per mile than the average car in Guam, and the Ford Transit Connect EV uses 32% less than the average light truck.

EVs only account for 7.7% of the 2020 petroleum savings in the wedge analysis. However, EV projects have the potential for additional benefits in Guam because of its forthcoming smart grid. The smart grid will enable Guam Power Authority (GPA) to transfer electrical loads from periods of high electricity demand (peaks) to periods of low demand (troughs). This hypothetical shift is illustrated in Figure 6, where a cumulative 6,600 kWh are shifted from the peak (8 a.m. through 5:30 p.m.) to the trough (10:30 p.m. to 7 a.m.). This shift could save the utility from turning on old, inefficient generators or adding new expensive generators to accommodate peak demand. Electricity demand added to trough times is usually met by the cheapest base-load generation or most efficient generation. Once the smart grid is in place, the batteries of electric vehicles can be used to shift the load because they can supply electricity to the grid during peak demand times, and they can be charged during times of low demand (Clement-Nyns et. al. 2011). Furthermore, the demand-stabilization capacity of EVs can also enable a greater portion of Guam's electricity to be generated by renewable energy sources like wind and solar, which have higher variability than most conventional sources (Denholm and Hand, 2011).

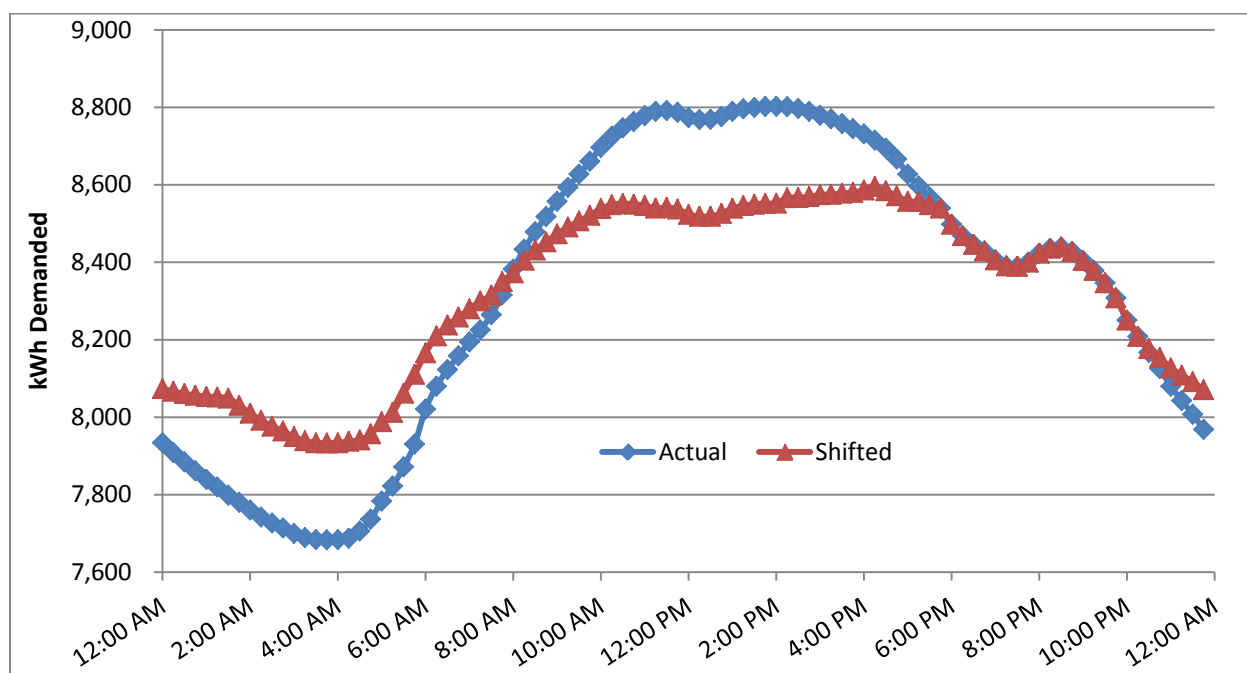


Figure 6. Example average daily load and shifted case

Source: Electric Reliability Council of Texas, 2012

Guam is at a particular advantage for EV penetration because range requirements are not as great on the small island as they are in the mainland U.S. This reduces the degree to which range anxiety will serve as an impediment to EV adoption in Guam.

Idle Reduction

This wedge illustrates the amount of diesel fuel to be saved by turning off the engines of stationary buses and heavy-duty trucks instead of idling. To reduce petroleum use by the amount shown, each of these vehicles needs to reduce its idle time by 45 minutes per weekday. We assume that each bus typically consumes 0.64 gallons of diesel fuel per hour of idling, and each truck burns 0.76 gallons per

hour (Gaines and Vyas, 2006). A 45 minute reduction is assumed to be a reasonable amount of idle time to cut, since in the mainland U.S., 90% of trucks idle more than one hour per day (Lutsey et. al. 2007).

This idle reduction will be achieved through a combination of policy measures and technological solutions. Shorepower electric units permit vehicles to operate their air conditioners without running their engines. Guam's climate is conducive to idle reduction policies since fuel gelling is not a problem in warm temperatures, as it can be in cold temperatures. However, tourist buses need to use their air conditioning when waiting for additional passengers. The idle reduction projects outlined later in this report take into account these two basic premises. We plan for idle reduction to account for 9.5% of the 2020 petroleum-use reductions.

Biodiesel

This wedge represents petroleum displaced by the use of biodiesel, which is a mature technology that is most commonly made from soybeans, rapeseed, palm oil, jatropha oil, coconut oil or waste grease. It can be used in all diesel vehicles at a blend of 5% (B5), in fleet-based HDVs at 20% (B20), and in fleets of slightly modified HDVs (in Guam's warm climate) at levels near 100% (B100).

The biodiesel wedge calls for all diesel fuel use in Guam to be B5. At this level, the biodiesel essentially performs as a lubricity additive and therefore meets the ASTM standard for conventional diesel and all vehicle manufacturers' warranty requirements. The states of Minnesota and Oregon have mandated that all diesel be B5 and have not reported any issues (American Trucking Association, 2012). The Philippines is using coconut-based biodiesel to meet a 2% biodiesel (B2) mandate with no reported issues (Corpuz, 2012). If Guam replaces all diesel fuel with B5, this strategy will contribute 5.4% to the 2020 goal.

Successful implementation of this strategy is largely dependent upon access to suitable feedstock. Some promising sources of feedstock include the following:

Waste Grease

Lucky One Pumping (now owned by Gresco) used to collect waste grease in Guam and process it into biodiesel. However, supplies were low, due to illegal dumping of waste grease by restaurants and other potential sources. Improved enforcement of grease-disposal laws could increase the supply of waste grease in addition to protecting the island's land and water. A survey by NREL found that approximately 22 pounds of waste grease are generated per person annually in U.S. cities (Wiltsee, 1998). With a population of 185,674 residents (not including its 1 million annual tourists), waste grease supplies in Guam could total just over 4 million pounds annually—sufficient feedstock to produce 511,000 gallons of waste grease biodiesel per year, since it takes about 8 pounds of waste grease to produce one gallon of biodiesel (Fortenbery, 2005). This would account for about 75% of the biodiesel needed to fulfill the wedge.

Coconut Oil

The climate and soil in Guam are conducive to growing coconuts. Furthermore, it can be done sustainably and symbiotically by intercropping with a number of food crops (Scheewe, 2003). Guam is well positioned to emulate the Philippine example of growing coconuts and using them as feedstock for coconut methyl ester (CME) biodiesel (Corpuz, 2012). This proposal is discussed in greater depth in the "coconut oil to biodiesel" section of this report.

Imported virgin oil

If waste grease and domestic coconut oil feedstock weren't adequately developed to fulfill Guam's B5 mandate, Guam could import feedstock from its neighbors. Biodiesel can be produced from a wide variety of virgin oils. Their availability can be ascertained by exploring the export levels of virgin oils,

as shown in Figure 7. Such investigations are a good first step in identifying sources of biodiesel feedstock, but sustainability must also be taken into account. A search at USDA 2012 reveals that most of the Philippines virgin oil exports are coconut oil, which would be very compatible with Guam's domestic supply of coconut oil. The same search also reveals that most of the virgin oil exported from Australia is rapeseed oil, and most of the virgin oil from China is peanut oil, both of which are generally grown in a more sustainable fashion than palm oil. Indonesia and Malaysia's virgin oil exports are predominantly palm oil, which is often produced in a very unsustainable fashion, with considerable impacts to soils, natural habitats, and water supplies. Guam should consider purchasing palm oil only from suppliers that are certified by a third-party organization, such as the Roundtable for Sustainable Palm Oil, (www.rspo.org).

