

UNIVERSITY OF HAWAII AT MANOA,
DEPARTMENT OF URBAN AND REGIONAL PLANNING

Planning Strategies for Transportation Fuel Consumption Reduction

An Evaluation of the Hawaii Clean Energy Initiative's Transportation Plan

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Abstract: The transportation sector is responsible for 28 percent of America's total energy consumption; over 90 percent of that energy comes in the form of petroleum. In Hawaii, transportation accounts for over 50 percent of total energy consumption, nearly all of which is petroleum based. As climate change impacts and the costs of oil continue to grow, curbing consumption of petroleum is essential to ensuring the environmental and economic health of future generations. This paper provides an overview and analysis of planning strategies to reduce petroleum consumption and examines the Hawaii Clean Energy Initiative's goal of 70 percent fossil fuel consumption reduction by 2030.

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Introduction

Controlling Oil Dependency

Technological advances in nearly every facet of the global commons have been occurring at an exponential rate since the Industrial Revolution. Increased computing power and the internet have fundamentally changed the way the world communicates, works, and lives. These changes have come with a cost, as per capita energy consumption in the United States tripled from 1960 to 2008 (Johnson 2008). Although the global marketplace is increasingly dependent on a digital infrastructure, the energy requirements to fuel that infrastructure and the global economy are still heavily reliant on petroleum (US EIA 2013). The physical movement of people and goods still requires functional physical transportation systems. These systems account for 26 percent of the world's total energy consumption, 28 percent of the United States' consumption, and 51 percent of Hawaii's consumption (US EIA 2013; US DOE 2013; HEPF 2008). As of 2012, 93.5 percent of the U.S transportation system was fueled by oil, 60 percent of which was imported (Grossman et al 2012). In Hawaii, nearly all of the transportation system's consumption comes from imported petroleum (HEPF 2008; HCEI 2011).

The 1973 Organization of Petroleum Exporting Countries' (OPEC) embargo and price increases during the wars of the early 21st Century illustrates that dependency on a sole source of energy for such a large portion of the economy is a socio-economic vulnerability (Grossman et al 2012). Additionally, transportation petroleum consumption leads to emissions of greenhouse gases (GHG), thus contributing to increased air pollution and the negative health and environmental impacts associated therein (Grossman et al 2012). Beyond the 1973 embargo, the 1970s saw the federal government take a more active role in environmental legislation than in its previous history; the economic conditions and environmental attitudes created conditions ripe for

action to curb petroleum consumption and emissions (Moore et al 2007). Federal Corporate Average Fuel Economy (CAFE) standards requiring minimum fuel efficiencies in new automobiles were implemented and transportation planners dedicated significant effort to developing and implementing strategies that could reduce consumption (Doris et al 2009; Flachsbart 1979). These strategies focused on increasing travel efficiency through improved engine technologies and alternative fuels, reducing vehicle miles traveled (VMT), pricing strategies, and changing travel behaviors (Flachsbart 1979; Srinivasan et al 1981). Similarly, recent years have seen strategies to reduce petroleum consumption at all levels of planning and governance being discussed and implemented with a renewed vigor (Ewing et al 2007). Today's strategies draw from those of the past with an increased emphasis on alternative vehicle and fuel technologies (Cambridge Systematics 2009).

The U.S. Energy Information Administration (2013) projects that demand for petroleum consumption will increase at a rate of approximately 1.1 percent annually through 2040. Two trends are working against each other: the world's population is growing but as climate change impacts and the costs of oil continue to grow, curbing consumption of petroleum is essential to ensuring the environmental and economic health of future generations (Brandes et al 2010; US EIA 2013). Many states, including Hawaii, are taking initiative to reduce consumption.

The Hawaii Clean Energy Initiative

The Hawaii Clean Energy Initiative (HCEI) was created in 2008 as an effort of the myriad parties that make up the state's energy sector in order to evaluate problems and devise strategies that will help to achieve clean energy goals (HCEI 2011). The HCEI states that achieving clean energy goals will provide improved environmental quality, economic benefits, and energy security for all of Hawaii's citizens. The ultimate goal is to achieve 70 percent clean

energy by 2030 (40 percent from renewable energy sources and 30 percent from efficiency measures) across four sectors: electricity generation and delivery, end use efficiency, transportation, and fuels (HCEI 2011). The electricity sector goal is for 40 percent of delivered energy to come from renewable sources, with execution strategies relying on aligning policies to clean energy goals and process, grid, and technological improvements (HCEI 2011). The end use efficiency sector aims to reduce the energy portfolio standard by 4,300 MWh through retrofit or new construction policies and codes, identifying non-building efficiency measures, and aligning policies to goals (HCEI 2011). The goals of the fuel sector are less defined, only hoping to meet as much of in-state demand for renewable fuels as possible by supporting biofuels within the local agricultural industry, investing in infrastructure, and matching supply to demand (HCEI 2011). The transportation sector has set a goal of reducing ground transportation petroleum consumption by 70 percent (HCEI 2011). The initiative is planning on using strategies to improve the vehicle fleet's efficiency, reducing VMT, better incorporating renewable fuels into the sector, and increasing the use of electric vehicles (EVs) (HCEI 2011). While each sector is valuable in achieving the HCEI's goals, this paper is limited to an evaluation of the HCEI Road Map's transportation plan.

Purpose and Methodology

This capstone paper will provide a selective review of literature on planning strategies to reduce transportation petroleum consumption and the HCEI Road Map's published transportation plan. Each strategy will be analyzed for documented performance and the potential for complementarity in order to evaluate the likelihood of achieving the HCEI's stated goal. Contributing performance criteria includes cost-effectiveness, ease of implementation, and

the demonstrated ability to reduce emissions, VMT, and petroleum consumption. Ultimately, this paper will answer the following research questions:

- 1) Does the Hawaii Clean Energy Initiative Road Map's transportation plan use strategies that will enable it to achieve its goal of 70 percent petroleum consumption reduction by 2030?
- 2) Are there strategies not included in the plan that would better address petroleum consumption reduction?