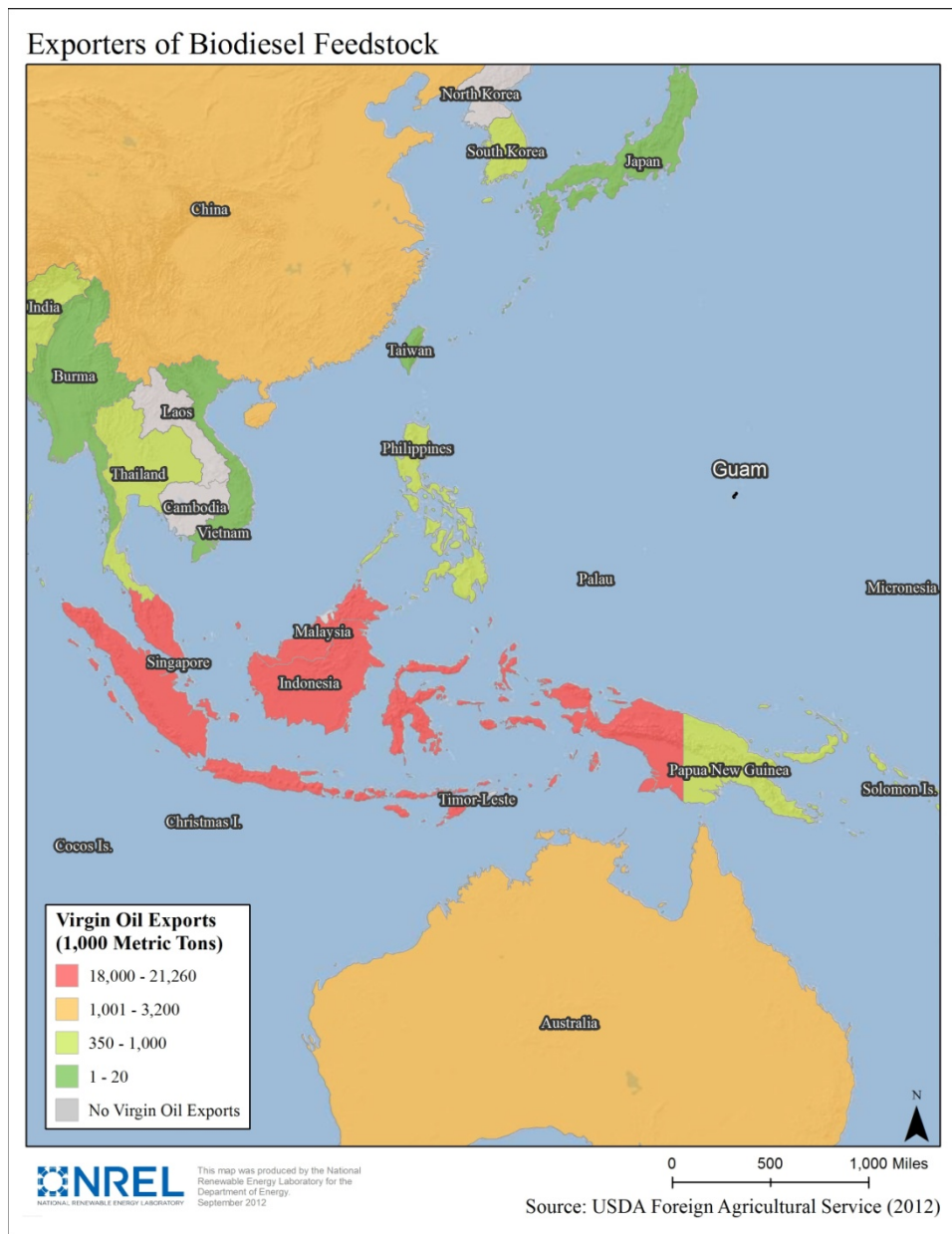


Figure 7. Exporters of biodiesel and renewable diesel feedstock

Taňgan Taňgan

Taňgan Taňgan is a plant that grows seeds with a high level of oils and triglycerides needed for biodiesel. Its oil is also known as castor oil, which has well-established pathways to biodiesel. Furthermore, Taňgan Taňgan grows well on Guam and has multiple secondary uses (StuartExchange 2013). One secondary use could be to gasify the woody stalk of Taňgan Taňgan to produce methanol, a key ingredient in biodiesel production. This secondary use is further examined in the “waste grease to biodiesel” section of this report.

Algae Oil

Algae oil can also be used as a feedstock for biodiesel production. While we do not expect algae biofuel to be a contributor to the 2020 goal, it may prove worthwhile to track the rapid progress of the industry. At some point before 2020, it may become more cost effective to grow algae and harvest its oil than to import vegetable oil from neighboring countries. Furthermore, algae biofuel is a good match for Guam since it can be grown in saltwater in places with a heavy solar load (Biofuels Digest, 2010).

Ethanol

It should be noted that blends of sugarcane ethanol were investigated but decided against. Ethanol would compete with biodiesel for land resources. Both fuels benefit from economies of scale at every level of feedstock production, fuel production, distribution, and use. So in order to achieve these economies of scale it was deemed best to focus exclusively on biodiesel instead of splitting the efforts between the two. Reasons for favoring biodiesel over ethanol are as follows:

1. The biodiesel industry can be jump-started with waste grease biodiesel. It can also be complemented by other feedstocks (Taňgan Taňgan and algae) that don't require traditional agricultural land.
2. A number of energy experts on Guam pointed out the need to use Guam's farm land for food production. Local food reduces the fuel and GHGs required to transport food extremely long distances. This is also a good idea from an energy security standpoint. When Cuba went through an oil crisis in 1990, they survived by focusing on food cultivation rather than cultivation of energy crops (Community Solution 2006).
3. Coconuts for biodiesel can be grown symbiotically with multiple food crops and are being grown in such fashion in the Philippines (Scheewe 2003). This is not the case with sugarcane.
4. Guam's farms are an average size of 9.6 acres (USDA 2010). It appears that new farms in the future will likely be small also. This size lends itself more towards intercropping coconuts than it does to monoculture sugarcane.
5. Economies of scale are more impactful for ethanol than for biodiesel. There are many small-scale biodiesel plants but very few small-scale ethanol plants because they have such high production costs.
6. The economics of sugarcane on islands have proven to be bad on Hawaii. They mandated E10, but have found that importing Ethanol from the mainland U.S. is more economical. Importing over such long distances minimizes the GHG benefits and negates the energy security benefits of biofuels.
7. Biodiesel can be blended at higher levels than ethanol before specialized vehicles need to be purchased.
8. Diesel is more expensive (despite not being taxed) and therefore 1 GGE of biodiesel is worth more than 1 GGE of ethanol on Guam.

Wedge Summary, Interaction, and Timing

There are numerous tradeoffs and interactions among the petroleum-use reduction wedges. Table 3 illustrates how we have delineated the wedges to avoid double counting.

Table 3. Wedge Summary

Allocation Priority	Wedge	2020 Goal	Portion of Total Petroleum-Use Reduction	Fuel(s)
1	VMT Reduction	LDVs travel 10% less	38.3%	Gasoline
2	Electric Vehicles	10% of new LDVs to be electric	7.7%	Gasoline
3	Fuel Economy Improvements	Fuel economy of new LDVs improves 6% per year	36.7%	Gasoline
4	Traffic Flow Improvement	Coordinate all 84 traffic signals	2.5%	Both
5	Idle Time Reduced	Idle time by 45 minutes per weekday for each HDV	9.5%	Diesel
6	Biodiesel	All diesel fuel contains 5% biodiesel	5.4%	Diesel

Allocation Priority

The Allocation Priority helps to reduce double counting by clarifying the order in which the petroleum reductions are subtracted from the total baseline fuel use. Further clarity is gained by accounting for the type of petroleum fuel—diesel or gasoline—associated with each wedge. All wedge tracking assumes that LDVs use gasoline and HDVs use diesel.

The VMT reductions are taken first, because any progress in this wedge affects the amount of gasoline use available to be reduced by any of the other wedges. We assume that all VMT reduction projects will be aimed at LDVs that use gasoline. This does not account for the potential increase in bus use due to increased mass transit, so non-bus HDVs may need to reduce VMT to make up for any increase by buses.

The Electric Vehicle and Fuel Economy wedges are based on new LDV sales. Therefore, for purposes of calculation, we assume that the pool of vehicles has been reduced commensurately with VMT. Although this will not necessarily be the case, it does not distort fuel-use reduction figures, since both the number of vehicles and per-vehicle VMT are multiplied (over fuel economy) when fuel use is calculated. After taking this LDV reduction into account, we predict annual LDV sales by looking at the number of vehicles that would be replaced any given year. The Electric Vehicle wedge is first calculated off this value, and the Fuel Economy wedge is then derived from the remainder of new vehicles, after the EVs are subtracted from the annual vehicle sales.

The Electric Vehicle and Fuel Economy goals are set to apply only to LDVs, because gasoline use represents a greater share of Guam's petroleum use than diesel use does. We apply the fuel economy goal only to gasoline-powered LDVs, because there is greater potential for fuel economy improvements in this sector. This is largely because fleets tend to consider life cycle fuel costs and other operating costs when purchasing HDVs, making fuel economy a major factor in acquisitions. In contrast, individuals who purchase LDVs (or any other energy-consuming device) tend to prioritize upfront cost over lifetime fuel savings (Hausman, 1979), so they do not maximize fuel economy.

Fuel (both gasoline and diesel) saved through traffic signal synchronization is applied after the Fuel Economy wedge, because the latter is based on the EPA-labeled fuel economy and does not take traffic flow into account. The Traffic Flow Improvement wedge is independent from the Idle Reduction wedge,

since there is no quantifiable relationship between the two. Diesel saved from both wedges is subtracted from the amount of diesel used before B5 is applied to the remaining diesel use.

We assume that most projects will be phased in on a regular schedule. Some schedules, like that for EVs, do not begin immediately though, because we deem it a better use of financial resources to wait until prices drop. Furthermore, dealers must develop the capability to service EVs, after which point we expect adoption to grow fairly quickly. Some schedules, like that of biodiesel, occur in large steps, because we assume that production capacity must be developed in discrete phases that coincide with infrastructure development. The Fuel Economy wedge starts immediately and grows at a steady rate, because fuel economy regulations take effect in 2012, and we assume a steady rate of LDV scrappage over time. The Traffic Flow wedge manifests its petroleum-use reductions in a single jump, since it requires a central infrastructure project. The VMT and Idle Reduction wedges gradually ramp up over time, since they require behavioral change and numerous small investments.

Tracking Progress

Tracking progress toward the fulfillment of the wedges and the overall achievement of the 2020 goal will require new data sources and improved data tracking.

Tracking overall progress is under way. The first step was to centralize all of the data listed in Table 1 under one roof. We gathered this data from numerous government departments and contractors in what turned out to be a very cumbersome process. We recommend that the relevant agencies and organizations send future data updates directly to the Guam Energy Office (GEO) so it can maintain a central database, and GETF can have quick access to the most up-to-date information. We recommend that the Department of Revenue and Taxation (DRT) collect odometer readings from vehicle owners as part of their annual registration renewals. This would enable the agency to track and analyze the VMT information. GETF could help DRT translate vehicle models and model years into fuel economy estimates for registered vehicles, in order to track fuel economy trends.