Since the 1970s, a great deal of academic effort has been dedicated to transportation petroleum consumption and GHG emissions. The bulk of the literature selected for this review has been published in the last decade so as current conditions are more accurately accounted for; however, several documents from the late 1970s through 1990s were selected as their foundational principles have endured (i.e., Flachsbarth 1979; Srinivasan et al 1981; US DOT / DOE 1980; Gordon 1991). This review includes narrative works (Moore et al 2007; Blair and Wellman 2011; Spears and Handy 2013), empirical research (Miyashiro et al 2010; Brandes et al 2010; Flachsbarth 1977; NRC 2002), case studies (Shoup 1997; Smart Growth America 2008), plans and reports (Lee Sichter LLC 2013; Oahu MPO 2011; US DOE 2013; US EIA 2013) and models (Calthorpe 2013; Srinivasan et al 1981; Kelly 2011; Ewing et al 2007; Cambridge Systematics 2009).

Literature Review

Planning Strategies to Reduce Transportation Petroleum Consumption

Reducing energy consumption contributes to a more environmentally and economically sustainable transportation system (Black 2010). Approaches to reduce consumption of petroleum in the transportation sector have evolved over the past four decades. While a degree

of variance exists in framing said approaches, literature generally reflects common principles throughout the discipline. Two studies released in the past decade, the Urban Land Institute's *Moving Cooler: Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions* (2009) and Reid Ewing et al's *Growing Cooler: The Evidence of Urban Development and Climate Change* (2007) frame these principles as "legs of a stool." These "legs" all support the stool "seat" of emission and consumption reduction and will be used to frame the review of individual strategies that follows. In *Moving Cooler*, the authors describe factors for reducing GHG emissions as the stool's four legs (2009):

- 1) Factors related to travel activity and reducing VMT.
- 2) Factors related to technology and vehicle fuel efficiency.
- 3) Factors related to vehicle and system operations and travel efficiencies.
- 4) Factors related to fuels and reducing the carbon content of the fuel burned.

The analysis provided in *Growing Cooler* (2008) consists of three similar "legs," including system operations as part of fuel efficiency and VMT reduction. These "legs" all support the stool "seat" of emission and consumption reduction and will be used to frame the review of individual strategies that follows. Several strategies to support the legs of each stool are presented in these and other scholarly articles and will be discussed at length throughout the remainder of this section. A summary of strategies is shown in Table 1.

Table 1: Consumption Reduction Factors and Supporting Strategies (Sources: Appendix 1)

		Consumption Reduction Factors			
		VMT Reduction	Technology and Fuel Efficiency	Vehicle / System Operations	Fuel Diversification
Strategies	Pricing	X	X	X	X
	Land Use / Smart Growth	X		X	
	Public Transportation	X		X	
	Commuting Strategies	X	X	X	X
	Alternative Fuels / Vehicles		X	X	X
	Regulations	X	X	X	
	Operations / ITS		X	X	
	Freight	X		X	X

Literature suggests that individual strategies can complement each other to further reduce petroleum consumption (Harrington and McConnell 2003; Cambridge Systematics 2009; Ewing et al 2007; Brandes et al 2010). Conversely, some strategies are non-complementary; planners and policy-makers should understand the breadth of strategies being implemented to ensure the right mix is present (Flachsbar 1979). Examples will be discussed in the analysis portion of this paper.

The most common metrics reflected in academic literature are VMT, fuel consumption per mile or year, and amount of metric tons of GHG emitted (Gordon 1991; Cambridge Systematics 2009; Knittel 2012; Morrow et al 2010; Ewing et al 2007). Consumption of petroleum is the leading cause of GHG emissions and transportation is responsible for one-third of such pollution in the US (Grossman and Lovaas 2012). The EPA (2014) has calculated that 8.89×10^{-3} metric tons of carbon dioxide are burned per gallon of gasoline consumed, thus quantifying the direct correlation between emissions and consumption. As such, this review and analysis uses the emission reduction strategies presented in literature as a proxy for consumption reduction (Fesharaki et al 2003; Gordon 1991).

Pricing Strategies

Perhaps the most expansive and effective strategies for reducing petroleum consumption are those related to the cost of travel itself (Knittel 2012; Flachsbar 1979; Cambridge Systematics 2009; Srinivasan et al 1981). Though not always explicitly expressed the economic and social cost of travel is present throughout all consumption reduction strategies. When factoring in the costs of motor vehicle infrastructure, petroleum subsidies, free parking, and the lost utility of sitting in traffic, the price motorists pay for traveling in private vehicles is significantly less than the actual cost (Diesendorf 2002). Pricing strategies include incentives

and disincentives aimed at better capturing the “true” cost of private vehicular travel, thereby reducing VMT and managing existing capacities in a more efficient manner (Cambridge Systematics 2009).

One of the most common pricing strategies is increasing prices on motor fuel through taxes and market forces (Knittel 2012; Cambridge Systematics 2009; Miyashiro et al 2010). Taxes can be levied at federal, state, and local levels, but policy makers below the federal level are typically reluctant to levy additional fuel taxes due to their general political unpopularity (Harrington and McConnell 2003; Moore et al 2007). Market increases in the cost of oil over the past decade have changed consumer behavior in terms of reducing the amount of miles traveled through trip consolidation, the use of public transportation, and in making fuel economy a top priority in purchasing a new vehicle (Miyashiro et al 2010; Harrington and McConnell 2003). For example, Miyashiro et al’s (2010) analysis of Hawaii residents’ response to the 2008 gas price spike found that 56.5 percent of respondents reduced VMT as a result of higher gas prices.

Pricing strategies can be implemented beyond the price of fuel and throughout the trip cycle. Parking fees and toll roads are other strategies that can contribute to reduce VMT (Cambridge Systematics 2009). Parking fees can be privately or publicly assessed and have demonstrated an ability to encourage carpooling, therefore reducing VMT (Cambridge Systematics 2009; HEPF 2008; Spears and Handy 2013). Tolls can also be implemented in a variety of ways. Toll roads on rural or limited access roads, as well as into cordoned urban areas can discourage vehicular traffic while also using revenues to reinvest in transportation infrastructure, thus reducing VMT and the public cost of infrastructure (Cambridge Systematics 2009). Finally, congestion pricing through high occupancy toll (HOT) roads allow for motorists

to pay a fee to use an express lane, theoretically increasing the efficiency of all vehicular traffic across a system (Moore et al 2007).

Incentive pricing strategies can also support VMT reduction. Usage based pay-as-you-drive (PAYD) insurance charges drivers higher rates for driving more miles, thus providing an incentive for motorists to drive less and save money while reducing VMT (Harrington and McConnell 2003). A similar strategy is for states to charge fees for VMT, either through annual inspections or electronic metering (Cambridge Systematics 2009). Though effectively a tax, motorists have an incentive to drive less under such a program. This strategy is currently present in several European countries, though Oregon is the only state to experiment with a VMT fee policy, and it is presently limited to a pool of 5,000 volunteers (Snyder 2010; Dawid 2013). However, several Secretaries of Transportation have called for similar programs in the US and several states have explored implementation (Snyder 2010; Dawid 2013).

While pricing strategies are proven to be effective in reducing VMT automobile traffic is still the preferred and most accessible form of transportation for most commuters, as such implementing pricing strategies is politically unpopular (Cervero 2001; Poumanyvong et al 2012). Additionally, social equity concerns on their potentially regressive nature are valid; if citizens, particularly those of lower income, have no access to an alternative mode of transportation, imposing additional fees on an already burdened populace is a difficult course of action (Morrow et al 2010; Flachsbar 1979; Moore et al 2007). Harrington and McConnell (2003) found that if funds from pricing strategies are used to invest in infrastructure and increase mobility, thus creating relative revenue neutrality, citizens are more apt to support such fees. Investing revenues in strategies that support public transportation and smart growth land use patterns can contribute to reducing petroleum consumption.

Public Transportation Strategies

Transportation systems shape the social interactions, form, ecosystems, and economy of urban areas more than any other development factor (Rodrigue et al 2013). Although the preferred method of travel for most commuters is the personal automobile, planners, community leaders, and city officials often advocate the necessity of public mass transportation in order to enhance mobility for workers of all income levels while reducing congestion and providing for a more environmentally friendly transport solution (Cervero 2001; Poumanyvong et al 2012; Gordon 1991). However, a mass transit system requires a significant capital investment and a substantial recurring maintenance budget; critics argue that as personal automobile is preferred by most any such investment is wasteful. While the majority of commuters do prefer to use a private automobile, the national share of commuters using public transportation increased from 3.0 percent to 5.0 percent between 1990 and 2010, with significantly higher shares in urban areas with accessible mass transit (Cervero 2001; Poumanyvong et al 2012; Gordon 1991; US Census 2010). This demonstrated upward trend in concert with indications of an increased amiability to riding mass transit illustrates that public transportation strategies could well be increasingly effective in reducing VMT and consumption (Miyashiro et al 2010; Knittel 2012).

Public transportation strategies include service improvements to existing routes, for example more frequent service and express routes, as well as infrastructure investments (Ewing et al 2007). Capital investments include those for new infrastructure or the expansion of existing facilities that increase a community's available transportation alternatives (Ewing et al 2007). These investments are significant and require political support for implementation. As such fares for riders are often subsidized to attract support and riders for these investments (Cambridge Systematics 2009). Although rarely cost effective, subsidizing fares is the most common

strategy to incentivize public transportation in that every publicly funded transit system contains subsidized fares (Knittel 2012). An efficient transportation system enhances the mobility of workers and therefore the economy of a given city, thus cities invest in public systems when they believe a socioeconomic benefit will occur, whether or not the result is entirely cost effective (Moomaw and Shatter 1996; Cervero 2001).

Literature suggests that access is a significant contributor to modal choice; those with access to transit tend to use it, and those with access only to roads tend to drive (Smart Growth America 2008). The aforementioned strategies enhance a community's transportation alternatives through direct system improvements. Beyond direct system improvements, implementing land use plans that improve access to public transportation can reduce the consumption of petroleum.

Land Use and Smart Growth Strategies

Throughout its history, many Americans have preferred single-family homes with large private yards. The Federal-Aid Highway Act of 1956 and various veteran's assistance programs encouraged families to move out of urban centers and into the emerging suburbs so as families could experience the best of the city and the countryside (Hayden 2003; Mintz and Kellogg 1989). Many believed that suburbs were modern versions of Ebenezer Howard's garden cities, with the automobile serving as the transportation conduit to the larger cities when such travel was necessary. This rapid expansion of development with a supposed focus on being closer to nature actually had negative environmental, economic, and social impacts, ultimately leading to as "a loss of quality urban livability" (Jacobs and Appleyard 1987). Characterized by low density, auto-centric development in previously green fields at city peripheries, some believe

sprawl patterns to be among the most negative trends of American life (Blair and Wellman 2011).