Projects undertaken through the plan can be tracked in the Clean Cities Annual Reporting website (www.eere.energy.gov/cleancities/toolbox/annual_reporting.html), which NREL maintains. As of this writing, NREL had already set up an account for Guam to use. As seen in Figure 8, the reporting website collects all data needed to calculate petroleum-use reduction, has default assumptions for questions the user is likely not to know, and calculates the petroleum savings for any of these projects. The input categories (as shown on the left-hand navigation) closely align with all wedge categories except for traffic flow. There is even a section to report outreach events such as educational campaigns, and marketing-based calculations that convert these outreach activities into petroleum saved. Guam's reporting account can be accessed by more than one user, so multiple agencies and organizations can input the data directly.

The screenshot shows the '2012 Clean Cities Annual Report' interface. The top navigation bar includes 'Annual Report Dashboard', 'ADMIN: Annual Reports', and 'Summary Reports'. The user is logged in as 'Caley Johnson' with links for 'My Account' and 'Log Out'. The left sidebar lists various report categories: 2012 ANNUAL REPORT, MAIN FUNCTIONS, GENERAL, FUEL STATIONS, VEHICLE & FUEL INVENTORY, FUEL ECONOMY, and IDLE REDUCTION. The main content area is titled '2012 Clean Cities Annual Report' and 'Vehicle Miles Traveled Reductions » Add Project'. The form contains the following fields:

- Fleet name ***: Text input with 'Guam Ride Share Website'.
- Vehicle class ***: Radio buttons for 'Light-Duty' (selected) and 'Heavy-Duty'.
- Method ***: Dropdown menu with options: 'Car sharing (e.g., Zipcar)', 'Carpooling', 'Mass transit', 'Non-motorized locomotion (e.g., bicycles)', 'Telecommute', and 'Other'. A tooltip is visible for 'Car sharing' stating 'Saved by this project. Off the road or used less.' and for 'Other' stating 'Taken off the road or used less'.
- Fuel type ***: Dropdown menu with 'Gasoline' selected.
- Fuel economy of vehicles ***: Text input with '20.5' and 'MPG'.
- Number of vehicles ***: Text input with '200'.
- Vehicle miles traveled reduction per vehicle ***: Text input with '300' and 'miles'.

Figure 8. The Guam account on the Clean Cities Annual Reporting website

To track VMT reduction, the Guam Regional Transit Authority (GRTA) must report its bus passenger count into the reporting website. GRTA must also estimate the distances these passengers travel. GRTA could also serve as the repository of ride-share data from any of various ride-share websites used by Guam residents and workers. GRTA can then easily enter the data into the VMT reduction section of the reporting website, and the site will calculate fuel saved and GHG emissions reduced. The VMT wedge could be much better managed if GRTA or the Department of Public Works (DPW) conducted a Guam household travel survey. Such a survey would track shifts in travel patterns over the years, and could be modeled off of or collaborate with the existing National Household Travel Survey conducted by the U.S. Department of Transportation.

The EV and Biodiesel wedges will be relatively simple to track in the Alternative Fuels and Vehicles section of the reporting website. GETF will likely be involved in the first fleet EV purchases and can record them directly in the reporting website. Auto dealers can report their EV sales to GETF, and fleets can report VMT of their EVs to GETF. Finally, if the Department of Motor Vehicles (DMV) begins logging fuel type and odometer readings with vehicle registration information, it can provide all necessary data for petroleum-use calculations. Biodiesel can be reported to GEO by motor fuel retailers in the same manner that gasoline and diesel fuel are tracked.

Petroleum savings from idle reduction can be entered into the Idle Reduction section of the reporting website. Timers on shore-power units (which provide power to run air conditioners on buses) can provide data on the number of hours of idling they reduced. Businesses, schools, tourist sites, and other organizations can enter estimates where policies have been enacted to reduce idling.

To track fuel economy improvements, GETF must obtain vehicle sales records from the Department of Revenue and Taxation. The average fuel economy of the new fleet can be derived from these estimates to track progress toward our fuel economy goal. Individual fuel economy improvement projects can be entered into the reporting website, which will quantify resulting petroleum savings.

The Traffic Flow wedge will be the most difficult of all for which to track progress, partly because it is the one wedge that can't be reported through the website. Traffic signal synchronization packages are able to calculate estimated fuel savings, but a more holistic system is needed to account for savings resulting from other projects. NREL is currently pursuing a novel combination of models that will enable it to calculate fuel savings from traffic flow improvements. One of these models, the Future

Automotive Systems Tool (FAST), was developed by NREL to translate drive cycle and vehicle type into fuel use. The other model is a traffic simulation model, Verkehr In Städten - SIMulationsmodell (VISSIM), which translates road configuration and traffic flow into drive cycles. By connecting these two models, NREL hopes to calculate the fuel savings for each traffic flow improvement project. The fidelity of these models will be maximized if DPW can conduct more in-depth traffic counts to understand how many vehicles are traveling over any given section of road in Guam.

Projects

The first step on the path to reducing Guam's petroleum use was to set the overall target of 20% by 2020, as done by Governor Calvo. The next step was to break that goal down into the wedge-based goals listed in Table 3. The third step was to identify specific projects by which to achieve the wedge-based goals. This involved work by various agencies, organizations, and companies throughout Guam, with coordination and supplementation by GETF. A number of the projects have been described in Parsons Brinckerhoff, 2008; PB Americas, 2010; and Parsons Brinckerhoff, 2012. The fourth step is to prioritize the projects so that they may be pursued and funded in a strategic and systematic manner, as outlined in this section.

Project Prioritization

GETF prioritized specific projects based the four factors listed below. The factors currently carry the label of low, medium, and high, but it is the intention of GETF to be able to translate these labels into actual numbers, such as project cost, petroleum saved, and years until project fruition. The ratings are all relative: Projects with the worst ratings in any given category have already been removed from the list. The four factors, in descending order of importance, are as follows:

- **Project cost** is deemed the most important factor, because it limits the number of projects that can be taken on. This factor includes up-front cost, not life cycle cost. (The next category, petroleum-use reduction, is the other main driver in life cycle cost assessments, so it is already taken into account.) For divisible projects such as pedestrian paths or bus route expansion, Table 4 represents the cost of the less expensive projects rather than the cost of all projects. It should also be noted that prioritizing foremost on cost ignores the fact that outside funding may become available (such as for buses) that should be taken advantage of in a timely manner.
- **Petroleum-use reduction** represents the quantity of petroleum a given project displaces by 2020. Ultimately, GETF will be able to combine the first two categories into a cost-per-gallon-displaced metric for a more straightforward comparison.
- The **popularity** rating predicts how well received the project will be by the general population (voters) and whether the project will foster interest in further petroleum-use reduction work. In general, the popularity rating rises with increased cost savings, time savings, convenience, safety, and healthfulness of transportation. But to accurately assess the popularity of proposed projects, it will ultimately be necessary to conduct community outreach, through means such as focus groups or surveys.
- **Time frame** considers how quickly the project can begin reducing petroleum use. This rating considers one to two years as short, three to four years as medium, and five to 10 years as long. Ultimately, time frame could be taken into account numerically by applying a discount factor to the cost-per-gallon displaced metric mentioned above.

It should be noted that the four factors do not account for many significant project attributes, such as how they build on one another, whether the appropriate partners are willing to participate, and what hurdles they must overcome. Furthermore, various organizations may want to re-order the project

prioritization factors (such as popularity first) depending on their mission and goals. Therefore, Table 4 should not be viewed as a step-by-step plan to meet the 2020 goal, but rather a general framework for assessing and prioritizing projects.

Table 4. Proposed Projects by Rank

Rank	Wedge	Project	Cost	Petroleum Reduction	Popularity	Time Frame
1	VMT	Rideshare website	Low	High	High	Fast
2	VMT	Bus tracking and coordination system	Low	High	High	Fast
3	Biodiesel	Waste grease to biodiesel	Low	High	Med.	Fast
4	Idle Reduction	Idle reduction initiatives for delivery trucks and school buses	Low	High	Med.	Med.
5	Fuel Econ.	Feebate for improved fuel economy	Low	High	Low	Slow
6	VMT	Bike route	Low	Med.	High	Med.
7	Fuel Econ.	Rewrite government vehicle purchase specifications	Low	Med.	Med.	Fast.
8	Fuel Econ.	Education campaign for fuel economy	Low	Med.	Med.	Med.
9	VMT	Education campaign for alternative transportation	Low	Med.	Med.	Med.
10	VMT	Coordination plan for taxicabs and GRTA	Low	Med.	Med.	Med.
11	Fuel Econ.	Guam motorcycle and bicycle safety strategic plan	Low	Low	Med.	Slow
12	VMT	New buses and routes	Med.	High	High	Fast
13	VMT	Telework	Med.	High	High	Med.
14	Fuel Econ.	Mobile emissions testing facility	Med.	Med.	Low	Med.
15	VMT	Bike share system	Med.	Low	High	Fast
16	Idle Reduction	Shorepower for buses	Med.	Low	High	Med.
17	VMT	Coordinate ADA compliance with biker and walker-friendly facilities	Med.	Low	Med.	Fast
18	Biodiesel	Coconut oil to biodiesel	Med.	Low	Med.	Slow
19	Traffic Flow	Traffic signal coordination	High	Med.	High	Med.
20	EV	EV trial fleets	High	Med.	Med.	Med.

1. Rideshare Website

Seventy percent of commuters in Guam drive alone, as shown in Table 2. Filling empty seats in their cars is a great way to commute while adding very little extra cost or petroleum use. There are three primary challenges to this means of commuting: (1) finding a driver who is going to and from convenient locations at a convenient time, (2) ensuring that this driver is a safe person to ride with, and (3) maximizing flexibility in the face of unforeseen circumstances. Rideshare websites and smartphone applications overcome the first problem by searching for drivers with compatible locations and times. They overcome the second problem by provide safety through accountability. They help alleviate the third problem by making backup rides easier to find and many rideshare programs offer a guaranteed ride home from a taxi in the case of an emergency.