Smart Growth emerged over the last quarter of the twentieth century as a set of principles that guides dense, compact, mixed-use, and less auto-dependent development without the environmental and social problems inherent in sprawling patterns (Burchell et al 2000). Defined by the U.S. Environmental Protection Agency (EPA) as development that “serves the economy, the community, and the environment,” Smart Growth strives to achieve a unique sense of community and place; expand the range of transportation, employment, and housing choices; equitably distribute the costs and benefits of development; preserve and enhance natural and cultural resources; and promote public health (US EPA 2013). One way that smart growth is being realized is through transit-oriented development (TOD). The Federal Transit Administration (FTA) states that TOD “generally refers to higher-density development, with pedestrian priority, located within easy walking distance of a major public transit station or stop(s). TODs are viewed as offering the potential to boost transit ridership, increase walking activity, mitigate sprawl, accommodate growth, and create interesting places” (TCRP 2007).

TODs and other land use strategies that use Smart Growth principles reduce consumption by increasing the ability of people to use non-motorized forms of transportation (Cambridge Systematics 2009). In King County, Washington, a comprehensive study found that residents of the most pedestrian friendly neighborhoods drive 26 percent fewer miles than those in the most sprawling neighborhoods (Frank 2000). A similar study in Atlanta found that walkable land use patterns reduced VMT by 30 percent (Smart Growth America 2008). Aiming to produce similar results, the Hawaii Community Development Authority’s Kaka’ako Community Development

District TOD Overlay Plan (2013) uses the “Six D’s” as guiding principles in order to reduce VMT:

- 1) Destinations: Coordinate land use and transportation.
- 2) Distance: Create a well-connected network of complete streets and bicycle networks with a coordinated multi-modal way-finding system.
- 3) Design: Create places for people to enjoy.
- 4) Density: Concentrate and intensify activities near transit stops.
- 5) Diversity: Encourage mixed uses.
- 6) Demand Management: encourage the auto-trip not taken through parking incentives and fees.

The Kaka’ako plan understands that development patterns that encourage walking and biking tend to discourage the use of automobiles, thus reducing petroleum consumption (Lee Sichter LLC et al 2013). Literature suggests that compact development can reduce VMT, though the degree of which is dependent on the degree of density and accessibility of development patterns to non-motorized modes as well as the socioeconomic background of residents (Brandes et al 2010; Cambridge Systematics 2009; Ewing et al 2007). Critics argue that developmental VMT reduction estimates do not account for self-selection or any socioeconomic factors of community residents, for example, income, age, and employment status that also contribute to low VMT, thus quantifying actual reduction explicitly from development patterns is difficult (Chatman 2013; Frank 2000). However, unlike alternative vehicle and fuel strategies, technological improvements are not necessary for further consumption reduction (Brandes et al 2010). Plans such as this require significant planning and political effort and while VMT reduction appears incrementally over time, the reduction realized as a result is permanent

(Brandes et al 2010). While many still prefer the suburban scenarios previously described, demand for smart growth development is increasing amongst younger generations and more senior, “empty nest” demographic groups, thus barriers to implementation are steadily decreasing (Duggal 2013; Ewing et al 2007; Miyashiro et al 2010).

Commuting Strategies

As the cost of motor fuel has increased, strategies to increase the efficiency of commuting are becoming more diverse and widespread (Miyashiro et al 2010). Commuting strategies include those that encourage carpools, vanpools, or car- and bike-sharing programs (Cambridge Systematics 2009). From a typical traveler’s point of view, the most likely trip that can be achieved via a carpool or transit is the commute to and from work; as such, both private industry and the public sector play a role in implementing commuting strategies (Srinivasan et al 1981). The most common public sector strategy to encourage carpooling is the implementation of high occupancy vehicle (HOV) lanes that allow for express travel for HOVs, however public carpool / vanpool programs are also readily available in most urban areas (Moore et al 2007). Theoretically, carpooling removes vehicles from the road, thus reducing VMT and petroleum consumption. In the private sector, companies encourage commuting strategies through employee coordination programs; by providing financial assistance for those who carpool, walk, or bike to work; or by subsidizing transit fares (Cambridge Systematics 2009). Employers with such programs reduce their need to provide parking for employees, which can be a significant overhead expense (APERC 2007).

Realizing that a typical commuter’s private automobile is parked 23 hours in a given day, car- and bike-sharing programs are relatively new strategies that reduce the need for people to own vehicles by creating shared resources in which travelers are charged either per use or

through a membership agreement (Grossman and Lovaas 2012; Cambridge Systematics 2009). Members of car-sharing programs tend to use transit, walk, or bike for most trips and only need cars for occasional trips, i.e., grocery or other shopping, as a taxi, or if their final destination is beyond walking distance from a transit stop; thus they have access when it is absolutely necessary without the full overhead and lifecycle maintenance costs of car ownership (HEPF 2014; UC Berkley 2014). Shared cars (or bikes) can be subsidized publicly or privately, receive preferential parking assignments, and generally use fuel-efficient vehicles (Davis et al 2013). While the potential for consumption reduction is evident it is unclear how many people uses shared vehicles, thus accurately predicting consumption reduction is challenging (Grossman and Lovaas 2012).

Finally, commuting strategies that encourage alternative work schedules and telework aim to improve commuting by physically eliminating it or by lessening traffic at peak times (Moore et al 2007). Alternative work schedules include a four-day work week or non-standard scheduled work times and are used more for congestion relief purposes than explicitly to reduce VMT (Moore et al 2007). In fact, these programs could be counterproductive for consumption reduction purposes. Since non-work trips on additional days off are likely to increase and decreased congestion makes vehicular transportation more attractive, VMT and petroleum consumption can increase as a result of these policies (Flachsbar 2013). Telework's effect on VMT reduction is inconclusive at this time; although the technical potential to reduce consumption is evident, it is unclear how large a portion of the work force is able to take advantage of the practice (Grossman and Lovaas 2012; Harrington and McConnell 2003). As with alternative work schedules, telework can also create a rebound effect in which non-work trips substitute for work trips, thus nullifying any reduced VMT (Grossman and Lovaas 2012).

Alternative Fuel / Vehicle Strategies

While critics argue that VMT reduction strategies outside of public transit subsidies are underused, strategies to reduce consumption through the use of alternative fuels and vehicles are at the forefront of the discussion (Knittel 2012). Such strategies generally fall into one of three categories (Knittel 2012; Cambridge Systematics 2009):

- 1) Alternatives to petroleum based fuels.
- 2) Alternatives to internal combustion engines.
- 3) Increased fuel economy of existing vehicles.

By providing motorists alternatives to petroleum burning vehicles, proponents believe that dependency can be eliminated while still providing people with their “preferred” mode of travel (Knittel 2012; Cervero 2001). The most common alternative fuels are ethanol biofuels derived from corn, soybeans, sugars, grasses, and wood chips (Knittel 2012). While the direct consumption of petroleum by automobiles is reduced by these biofuels, when factoring in land requirements, competing uses of crops for food, and the lifecycle emissions to process said crops into fuel, net petroleum consumption and emissions can be greater than that from simple petroleum burning vehicles (Searchinger et al 2008). Lifecycle energy effects vary by crop, the geographic location where it is grown, and the style of farming used in cultivation, as well as the conversion method used (Whitaker et al 2010).

Methanols derived from natural gas, compressed natural gas (CNG), and cellulosic ethanol biofuels derived from non-food crops do not possess many of the aforementioned negative effects of non-cellulosic ethanol biofuels and provide a potentially sustainable alternative to petroleum-based fuels (Harrington and McConnell 2003; Knittel 2012). At present CNG vehicles do not have the range of standard petroleum vehicles, are more expensive with

less horsepower, and require new refueling infrastructure to support widespread deployment; as such, continued improvements to CNG technologies are required for a significant level of implementation (Knittel 2012; DBEDT 2012; Aguirre et al 2012).

Many view hydrogen as the definitive alternative fuel to reduce petroleum consumption as it can be burned directly in an internal combustion engine and be used as part of a fuel cell for an electric vehicle (EV) (Knittel 2012). Presently the use of hydrogen in either scenario is not simple. Though hydrogen can be produced in a carbon-free way, the process is still extensive and expensive (Knittel 2012). Additionally, the infrastructure for refueling and distribution generally involves significant capital investment at this time (HEPF 2014). Finally, absent a technological breakthrough in liquid storage, hydrogen is likely to be stored as a compressed gas, thus increasing the required space for storage tanks or reducing the range of vehicles (Knittel 2012).

EVs are steadily improving in range and quality, but a number of challenges currently prohibit their widespread proliferation into the fleet. One challenge for EVs is the current state of battery size and technology limits the range to a significantly lower distance than that of comparably sized petroleum based vehicle (DBEDT 2012). For example, the Nissan Leaf, a compact car, averages a range of 73 miles whereas similarly sized standard vehicles can travel up to four-times that distance on a single tank (Knittel 2012). While the short range might not be prohibitive for urban commuters, the “true cost” of an EV battery is variable. This is due to the fact the EV battery production requires more energy than standard batteries and that the energy used to charge EV batteries may contain petroleum (Aguirre et al 2012). Finally, EVs are not yet to the point where operating costs outweigh upfront purchase costs for most consumers, thus a technological breakthrough that lowers the initial investment is likely required to increase the

market share of EVs (Knittel 2012; Aguirre et al 2012). However, hybrid electric and plug-in hybrid vehicles (HEV/PHEV) powered by both petroleum and electric batteries are increasingly becoming a cost competitive alternative to standard vehicles. HEVs economize battery costs by intelligently switching between power plants so as the vehicle is operating in the most efficient mode available, i.e., electric use for city driving and petroleum use for highway driving (Eng 2003). While initial investment costs are still more than standard vehicles, lifecycle HEV costs are competitive (Knittel 2012; Aguirre et al 2012).

As the quality and efficiency of alternative fuels and vehicles continues to mature, many states are utilizing strategies that invest in the technologies. These occur either by government fleets purchasing EVs and HEVs, subsidizing consumers to increase the cost competitiveness of EVs and HEVs, or by providing financial incentives to companies conducting research and development in pursuit of the “required technological breakthrough” that will lead to proliferation in markets (Grossman and Lovaas 2012; Greene and Plotkin 2011). Beyond financial incentives, both federal and state governments are implementing policies and regulations that produce targets for alternative fuel consumption and overall vehicle efficiency (Morrow et al 2010; Smart Growth America 2008).

Regulatory Strategies

Regulatory strategies for reducing petroleum consumption, while diverse, generally fall into one of three categories:

- 1) Those related to pricing.
- 2) Those related to land use.
- 3) Those related to efficiency.

As previously discussed, pricing regulations include taxes on motor fuels, VMT fees,

and road tolls (Cambridge Systematics 2009). Bridging the gap between pricing and land use regulations are strategies related to parking controls, either through outright restrictions or fees (Cambridge Systematics 2009). Land use regulations include restricting auto use in certain zones as well as implementing zoning and land use plans with documented consumption reduction performance (Cambridge Systematics 2009). Regulations on efficiency are the primary mechanism the American federal government uses to incentivize market forces to reduce petroleum consumption (Harrington and McConnell 2003).

The Corporate Average Fuel Economy (CAFE) standards of 1975 were enacted in response to the 1973 oil embargo and subsequent high gas prices; these regulations were the first to require minimum fuel efficiency in new motor vehicles, gradually improving over the course of two decades (Grossman et al 2012). Vehicle manufacturers made a concerted effort to meet the new requirements, thus increasing the fuel efficiency of the total motor vehicle fleet and reducing consumption of petroleum (NRC 2002). Although manufacturers continued to make fuel efficiency improvements beyond those imposed in CAFE standards as technological advancements allowed, the regulations themselves were not updated again until 2007; President Obama's administration enacted a subsequent update that took effect in 2011 (Doris et al 2009; Morrow et al 2010; NHTSA 2010; CBS 2012). Until 2009 states were not authorized to impose regulations that exceeded those in CAFE standards, since then several states have created regulations that exceed the standards as part of their consumption reduction strategies (Doris et al 2009). In addition to the CAFE updates, the newly enacted Federal Renewable Fuels Standard requires that 12 percent of consumption in 2022 is from renewable sources (Greene and Plotkin 2011). These new regulations can complement pricing and alternative fuel strategies in order to encourage the technological breakthroughs required for increased consumption reduction.