There are some universal rideshare websites that can be used in Guam (see National Center for Transit Research, 2011), but there are also advantages (such as improved usability) to tailoring a website to a specific locale. All rideshare websites ask for users' departure and destination locations and time of travel in order to identify good rideshare groups. It should be noted that Guam is particularly well-suited for ride coordination since it has just a handful of primary routes, thereby increasing the likelihood that

potential carpoolers will find appropriate matches. Rideshare websites require users to create an account, which increases accountability. These sites are hosted and sponsored by local governments, nonprofits, and entrepreneurs who can benefit from directed advertising opportunities provided by such sites. Advanced features include rider and driver reviews, payment transfers, fuel-savings calculators, and free taxi rides as backup.

The cost to use a pre-existing rideshare website is very low, but it is not much more expensive to tailor one to a specific subgroup of commuters and then maintain it. The petroleum-use reduction is rated as high, because both the number of potential users and the savings for any given user are large. It should be noted that the populations with the highest computer ownership rates are also the populations currently least likely to be carpooling and therefore the most likely to be able to convert from single occupancy vehicles to high occupancy vehicles. The website would be highly popular since it offers great cost savings to the user. The time frame is short, because it would be relatively quick and easy to promote the website, and people are likely to try it early or not at all. The key to success is finding an appropriate organization or individual to set up the website and promote it. This organization could be GRTA, since it could incorporate the rideshare site with its bus route site. Alternately, a large employer could do so and then expand to an audience beyond its own employees.

2. Bus Tracking and Coordination System

Improving the convenience of usability of fixed-route bus systems has great potential to increase ridership, and therefore petroleum-use reduction. Fortunately, personal computers, mobile phones, and smartphones have opened up many opportunities to do so. Two of the most effective and popular tools are route planners and bus trackers.

Online route planners allow riders to find the most time- and effort-efficient route available without having to consult route maps or schedules. They allow a user to enter a starting location and destination location via a computer or smartphone, and the program then generates step-by-step directions and times for taking the bus. Such tools can also function through texts and recordings on non-smart mobile phones. The first crucial step in setting up a route planner for GRTA is to format the schedule data according to the General Transit Feed Specifications (GTFS) published by Google at <https://developers.google.com/transit/gtfs/>. Once an agency's data is in GTFS format, it is relatively simple for Google to add its transit instructions to Google Maps. Google plans to expand its coverage from 70% of the U.S. population today to 100% in the near future, and it also plans to enable transit agencies to directly upload their data (Ferris, 2012). If GRTA's progress moves faster than Google's expansion plans, GRTA can open its GTFS-standardized data (through a contractor, if needed) to outside application developers, as explained on the GTFS website. Dozens of transit agencies have done this, resulting in hundreds of open-source iPhone apps that help transit riders navigate their systems (APTA, 2012). Many of the applications were built from scratch, while many others redirected the open-source program "OneBusAway" to their agencies. Some of the smaller transit agencies spurred developers with a prize for whoever developed the best application.

Bus trackers are GPS-based transmitters that track a bus's location to give real-time information that enables coordination with passengers and other buses. These transmitters can be integrated into route-planners so riders know exactly when their buses are coming. This is particularly useful on routes where buses do not circulate very frequently (as is the case in Guam), and therefore, there is a large risk associated with missing the bus. It is also particularly useful in areas where buses deviate frequently from their set schedules, as is also the case in Guam (PB Americas, 2010). There are a series of GPS trackers available through which GRTA could make the data available in "GTFS-realtime" to open-source programmers and application writers. Some WiFi boxes (such as MoveBox) can double as GPS trackers. Each of these costs less than \$2,000 per year to operate, and they have the obvious side-benefit of providing wireless Internet connections to commuters. A number of companies providing computer

aided dispatch/automatic vehicle (CAD/AV) location systems include real-time passenger information. These systems are more expensive than the open-source systems, but the operator does not have to rely on the open-source community. One of the most popular companies to offer the full-package tracking service is nextbus.com (see Figure 9). There would be significant public-relations benefits to rolling out the bus trackers at the same time that GRTA introduces its new buses, as outlined in Project 17.

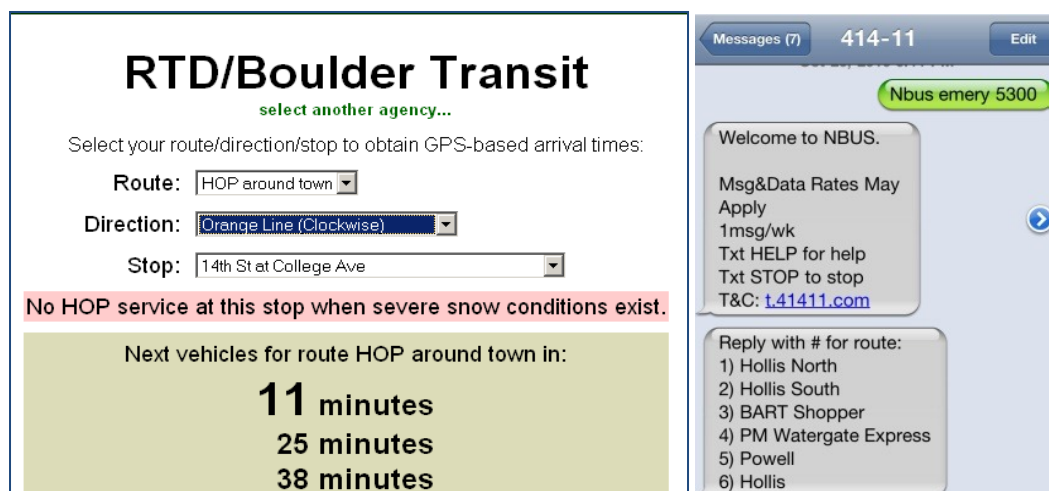


Figure 9. Nextbus time forecasts via website (left) and text (right)

The overall cost of GRTA adding a bus tracking and coordination is deemed low, but could vary depending on equipment and services purchased. Potential fuel savings are high, because this system could serve as a turning point for GRTA bus ridership, ideally increasing to a point at which the system is able to expand both in bus frequency and number of routes. The popularity would clearly be high, as real-time information would eliminate uncertainty and wasted time on the part of riders. The time frame is fast: A contractor could format the schedule data into GTFS fairly quickly, and open-source programmers are notoriously fast in developing route-planning applications and websites once the data is made available.

3. Waste Grease to Biodiesel

As discussed in the biodiesel portion of the wedge analysis, a majority of the biodiesel needed to implement island-wide B5 could be sourced from waste grease. Gresco is one of three companies collecting waste grease in Guam, and it already has the equipment and expertise necessary to process the grease into biodiesel since it purchased Lucky One Pumping, which used to produce high quality waste grease biodiesel. It is therefore important to assess the Lucky One biodiesel project to determine if it is feasible for Gresco to recommence it.

The main challenge the original biodiesel project faced was that too much waste grease was being dumped illegally, therefore diminishing feedstock supplies. Anti-dumping laws must be more strictly enforced in order to increase the feedstock available for processing. Furthermore, the two educational campaigns (projects No. 7 and No. 8 in this list) should include outreach and messaging regarding proper grease disposal.

A second challenge is securing an economical source of methanol, which is a key component in the production of biodiesel. It takes roughly 10 pounds of methanol to produce 100 pounds of biodiesel (AFDC 2013). Methanol prices are inflated on Guam since it is considered a toxic substance and therefore requires inflated shipping charges over long distances. Fortunately, methanol is relatively inexpensive to produce, as evidenced by the fact that it costs only \$1.55 per gallon in the mainland U.S. and even less in Europe and Asia (Methanex 2013). It can be produced from feedstocks available on Guam. The most common feedstock is methane, which can be captured from landfills, wastewater

treatment facilities, or livestock operations. In addition, methanol is being produced from biomass gasification in a growing number of countries. Tañgan Tañgan is therefore an attractive candidate for biomass that can be turned into methanol.

With sufficient available feedstock and an economical source of methanol, Gresco could recommence biodiesel production. Once it establishes this second revenue stream (in addition to its grease-collection fees), it will be able to charge less for waste-grease collection. Such a drop in prices would likely further reduce the rate of illegal grease dumping and would also push the other waste-grease collectors to produce biodiesel to increase their competitiveness.

This project could be undertaken at relatively low cost, because Gresco already has the equipment needed to collect and process grease. Furthermore, this program would reduce damage that waste grease currently causes to water drainage systems, which costs Guam approximately \$600,000/year to repair. Guam would likely incur some added personnel costs to step up enforcement of grease disposal regulations. The potential petroleum-use reduction is high, as estimated in the biodiesel portion of the wedge analysis. Waste-grease projects are generally popular, because they constitute a win-win solution that addresses both waste disposal and fuel production. However, the increased enforcement of anti-dumping laws is likely to be unpopular among current dumpers, reducing the overall popularity of the project to medium. The time frame should be fast since one producer already has the equipment needed to collect and process waste grease.

4. Idle Reduction Initiatives for Delivery Trucks and School Buses

The idle reduction goal, as discussed in the Idle Reduction section, is to be achieved with two projects: a shore-power project that focuses on tour buses (discussed below) and an idle reduction policy project. In 2010, the Guam legislature rejected an idle-reduction bill (Bill 341-30) largely because it would have banned tour buses from idling without providing any alternatives by which they could run their air conditioners. A new proposed idle reduction policy would instead institute limitations on idle time at garages, at delivery points by delivery trucks, and at schools by school buses. Such policies would require driver training and reinforcement through signage (e.g., Figure 10) at locations where idling is now common.



Figure 10. No idling sign with violation report number

Source: New Jersey Department of Environmental Protection

School buses are a particularly good fleet through which to spearhead an idle reduction campaign, because their idling is very centralized, and therefore enforceable. Furthermore, children are more vulnerable to harmful vehicle emissions than adults are (Gill, 2006), which strengthens the case against idling at schools. These factors have led EPA to aggressively address school bus idle reduction, and it has developed an idle reduction toolkit (EPA, 2012) to help organizations implement their own idle reduction programs. The toolkit provides step-by-step guidance, free no-idle zone sign templates, sample idling policies, flyers, driver pledges, and other tools.

Delivery trucks are another promising application through which to implement idle reduction policies. Most such policies restrict idle time to five minutes, because some diesel manufacturers recommend a 5-minute warm-up (Oregon DEQ, 2010). The most effective enforcement schemes include some element of citizen reporting made possible through a phone number listed on anti-idling signage (e.g., Figure 10).

The cost of the school bus and delivery truck idle-reduction initiatives is deemed to be low, because affected fleets would save on fuel costs, signage is relatively inexpensive, and enforcement could rely on free citizen reporters. Fuel savings would be fairly significant, since the policies would impact up to 7,000 trucks and 130 school buses. Popularity is deemed to be medium, because some drivers might deem the policies to be intrusive, while a majority of people (especially parents) would likely appreciate cleaner air and reduced health risks to children. The timeline is medium: School campaigns could be implemented relatively quickly, but broader idling restrictions would require legislative action by municipalities and/or the Guam legislature.

5. Feebate for Improved Fuel Economy

Throughout the world, there are three main policy mechanisms that are commonly employed to increase fuel economy:

1. Motor fuel excise taxes
2. Fuel economy and emissions standards for new vehicles, applied to the manufacturer
3. Vehicle registration fees and rebates.

We recommend that Guam focus on the third of these options, because increasing the motor fuels tax is politically difficult (especially with the current high gasoline and diesel prices), and because the U.S. CAFE standards now already apply to vehicles sold in Guam.

Guam currently has an initial vehicle registration fee of \$18 and annual registration fee that increases with vehicle weight (Guamtax, 2007). Weight is a decent proxy for fuel consumption since a 10% increase in weight increases fuel consumption by 7% (Cheah 2010). The existing fee schedule rewards the purchase of lighter, more fuel efficient vehicles, but not at a magnitude sufficient to influence vehicle selections. Furthermore, it discourages the use of technologies such as batteries that can improve fuel economy but are heavy.

Other countries have structured their registration fees in ways that profoundly affect vehicle choice and average fuel economy. Two exemplary models can be found in Portugal and France, whose vehicles are the most efficient in the European Union (JATO, 2011).

Portugal's vehicle registration tax has a component that is based directly on a vehicle's carbon dioxide emissions. This mechanism is the most direct way to minimize greenhouse gas emissions and fuel consumption. Another component of Portugal's registration tax is based on engine displacement: Vehicles with larger, higher-emitting engines are subject to higher registration taxes. Taxing based on

engine displacement is a less direct way of encouraging more efficient vehicles, because it doesn't take into account the fact that some engines of a similar size are much more efficient than others. To address this, Portugal applies a tax discount of 10% to 50%, depending on a variety of factors such as vehicle weight or use of hybrid technology. A shortfall of Portugal's system is that the tax remains relatively flat for efficient vehicles, which provides very little incentive for people to choose incrementally more efficient vehicles within this range.

In addition to its vehicle registration taxes, Portugal has an annual ownership tax that increases with engine displacement (for passenger cars) and vehicle weight (for commercial vehicles). This annual tax can influence some people who are less influenced by the vehicle purchase tax. The reason some people could be less influenced by the vehicle purchase tax is because this tax comes at a time when purchasers have resigned themselves to a very expensive purchase, so the incremental cost of the tax is less influential. The annual fee comes at a time when the owner can focus entirely on the pain of that fee without its being diluted by the much larger purchase cost and the emotions associated with buying a new vehicle.

France has implemented a successful policy, called the Bonus-Malus (good-bad), that combines escalating taxes for inefficient vehicles (less than 35 mpg) and large bonuses for efficient vehicles (greater than 43 mpg). This policy is based on the much-publicized "feebate" program that Canada has also implemented (Cohen et al., 2010). The Bonus-Malus policy has had a large impact on France's vehicle fleet, as the market share of economy cars grew from 44% in 2007 to 57% in 2009 (RMI, 2010). One shortcoming of the legislation was the stair-steps between vehicle categories that failed to apply consistent pressure toward more efficient vehicles. A second shortcoming of the legislation was that the rebates and fees weren't correctly balanced. It was intended to be revenue neutral, but due to its unexpected success at attracting purchasers to efficient vehicles that were eligible for rebates, the policy ended up costing the government a substantial amount.

Based on the experiences in Portugal and France, we make the following recommendations for Guam:

1. Institute a one-time registration fee (in addition to the annual registration fee) that is transparent at the time of the purchase decision. When making a decision, up-front costs are much more influential than costs to be incurred down the road (Hausman, 1979).
2. Peg this registration fee directly to fuel economy, so more efficient vehicles pay less.
3. Offer a rebate instead of a fee to the most efficient vehicles. This creates a more clear distinction between the most and least efficient vehicles and therefore exerts more pressure toward purchases of efficient vehicles. The availability of rebates would also be likely to improve the popularity of the program and therefore the political feasibility.
4. The rates of increase for both the fee and the rebate, as well as the inflection point (in mpg) between the fee and rebate, need to be set specifically to Guam's circumstances, because driving economics and fuel use are very dependent on location. Doing so will enable Guam to target how much revenue it hopes to generate from the feebate, or alternatively, how much funding it would like to expend. An assessment performed for the state of California (Bunch et al., 2011) has many lessons to offer in this regard.

The cost of the feebate is deemed low, because it should be revenue-positive. The potential for petroleum-use reduction is very high, because the policy applies to so many vehicles. Its popularity may be low at first, since it will cause people to focus on fees that they had previously just accepted as part of car ownership. The time frame will be slow, since the policy would likely require economic analysis and considerable deliberation by the legislature.

6. Bike Route

One major means of reducing VMT is by encouraging and enabling bicycling. A good way to do so is to establish a central bike route, where bikers can travel safely and conveniently. Once they reach a “critical mass” on this route, hubs can be added to connect the primary route to additional routes. I Bike and the Guam Cycling Federation have already identified an ideal location for a central hub that would connect places of work, hotels, tourist sites, schools, and housing, optimizing its appeal to commuters, students, tourists, and errand-runners (Figure 11). The proposed route has a limited number of hill climbs that should be manageable for most riders. The current route can be ridden as is, but further steps should be taken to increase its safety and popularity.

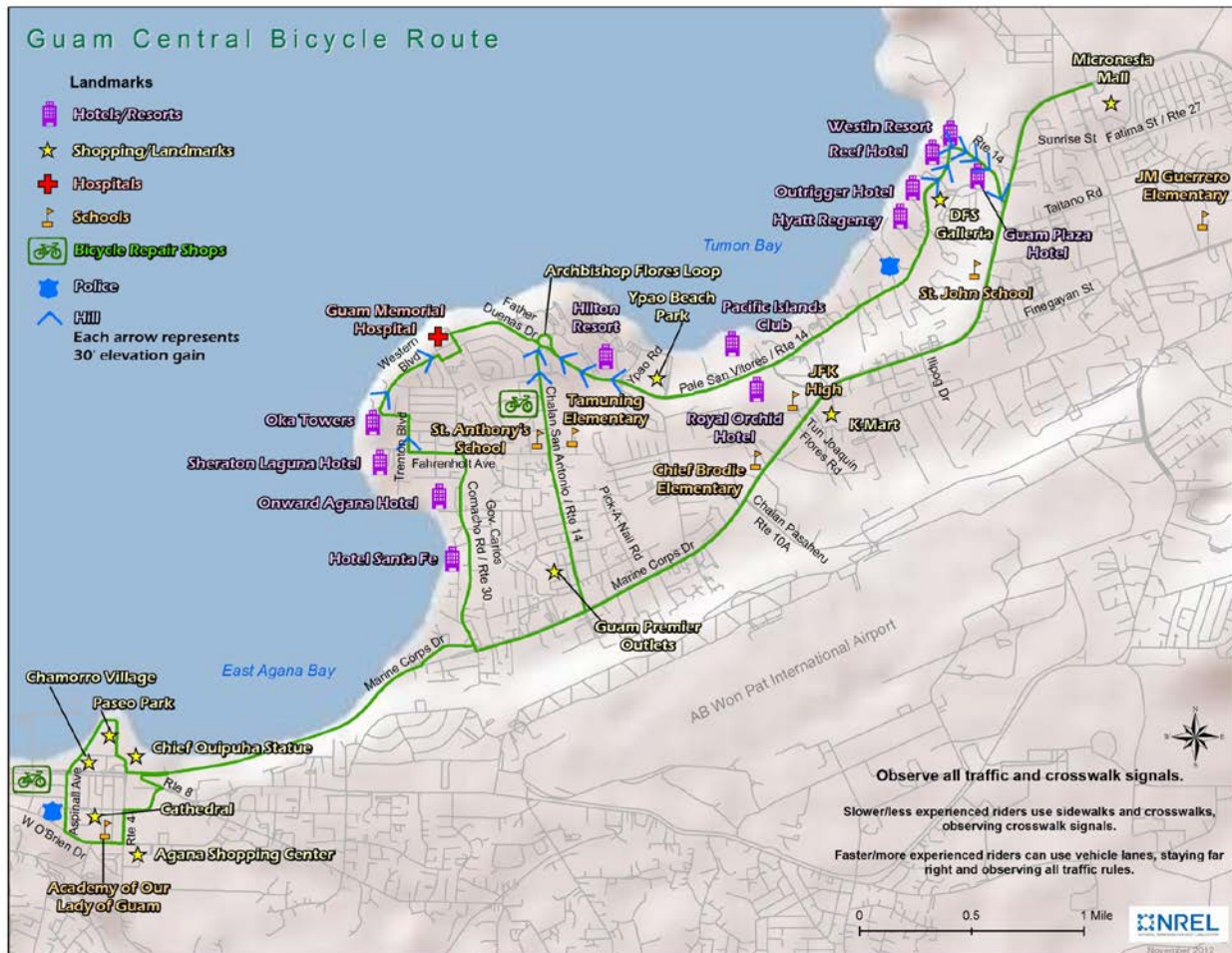


Figure 11. Guam central bicycle route

Subsequent steps would utilize the Design Guidelines and Standards (Alta, 2012). They are listed in order of decreasing necessity and increasing cost. The first steps are very necessary and relatively inexpensive. The latter steps are less necessary, but would make for a much improved bike path that would appeal to tourists and commuters alike. The steps are as follows:

1. Post signage along the route to alert drivers to the presence of bicyclists. These signs can double as directional signs to tell bikers where the route is.