While federal cap-and-trade systems for emissions are not currently in place in America, several states on the west coast and in New England have implemented such policies as part of the broader strategy to reduce pollution and oil dependence (Doris et al 2009). Finally, a “last resort” regulatory strategy that has only been used in extreme circumstances in the US is rationing of fuel (Flachsbart 1979). While mandating rations on a populace is a guaranteed way to significantly reduce ground transportation petroleum consumption, implementation is difficult and politically unpopular except during a state of emergency (Davis et al 2013).

Operational and Intelligent Transportation System (ITS) Strategies

Improvements to the operation of the vehicular traffic system can occur through a broad range of strategies that use the existing infrastructural capacity of the system (Cambridge Systematics 2009). These include educational programs to improve safety and more fuel efficient driving, traffic management systems, and various in-vehicle technologies to increase efficiency (Cambridge Systematics 2009). Though many functions can be fully automated traffic management systems (TMS) typically include a traffic management center (TMC) to coordinate the road operations of a given area (Cambridge Systematics 2009). A TMS can ensure traffic signals are coordinated to decrease congestion, meter on-ramps to control flow onto freeways, and provide real time traffic and weather advisories to traffic update signs to inform motorists of upcoming conditions (Cambridge Systematics 2009; Harrington and McConnell 2003).

In-vehicle ITS strategies include smart-toll systems which track a vehicle’s usage of toll roads through a radio frequency identification (RFID) system, thus skipping toll lines, reducing idling time, and moving more efficiently (Cambridge Systematics 2009). IntelliDrive systems are similar to traffic update signs that provide real time updates to drivers, but differ in that the

infrastructure is included within a vehicle and directly communicates from a TMC or similar entity to a driver (Cambridge Systematics 2009). In-vehicle systems similar to those described could also be used to track VMT for the purposes of PAYD insurance or VMT fees (Dawid 2013). Similar to in-vehicle ITS strategies are online scheduling tools and smart phone applications that increase the accessibility of public transit as well as bike-, ride-, and car-sharing systems (Davis et al 2013). One challenge to these more “personal” ITS strategies is that they are not likely to be legally mandated due to privacy concerns; thus must be implemented on a voluntary basis (Kubik 2006; Dawid 2013).

Traffic flow improvements can also include reversible lanes, one-way streets, and the widening of intersections, all in an effort to improve system efficiency and reduce idling time while maintaining the system’s given infrastructure (Davis et al 2013). Alternatively, expanding a given transportation system’s capacity is another strategy to improve efficiency and reduce consumption (Cambridge Systematics 2009). The theory behind capacity expansion and operational improvements is that decreasing idling time increases efficiency and thus reduces consumption (Cambridge Systematics 2009). However, evidence shows that the more automobile traffic is able to flow freely, the more likely people are to drive, and thus it is possible that capacity expansion and traffic efficiency improvements can actually increase petroleum consumption (Oahu MPO 2011; Gordon 1991). See Downs (2004) for a more complete discussion of this topic.

Freight Strategies

The strategies discussed thus far are largely focused on the movement of people; when discussing ground transportation petroleum consumption one must also consider the movement of goods through freight transportation. Freight transportation accounts for roughly one-third of

ground transportation petroleum consumption; as such, strategies to reduce consumption in this sector are crucial to reducing overall consumption (US DOT 2013). The strategies primarily rely on optimizing the modes of freight transportation by using rail- or water-based systems where capacity exists; allowing increased load restrictions for short distances, thus reducing VMT; and reducing the amount of time heavy trucks are idling through ITS systems and time of day restrictions in central business districts (Cambridge Systematics 2009).

Complementary and Non-complementary Strategies

The aforementioned strategies have the potential to reduce petroleum consumption individually, but policy rarely relies on a singular strategy. The potential for strategies to work together to reduce consumption to a greater degree is ample; however, the potential for strategies to work against each other cannot be discounted either. Strategies that improve motor vehicle travel efficiency i.e., alternative work schedules and decongestion measures, have the potential to make personal vehicle travel more attractive, thus these strategies are non-complementary with commuting strategies and public transit programs (Flachsbar 2013). Regulated increased fuel efficiency standards reduce the per mile consumption of vehicles but if they are implemented without similar controls on the cost of petroleum they can encourage more driving, thus negating the net reduction (Morrow et al 2010). This complementarity was demonstrated as the cost of fuel declined after the sharp increase in the 1970s; the consumption reduction as a result of the CAFE increased fuel economy standards is projected to be 10 to 20 percent less than it would have been had oil prices remained high (Harrington and McConnell 2003). It is also important to reconcile consumption reduction strategies with land use planning strategies. As illustrated by Smart Growth America (2008), there is no net reduction in consumption to a 10 mile per gallon

improvement in fuel economy if a car has to drive 10 extra miles to arrive at its destination.

General relationships between strategies are shown in Table 2.