2. Paint bike lanes where there is sufficient room and "sharrows" (Figure 12) where there is not room. Bike lanes require a combined bike-plus-vehicle-lane width of 14 feet. Sharrows have no firm space requirement, and can be used on any of Guam's roads, since the speed limits are less than 40 mph.



Figure 12. Sharrow, or shared lane marking

Photo from Will Sherman, Nelson/Nygaard Consulting Associates

3. Designate a bike path through Guam Memorial Hospital parking lot. This would safely and quickly bypass a potentially dangerous section of road.
4. Work with major employers and schools along the route to provide bike racks, locker, and showers to enable bicycle commuters to change clothes and store their gear.
5. Move street light and signage poles from the center of sidewalk along Marine Corps Drive and Pale San Vitores. The poles currently limit bicycle flow to one direction. This will become a problem as bicycle ridership on these sections increases. As a preliminary step, wide signs should be raised so only the pole (as opposed to the full width of the sign) impedes bicycle flow.
6. Add a bike path between the businesses lining Marine Corps Drive and East Agana Bay. This path would be safe from vehicles on the highest-speed section of Marine Corps Drive, and it would greatly add to the allure of the bike route. It could pass through portions of Oceanside Park and an under-utilized parking lot.
7. Add a pedestrian/cyclist bridge over Marine Corps Drive between JFK High School and Kmart. This would allow cyclists and pedestrians to bypass a busy intersection and serve as a short-cut, relative to the existing crossing. Pedestrian and bicycle traffic demand at this spot is currently so high that a fence had to be erected to prevent people from crossing the road there.

The cost of the bike route is considered low, because a safe, convenient route can be established through Steps 1 through 4 above without significant expense. However, a much-improved route, with added appeal to commuters and tourists, (Steps 5 through 6) would require funding of a greater magnitude. Resulting petroleum-use reduction would be medium, due to the confluence of two factors: 1) Each car replaced by a bicycle results in a 100% petroleum-use reduction. 2) Growth in ridership would likely manifest rather gradually. The bike path would be highly popular, because it would enable residents and

tourists to take recreational rides in addition to serving as a free means of commuting to work. The time frame is medium, because signage and lane-marking could be put in place relatively quickly, but it could take time to attract sufficient numbers of bicycle commuters to start saving significant amounts of petroleum.

It should be noted that the bike route would likely increase the usefulness of Guam's bus system and vice-versa. All weekday fixed-route buses start and end at the Guam Regional Transit Authority (GRTA) transit center at the Chamorro Village (PB Americas, 2010), which is located on the proposed central bike route. Ideally, the bike route would be developed and promoted to maximize opportunities for multi-modal transportation.

7. Establish Government Vehicle Purchase Specifications

The government of Guam uses much fuel in its vehicle operations. They could save a substantial amount if they set a centralized policy that promoted the purchase of more efficient vehicles. Furthermore, since they generally operate their vehicles for only three years before selling them to Guam residents, the fuel economy of new government vehicles will affect the fuel economy of the general pool of vehicles on Guam.

There have been two bills in 2011 (B376-31 and 381-31) that proposed to standardize procurement policies across government agencies with the aim of improved reliability and efficiency. One of them directed the Office of Procurement and GEO to promulgate vehicle specifications and standards. Another required the Office of Procurement to assess vehicles based on total cost of ownership and to establish a maintenance contract when the purchase is made. All of these components would lead to reduced fuel use and lower costs, but neither bill was enacted.

More recently, a bill (014-32) was introduced that proposes a minimum combined (city-highway) fuel economy of 25mpg for government vehicles. This bill would encourage larger vehicles to become more efficient and would encourage downsizing, but would not provide much incentive for smaller vehicles to be more efficient.

One way to increase fuel economy in all vehicles while ensuring that functionality needs are met is to set requirements based on vehicle needs rather than vehicle attributes. Attributes such as engine displacement, vehicle weight, and wheel base are likely discussed at the agency level right now when deciding vehicle purchases. These attributes are tied directly to fuel consumption, often discouraging new efficiency technologies. Legislation that places the decision in the hands of the Procurement Office would allow a step away from this system. The Procurement office could then group their vehicles according to performance requirements such as acceleration, payload capacity, towing capacity, number of seats, and cargo space. All of these performance specifications are available on fueleconomy.gov. Once grouped by performance categories, the Procurement Office can set a minimum fuel economy for each group and therefore demand the purchase of efficient vehicles while being sure to meet the performance needs of the agencies.

8. Education Campaign for Fuel Economy

An education campaign for improved fuel economy would help raise public awareness of vehicle fuel economy, related cost implications, and options for reducing costs. The campaign would teach residents how to track their personal fuel economy, give them resources to compare vehicles, and find efficient vehicles that meet their needs. The campaign would also promote vehicle maintenance and driving tips to enable drivers to maximize the fuel economy of their existing vehicles. The campaign should consist of advertisements and flyers at gas pumps, where fuel expenditures are most salient. The flyers should

direct people to classes where experts from GEO can provide instruction about saving money by improving fuel economy.

The cost of the campaign should be relatively low. Gas stations would likely display campaign flyers at discounted advertising rates, because the flyers will let customers know that station owners are trying to save them money and that fuel retailers are not the source of pain at the pump. Car dealerships could provide funding and expertise because collaborating with the campaign could lead to increased car sales. Petroleum-use reduction is expected to be less significant than that from the feebate program, because it won't reach as many people. However, petroleum-use reduction could still be substantial, because the campaign will reinforce the feebate program by educating vehicle owners about how they can minimize their registration fees or earn rebates. The popularity should be medium, because people would appreciate receiving tips on saving money.

9. Education Campaign for Alternative Transportation

An education campaign for alternative transportation would be needed to educate people about new bus routes, how to track buses, rideshare websites, and new options to walk or bike safely. It should tout the co-benefits of alternative transportation, such as the health benefits associated with biking and the safety benefits that bus riding has over driving. This campaign should consist of advertisements on the sides of buses that not only educate the public about new options, but also market the bus as a safe, convenient, social, and fashionable means of transportation. The TransMilenio bus system in Bogota successfully conducted just such a campaign, which could be used as a model for Guam. The second phase of the education campaign would entail extensive community outreach, whereby representatives from GETF or other appropriate organizations such as I Bike attend various community meetings to deliver short presentations on alternative travel options and sources of transportation information. Finally, GRTA should create and maintain a website to provide easily searchable information about alternative transportation options, complete with links to maps and schedules.

The education campaign should include outreach to the Mayors Council of Guam to illustrate the need for and benefits associated with new bike lanes. The purpose of this outreach would be to discourage mayors from invoking the "safety exemption" in an executive order that would require all new or upgraded roads to include bike routes. The safety exemption enables mayors to request center turning lanes instead of bike lanes, and the majority of them make this choice. Addressing this choice by educating the mayors will be critical for expanding Guam's bicycle infrastructure beyond the central route (Project 5).

The cost of this education campaign could be relatively low, since the majority of advertising would be on the side of GRTA buses, and the expenses would entail sign production and the opportunity cost of not renting to other advertisers. Sending speakers to community meetings would be very inexpensive, and creating and maintaining a Web presence is not very expensive, relative to other strategies for petroleum-use reduction. The petroleum-use reduction potential of this project is medium, because it is

Passenger Miles per Gallon

When comparing rideshare, mass transit, and fuel economy projects, a common metric with which to compare them is *passenger-miles per gallon* (pmpg). This is the vehicle mpg multiplied by the number of passengers traveling in the vehicle. The comparisons in this table illustrate the impact the number of passengers has on the overall efficiency of a transportation mode. It can also serve to prioritize VMT-reduction projects by helping to illustrate which actions result in the greatest impacts to petroleum-use reduction.

Vehicle	Vehicle mpg*	Passengers	Passenger mpg (pmpg)
Honda Civic	32	1	32
Honda Civic	32	2	64
Ford E350 Van	11	7	77
Transit Bus	3.1	20	62
Transit Bus	3.1	40	124
Demand response shuttle	6.6	½**	3.3
Taxi Cab	20	½**	10

*Fuel economy from www.fueleconomy.gov and Davis et al., 2012.

**Assuming that 1 passenger is taken to destination, then empty cab or shuttle is driven back to originating point.

not expected to have a substantial overall effect on ridership, but the per-rider petroleum-use reduction will be very significant. Popularity is expected to be medium, because the public is not likely to be passionate about the campaign, one way or another. The time frame is medium, because it will take time to plan and execute the education campaign to the point of changing people's travel behaviors.

10. Coordination Plan for Taxicabs and GRTA

Taxis and other demand response vehicles have the lowest fuel economy of any mode of transportation, when compared on a passenger-miles-per-gallon (pmpg) basis (see box above) (Davis et al., 2011). This is largely due to the fact that a significant portion of the vehicle miles traveled by taxis is accrued when the vehicle is not carrying a passenger. Therefore, the fact that Guam's taxi fleet has decreased by 64% during the past 13 years should be seen as an opportunity.

GRTA should propose a business agreement to taxi companies whereby taxi riders would transfer over to the fixed-route bus, and taxis would be utilized as part of the GRTA demand response transit service. As part of the agreement, taxis would post bus route schedules and maps in their cabs. Furthermore, if a taxi request came from a location on a bus line shortly before the bus was scheduled to pass, the dispatcher would be obligated to notify the requestor about the approaching bus. In return, GRTA would utilize taxis in their demand response program, since taxis are more efficient (and therefore less

expensive to operate) than GRTA's larger demand response vehicles when carrying a small number of people. The taxi owners would likely be amenable to this proposition, since their current drop in numbers is a sign that the profitability of their existing business model is declining. Honolulu is taking initial steps with such an agreement and is finding the terms to be mutually beneficial to the transit authority and taxi companies. Many details of the agreement would need to be worked out, but the basis of the plan could be mutually beneficial to GRTA and taxi owners, while saving petroleum.

The cost of implementing such a plan would be low, since GRTA's payments to the taxicabs would be largely canceled out by savings in operational costs of their demand response vehicles. The potential petroleum savings are significant, achieved through replacing trips in a taxi (which must drive empty to pick the passenger up) with trips on a fixed-route bus. There are further petroleum savings from utilizing smaller, more efficient vehicles in GRTA's demand response program. However, when compared to other projects, we rank these petroleum savings as a medium. The popularity should be medium as well, since people will save money by transferring to fixed-route buses. The time frame will be medium, because this project requires considerable groundwork and negotiation with the Independent Taxi Association.

11. Guam Motorcycle Safety Strategic Plan

Motorcycles achieve an average of more than 43 mpg in the United States (with most newer models achieving much higher fuel economy), so increasing motorcycle ridership could improve overall fleet fuel economy. Guam has great potential for high motorcycle ridership due to its overall low average speed of 29 mph (Parsons Brinckerhoff, 2008), its year-round warm weather, and its relatively short commute distances. However, Guam's motorcycle registration rate (as a percentage of all LDVs) is lower than the U.S. average, indicating significant potential for fuel savings from increased motorcycle ownership and ridership. One of the most important things a government can do to increase motorcycle ridership is to improve the safety of ridership. Fortunately, many DOTs worldwide have implemented programs to improve motorcycle safety. Three of the most proactive programs have been implemented in France; Ireland; Bogota, Colombia; and the state of Florida. The Florida Motorcycle Safety Strategic Plan (Florida DOT, 2009) serves as a particularly good model for Guam. By combining elements of this plan with those of other locations, GETF has compiled the following list to improve the safety of motorcycle ridership:

1. Require Helmets. It should be noted that if resistance to this requirement is too high (as it has been in the past), this step can be changed to "encourage helmets." The encouragement can be conducted through an education campaign and/or helmet subsidy programs.
2. Require reflectors on the helmets.
3. Require that motorcyclists ride with their lights on at all times.
4. Require high-visibility vests, similar to those shown in Figure 13. However, keep in mind that this was a highly unpopular requirement in Bogota, France, and Ireland.
5. Allow relatively high noise levels on motorcycles. Many motorcyclists consider this to be the most effective way to make nearby drivers aware of their presence.
6. Prevent and crack down on drinking and driving. Florida found that 10% of motorcycle accidents occurred while drivers were under the influence of drugs and/or alcohol, and that collisions involving drugs or alcohol were more likely to be fatal than those that did not. As a result, the Florida campaign includes motorcycle-specific drinking and driving outreach, partnerships, and enforcement programs (Florida DOT, 2009).

7. Legislate rider education and training programs.
8. Develop a motorist awareness program to ensure that vehicle drivers are cognizant that they are sharing the road with motorcyclists and bicyclists (see, e.g., MAD, 2010).



Figure 13. High-visibility reflective motorcycle vests

Photo from Public Affairs, U.S. Air Force 162nd Fighter Wing Safety Office

The cost of developing a motorcycle safety strategic plan is likely to be low, since there is no infrastructure required. The main costs related to outreach, partnerships, and enforcement. Resulting petroleum-use reduction is likely to be low, especially as the difference between car and motorcycle efficiency decreases in the future. Popularity would likely be medium: Safety improvements are likely to be popular, but rider visibility requirements and DUI crackdown would be less so.

12. New Buses and Routes

GRTA currently does not own or operate any buses—it contracts the services out on a monthly basis. Monthly contracts all but eliminate the contractor's incentives to make any investments that would take more than three months to pay back. This disincentive to invest is evidenced by the average age of a fixed-route bus in Guam: 15.6 years—much older than the 12 years at which most transit systems replace their buses (PB Americas, 2010). Such deferred investments include new, more efficient buses, route planning software, and bus tracking hardware (as described in Project 10), and maintenance facilities that would keep the buses operating at higher efficiency. Furthermore, the contractor is paid on the basis of vehicle hours operated (PB Americas, 2010), so there is no incentive for it to optimize routes in a way that would transport the highest number of passengers using the least amount of fuel.

GRTA is initiating a move away from this operating plan. It is making headway in purchasing its own buses and establishing a maintenance facility (Parsons Brinckerhoff, 2012). By owning and operating the buses through a long-term public-private partnership, GRTA would be able to realize the cost savings from any petroleum-use reductions and can plan accordingly. It will then be in a position to

secure more stable funding from the Governor's Office and realize some internal revenue opportunities, such as advertising on the buses, bus stops, and bus stop announcement recordings.

Furthermore, this fundamental shift in bus and facility ownership paves the way to additional buses. The first additional buses should be used to increase the frequency that buses run on the current routes, since three of the five routes have a headway of two hours (PB Americas, 2010). This, along with bus trackers prescribed in Project 4, would greatly reduce the risk associated with missing the bus and therefore make the system more user-friendly.

Subsequent bus purchases should be used to add new routes and therefore tap into new populations of potential riders. PB Americas (2010) recommends how best to expand the routes. GRTA should be certain to maximize the synergies between new bus routes and the central bike route shown in Figure 11. It can increase the intermodality of both systems by placing bus stops on the bike route and adding bike racks near the bus stops and on the buses.

Purchasing new buses ranks medium on the cost category since new buses are expensive, yet there are federal sources of funding to bring this price down. This project also ranks high in the petroleum-reduction category since it would enable GRTA to carry many passengers—many of whom would otherwise be commuting in their own cars. It would be highly popular since additional buses would make the system a viable means of transportation to many more people. The time frame is fast, as GRTA is already moving forward on securing funding for the bus purchases.

13. Telework

Telework reduces VMT by enabling employees to work from home (telecommuting) instead of commuting every day, and by allowing employees to participate in meetings over the phone or Internet (teleconference). It requires programs and capabilities such as videoconferencing, voice over Internet protocol, virtual private networks, and collaborative software. These capabilities usually require a fairly sophisticated information technology staff to keep systems running and secure. Telecommuting requires a level of trust between the employer and employee that is easiest to achieve with pre-existing employees whose jobs are based on deliverables rather than on the amount of time worked. It is important to define the program well and to set policies that outline what is expected of the employees (including training) and the circumstances under which their telecommuting privileges might be revoked. A useful guide for setting policy and choosing the proper technology bundle for telecommuting is the MegaPath whitepaper "How to Implement a Successful Telecommuting Program" (MegaPath, 2006), and additional telecommuting resources can be found at www.telecommuter.com.

Telework has some unique benefits beyond those of other VMT reduction strategies. It saves more of the commuter's time than any other strategy, and it reduces traffic more than any other strategy. It serves as a valuable recruitment tool for companies, widens the geographic range of potential employees, and can reduce costs associated with office space. Teleconferences are one of the few ways to reduce the skyrocketing amount of fuel used by the airline industry.

The costs of teleworking are considered medium, since most programs require equipment, software, and technicians on the part of the employer. The petroleum-use reduction is deemed to be high, since the potential number of telecommuters is large, and the amount of petroleum saved per telecommuter is substantial. Popularity would be very high, as it has been proven to give employees a sense of freedom, improve productivity, and benefit employees' families (Gajendran and Harrison, 2007). The time frame is expected to be medium, because large-scale success will require participation by numerous independent employers.

14. Mobile Emissions Testing Facility

Vehicles that emit the highest levels of carbon monoxide and hydrocarbons also tend to be the vehicles with the worst fuel economy (Harrington, 1997). Therefore, Guam could improve the overall fuel economy of its vehicle population if it encouraged the replacement of these high-polluting vehicles. This can be done in such a way that doesn't place much of a burden on Guam drivers. A system called "Clean Screen" by Environmental Systems Products (ESP) requires vehicles to pass an emissions inspection before registration, but it uses mobile roadside detectors to exempt clean vehicles from going in to the inspection facility. Most vehicles would be exempted, and the remaining ones would simply receive a notice to report for inspection in the mail shortly before registration. Exempting a majority of vehicles greatly cuts down on equipment costs for emissions testing. Guam would only need a single van and an on-board diagnostics (OBD) reader to test the vehicles that aren't exempted. The OBD equipment is generally purchased by independent operators, and they recoup their costs through emissions inspection fees. ESP can usually coordinate the contracts so that emissions inspection fees or penalties pay for the entire program, including state oversight. A natural follow-on to such a program would be a subsidy to help low-income residents replace their "Guam bombs" with a more fuel-efficient vehicle. One option is to offer these people the Guam government's retired vehicles at a discounted rate.

Despite the fact that this program is cost-neutral to the government of Guam, the cost is considered to be medium, since the drivers of high-polluting vehicles essentially pay (through fees and penalties) for the operation of the system. The petroleum-use reduction would be medium, since the high per-car savings are cancelled out by the relatively low number of cars that would be removed from the roads. The system's popularity would be low. The time frame would be medium, because it would take some time to put in place the contracts and equipment.