Table 2: General Complementarity of Strategies (Flachsbart 2013; Morrow et al 2010; Harrington and McConnell 2003; Cambridge Systematics 2009)

C = Complementary N = Non-complementary U = Uncertain D = Method Dependent	Pricing	Land Use / Smart Growth	Public Transportation	Commuting Strategies	Alternative Fuels / Vehicles	Regulations	Operations / ITS	Freight
Pricing		C	C	C	C	C	C	C
Land Use / Smart Growth	C		C	N	C	C	N	U
Public Transportation	C	C		N	C	C	D	U
Commuting Strategies	C	N	N		D	C	C	U
Alternative Fuels / Vehicles	C	C	C	D		C	U	C
Regulations	C	C	C	C	C		U	C
Operations / ITS	C	N	D	C	U	U		C
Freight	C	U	U	U	C	C	C	

Moving Cooler (2009) analyzed bundles of complementary strategies deployed at different intensities and geographic levels in order to project consumption reduction. The analysis found the following combination of strategies to possess the highest potential for consumption reduction (Cambridge Systematics 2009):

“Strategies that contribute most to greenhouse gas reductions are local and regional pricing and regulatory strategies that increase the costs of single-occupancy vehicle travel, regulatory strategies that reduce and enforce speed limits, educational strategies to encourage eco-driving behavior that achieves better fuel efficiency, land use and smart growth strategies that reduce travel distances, and multimodal strategies that expand travel options. Well-designed bundles could provide both greenhouse gas reductions and improved transportation service, including changes in the travel choices available.”

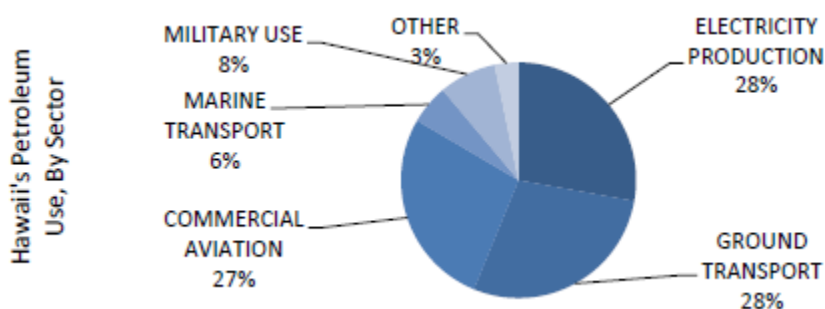
This best case scenario achieved a consumption reduction of 15 percent from the baseline over a 40 year period (a summary of the full analysis is available in Appendix 2). It is important to note that this projected reduction is at the national scale and does not account for alternative fuels, EVs, HEVs, or the potential for technological improvements therein (Cambridge

Systematics 2009). As suggested, individual local areas have a greater potential to reduce their consumption than the entire national system as the ability to influence attitudes, behaviors, land use patterns, and regulations is greater at local levels (Cambridge Systematics 2009). While it is impossible to fully project how much as yet unrealized technologies can reduce consumption, regulations and financial incentives can encourage market forces to achieve the innovation required to meet or exceed reduction targets (Greene and Plotkin 2011; Harrington and McConnell 2003). Local approaches that encourage a multi-faceted, flexible, and adaptive suite of strategies can lead to a reduction in petroleum consumption (Greene and Plotkin 2011).

HCEI Transportation Plan

The state of Hawaii has been among the nation's leaders in planning for sustainable energy solutions (HEPF 2014). However its remote location also makes Hawaii the state most dependent on imported fossil fuels (HCEI 2011). The Hawaii Clean Energy Initiative (HCEI) is a multi-tiered public and private venture that aims to reduce this dependency by laying out a roadmap for the state to achieve a 70 percent clean energy portfolio by 2030, 30 percent of which would come from improved efficiencies and 40 percent coming from locally generated renewable sources (Kelly 2011; HCEI 2011). As 28 percent of the state's petroleum consumption comes from the ground transportation sector, a key component of this initiative is reducing petroleum consumption by 70 percent within the sector (DBEDT 2013; Kelly 2011).

Figure 1: Hawaii Petroleum Consumption by Sector (DBEDT 2013)



Due to uncertainty about the development of fuel and vehicle technologies and the associated efficiency improvements therein, the HCEI adopted a multi-stage planning process that will review and update the strategies used to achieve the overall goal (HCEI 2011). The plan assumes that the general availability and improvements of alternative fuels, EVs, and HEVs will initially be slow but rapidly surge as improvements that decrease the initial purchase price of such vehicles are realized (HCEI 2011). The plan contains 5- and 10-year benchmarks that are intended to be updated as more information on technical innovations is available en route to achieving the ultimate goal of a sector-wide 70 percent consumption reduction (HCEI 2011). The remainder of this section explores the targeted objectives, strategic actions, and the associated benchmarks in the HCEI Road Map's transportation plan.

Improve Vehicle Efficiency of the Fleet

The strategy of improving vehicle efficiency relies on promoting the purchase of more efficient vehicles, promoting hybrid technologies to improve fleet efficiency goals, and evaluate switching to biodiesel for trucks and vehicles without other alternatives (HCEI 2011). This strategy relies on federal efficiency and renewable standards, guidelines for government owned fleets, and technological improvements to achieve the goals illustrated in Table 3 (US DOE 2013; HCEI 2011).

Table 3: Vehicle Efficiency Benchmarks (HCEI 2011)

2015 Goal	25 mpg average on all cars
	18 mpg average on all light duty trucks
2020 Goal	30 mpg average on all cars
	22 mpg average on all light duty trucks

Vehicle efficiency strategies are expected to account for 30 percent of the overall 70 percent reduction goal (Kelly 2011). Initial progress has been made towards this goal as HEVs

have been incorporated into state automobile and transit bus fleets. Sales of HEVs account for roughly two percent of the public and private fleet (HCEI 2011; DBEDT 2013).

Reduce VMT

The HCEI strategy of reducing VMT relies on further studies and educational strategies to illustrate alternatives to automobile travel to stakeholders. Specific strategic actions include promoting telecommuting, carpooling, and vanpooling; transit service alternative studies; and identifying ways to quantify the “true cost” of automobile travel costs to motorists such as highlighting the pass through of parking costs to employees (HCEI 2011). Interim targets are shown in Table 4.