15. Bike Share System

The bike route listed as Project 5 would realize synergies with the tourist industry in Guam. The route would serve as a tourist attraction and, making it likely that the tourist industry and Guam Visitors Bureau (GVB) would expand the route. However, since tourists do not bring their bikes with them, there is a chicken-or-egg problem in getting tourists on the bike route: Do the bikes or the bike path come first? The easiest way to solve this problem is for hotels, tourist sites, and GVB to invest in a bike share system.

Bike share systems consist of rental bicycles that electronically lock into racks such as that shown in Figure 14. A rider releases the bike by swiping a credit card. This serves as a deposit to ensure that he or she will return the bike to the system. The rider then rides to another rack in the system and locks it. At this point, he or she is charged for the amount of time on the bike, which enables the system's investors to recoup the cost of bicycles, racks, and maintenance. Payment schedules are usually set to encourage many short trips over few long trips in order to minimize bicycle downtime. A secondary source of funding can come from advertisements on the bikes and racks. A list of companies that supply bicycles and systems is maintained by the International Bicycle Fund at www.ibike.org/engineering/parking-systems.htm. Bike share technology is well established, and as of May 2011 about 165 cities around the world had bike sharing systems (Shaheen and Guzman, 2011).



Figure 14. B-Cycle bikes and rack in Denver, Colorado

Photo from Kevin Purdy, Trailsnet.com

Logical places for the first bike racks would be in front of a hotel on upper Pale San Vitores, at Chamorro Village (which is also the GRTA transit center), and at one of the shopping malls along the Guam Central Bicycle Route (see Figure 10). It is likely that these racks would be an attraction to hotels or other businesses that sponsor them, so the system can grow its number of locations as businesses pay to place a rack nearby.

The cost of the bike share system is considered to be medium. However, much of the cost would likely be paid by hotels and stores that seek to attract tourists. The associated petroleum-use reduction is low, since tourists would otherwise be riding the trolley, shuttles, or riding with multiple people in a taxi. However, the purpose of this project is to engage the powerful tourist industry in order to improve the bike-ability of Guam for everyone. Its popularity would likely be high among tourists and residents alike. Installation of the first few racks and first few dozen bicycles would take relatively little time.

16. Shorepower for Buses

Many buses in Guam would not be able to comply with the idle limitations prescribed in Project 3, because they need to run their air conditioners while loading, unloading, or waiting for passengers. As such, buses often idle at entrances to hotels, where the guests walk and congregate. This not only is a nuisance and potential health hazard for the guests; it could hurt business for the hotel.

Shorepower (so named because it was first developed for ships powering from electrical outlets on shore) is a common technology that enables trucks, RVs, and buses to power their lights, air conditioners, and other ancillary loads from an electrical outlet. This requires bus owners to install electrical equipment, including an inverter to convert 120-volt AC power to DC power, and hardware to plug into the electrical outlet. It also requires hotels to install a power outlet in a convenient location where the cord is not a tripping hazard. Equipment requirements and cost estimates can be viewed at www.the-step-project.org.

17. Coordinate Americans with Disabilities Act (ADA) Compliance with Biker- and Walker-Friendly Facilities

DPW has an active and consistently funded program to make transportation more accessible for the disabled (Parsons Brickerhoff, 2012). Yet much work remains, as illustrated in Figure 15. There are many synergies between ADA compliance and active transportation such as biking, walking, and skateboarding. Compliance measures such as curb ramps and obstacle removal should be prioritized in areas where both bicycles and wheelchairs would benefit. In particular, projects on the ADA compliance list should be prioritized if they are on the Guam Central Bike Route (Figure 10).



Figure 15. Terrain unfriendly to wheelchairs, bikers, and pedestrians

Photo by Caley Johnson, NREL

18. Coconut Oil B5

Since Guam doesn't produce enough waste grease to serve as feedstock for all of the biodiesel needed for universal B5, it should develop additional feedstock. Coconuts would be a logical feedstock, since Guam's climate and geography are conducive to good coconut crops. Furthermore, the pathway to turn coconuts into biodiesel is well established and has proven to be efficient and economical in the Philippines (Corpuz, 2012). Guam should emulate the Philippine industry of turning coconut methyl ester (CME) into biodiesel and blending it into diesel fuel at low levels. One source of coconuts is the abundance of pre-existing coconut trees on the island, whose coconuts are currently wasted but could be utilized through a variety of collection programs. Guam should also encourage multi-cropping of coconuts with food crops since coconuts are symbiotic with numerous crops (Scheewe, 2003). The

Philippine Coconut Authority's coconut planting/replanting and fertilization program (see www.pca.da.gov.ph) could provide mentorship when promoting and supporting coconut farmers. The coconut farming initiative could be led by the Chamorro Land Trust (who already requires farmers to plant trees), the University of Guam's Cooperative Extension, and the Guam Department of Agriculture.

The cost of this program is rated medium, since it would require a new biodiesel refinery. Such refineries in the United States are generally paid off with very little price increase in B5 (and even B20) since the biodiesel substitutes for valuable fuel lubricity additives (Babcock and Laughlin, 2012). The petroleum-use reduction is deemed low, because relatively small quantities would be utilized once the potential for waste-grease feedstock is fully realized. Popularity is expected to be medium, because developing a domestic fuel source is generally popular, yet it could require some land-use decisions that are unpopular with certain subpopulations. The time frame is slow, since the project would require a new biodiesel refinery, and new coconut trees must grow to harvestable size. However, it should be noted that in the mean time, either coconut oil or coconut biodiesel could be imported from the Philippines, since it is the world's largest exporter of the former and it has excess production capacity of the latter (Corpuz, 2012).

19. Traffic Signal Coordination

Guam used to operate a control center that coordinated traffic signals to optimize traffic flow and minimize the number of vehicle stops and starts. In 2002, a typhoon destroyed the network of cables the control center relied upon. The control center was replaced by individual timers, which were less expensive but result in many more petroleum-consuming stops and starts. DPW is now considering an overall repair of the traffic control center.

The cost of repairing the traffic control center is estimated at \$1.2 million over the next four years (Parsons Brinckerhoff, 2012), which is considered high on our scale. The petroleum savings, which we estimated at nearly 300,000 gallons per year in the "Planning for Petroleum-Use Reduction" section, is considered medium. This would perhaps be the most popular of all the projects, since poorly-timed traffic signals are currently a major frustration to drivers. The four-year time frame is considered medium.

20. EV Trial Fleets

Trial fleets of EVs are needed to introduce the Guam population to these vehicles in a positive light. GPA would be a good first fleet, since it has the means to keep its EVs well maintained. GPA vehicles have drive cycles with frequent stops and pauses, a pattern in which EVs have a particular advantage over conventional vehicles. Furthermore, GPA can use this test fleet to explore the advantages of vehicle-to-grid electricity storage.

Guam's Navy and Air Force fleets would also be good candidates for an early EV trial. They, like GPA, have the technical capacity to keep the fleet well maintained. Furthermore, the Federal Fleet Program requires them to acquire alternative fueled vehicles, and EVs would be a good way to comply.

Once EV mechanics are more readily available (after experience with GPA, Navy, and Air Force), rental car companies could provide the first opportunities for residents and visitors to drive EVs. Rental car fleets are good early adopters, because they derive a marketing benefit from offering cutting-edge and environmentally friendly vehicle options. Both Hertz and Enterprise already own many EVs nationally (ExtremeTech, 2011). They can charge a premium for the novel experience of driving an EV, and they can partner with hotels to provide charging equipment.

EVs still have a higher up-front cost than conventional vehicles do, so the cost for trial fleets is rated as high. Despite the high cost, GETF deems it strategic for Guam to gain experience with EVs so that it can

be poised to penetrate the market quickly as EV prices drop. Petroleum savings is deemed low, because the number of EVs in these fleets will be relatively small. Popularity is likely to be high, as cutting-edge technology is generally helpful with public relations. The time frame is medium, because trials will likely last up to five years.

Conclusion

Wedge analysis demonstrates that a 20% reduction in petroleum use in Guam's transportation sector is indeed achievable by 2020. Current inefficiencies in vehicles, traffic flow, and commuting options may be sources of frustration today, but they also translate to significant opportunities for improvement. Furthermore, the many co-benefits of such improvements, including increased convenience, safety, and health, have the potential to generate strong public support for on-the-ground projects that reduce petroleum use. The manufacture of biodiesel from waste grease and coconut oil could also provide on-island jobs.

The wedge analysis proves especially useful in its ability to break down an otherwise daunting overarching goal into manageable subordinate goals, strategies, and tactics, and to chart their growing contributions toward the central goal years into the future. The subordinate goals needed to reduce transportation petroleum use 20% by 2020 appear achievable:

- A more efficient transportation network can perform all necessary services while motorized vehicles travel 10% fewer miles. The stage will be set for this achievement by establishing a rideshare website, a central bike route, an education campaign for alternative transportation, a plan to coordinate with taxis and GRTA, a bus tracking and coordination system, a telework system, bike share system, coordination with ADA compliance, adding new buses and routes, and replacing tanker trucks with a pipeline project.
- Guam can purchase LDVs whose fuel economy is 6% more efficient every year. These purchases will be encouraged through a feebate system, an education campaign for fuel economy, a motorcycle safety strategic plan, and a mobile emissions testing facility.
- All 84 traffic signals can be coordinated through a repaired control center.
- EVs can comprise 10% of new LDV sales in Guam. This will require the leadership of EV trial fleets at GPA, U.S. Navy, and car rental agencies.
- Biodiesel can be blended at 5% into all diesel fuel used in Guam. This can be refined from on-island waste grease and coconut oil. Importing coconut oil from the Philippines could serve as a bridge while Guam develops production capacity.
- Idle time can be reduced by an average of 45 minutes per weekday for each medium- or heavy-duty truck. This can be achieved largely through idle reduction campaigns at schools and delivery locations. Shorepower can be installed at hotels to enable tour buses to operate air conditioners without idling.

In an effort to prioritize the allocation of limited funds, these projects were ranked according to cost, petroleum reduction, time frame, and popularity. Guam's next steps toward achieving its petroleum-use reduction goal entail implementation of projects in order of priority.

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