Table 4: VMT Reduction Benchmarks (HCEI 2011)

2015 Goal	2 % VMT reduction
2020 Goal	4 % VMT reduction

These strategies are expected to account for 10 percent of total consumption reduction (Kelly 2011). The HCEI transportation plan highlights the fact that public transit systems in the state are among the most highly ridden US systems per capita (HCEI 2011; US Census 2010). Thus, a focus on VMT reduction initiatives could make the public transit systems even more effective (HCEI 2011).

Incorporate Renewable Fuels into the Transportation Sector

One of the HCEI’s four sectors of focus is dedicated to analyzing and promoting local capacities for alternative fuel production; the initiative is also aiming to increase their incorporation throughout the transportation sector (HCEI 2011). To do so, the initiative suggests evaluating feasible alternative fuel options and understanding the required infrastructure by participating with programs such as the Hawaii Hydrogen Initiative (HCEI 2011). While the

transportation sector goals for the initiative rely solely on ground transport, this objective calls for evaluating the impact of drop-in replacement renewable fuels in the aviation and marine sectors to determine if such implementation can impact the overall consumption reduction target (HCEI 2011). Interim goals are shown in Table 5.

Table 5: Renewable Fuels Benchmarks (HCEI 2011)

2015 Goal	Maintain E10 standards and biodiesel usage levels
2020 Goal	50 MGY of renewable fuels

Renewable fuel strategies are expected to account for 40 percent of the total ground transportation petroleum consumption goal (Kelly 2011). Current E10 standards referenced in Table 4 require that 85 percent of the state’s petroleum for ground transportation must contain 10 percent ethanol (DOE 2013). As such, the HCEI counts the fact that 10 percent of the fueled transportation fleet is currently displaced with ethanol as an accomplishment that encourages overall goal accomplishment (HCEI 2011). The initiative also references the current hydrogen production, refueling facilities, and vehicle fleet available at Joint Base Pearl Harbor-Hickam as a reason for optimism in expanding related state capacities (HCEI 2011). It is worth noting that according to the US Department of Energy (2013), the state already consumed 52 MGY of renewable fuels in 2011, thus the 2020 benchmark should be revisited.

Electric Vehicles and Related Infrastructure

The final objective within the HCEI’s transportation sector goal is that of accelerating the deployment of EVs and related infrastructure. The initiative realizes that the costs, standards, and infrastructure needs are not yet fully understood and as such assumes most actions toward these strategies will occur later rather than sooner (HCEI 2011). Strategic actions for this objective focus on providing incentives for early adopters of vehicles and charging equipment,

working with industry to increase EV market penetration, and continually refining the incentive structures for EVs (HCEI 2011). Additionally, the initiative calls for the completion and development of the EV charging network laid out in the Hawaii EV Ready Program, a \$4 million program of grants for infrastructure (HCEI 2011). Specific program benchmarks are shown in Table 6.

Table 6: EV and Infrastructure Benchmarks (HCEI 2011)

2015 Goal	4,000 EV/ year sold
	Supporting Infrastructure installed
2020 Goal	10,000 EV/year sold

EV strategies are planned to account for 20 percent of the total sector consumption reduction goal (Kelly 2011). The HCEI is optimistic about EV and infrastructure objectives helping to achieve the overall transportation reduction consumption goal due to the existing programs and attitudes currently present in the state. Examples include the aforementioned Hawaii EV Ready Program as well as existing partnerships with automotive and infrastructure suppliers throughout the private sector (HCEI 2011).

Analysis and Discussion

The HCEI reflects literature in that it recognizes complementarity of strategies is required in order to significantly reduce petroleum consumption (HCEI 2011; Greene and Plotkin 2011; Cambridge Systematics 2009; Ewing et al 2007). It also demonstrates an awareness of the necessity for reflective planning by advocating for frequent reviews and revisions as technologies mature (HCEI 2011). The Road Map for the transportation sector also uses the consumption reduction factors generally reflected by strategies illustrated in Table 1. A summary of HCEI transportation sector strategies are shown in Table 7.

Table 7: HCEI Strategies Summary (HCEI 2011; Harrington and McConnell 2003; Davis et al 2012)

% of Goal	Strategy	Reduction Potential
30%	Improve Vehicle Efficiency	
	Purchase more efficient vehicles	10-20%
	Promote hybrid technologies	10-20%
	Evaluate biodiesel switching (freight)	TBD
10%	Reduce VMT	
	Promote telecommuting	Unknown; 1.4%
	Promote car- and van-pooling	2-5%
	Transit service studies	TBD
	Quantify "true cost" of autos (parking fees)	2-12% VMT
40%	Incorporate Renewable Fuels	
	Evaluate feasible alternative options	TBD
	Understand infrastructure requirements	TBD
	Evaluate drop-in replacement aviation / marine	TBD
20%	EV and Related Infrastructure	
	Provide incentives for early adopters	TBD
	Work with industry to increase EV penetration	TBD
	Refine incentives	TBD
	Complete Hawaii EV Ready program	TBD

This section will discuss the strategic actions targeted within the HCEI's demonstrated performance, discuss elements not included, and discuss some challenges to accomplishing the goal of 70 percent petroleum consumption reduction.

HCEI Targeted Strategies' Demonstrated Performance and Potential Issues

The HCEI road map states that initial reductions in petroleum consumption will initially come from VMT reductions and efficiency increases whereas results from EVs and alternative fuels will be realized as the technologies improve over time (HCEI 2011). This assertion is justified by Greene and Plotkin (2011), Smart Growth America (2008), Cambridge Systematics (2009), as well as Ewing et al (2007).

VMT Reduction Strategies

The HCEI advocates for promoting telecommuting, carpooling, and vanpooling. Telecommuting's ability to reduce vehicle consumption is difficult to quantify as the percentage of the population participating in such programs is unknown (Grossman and Lovaas 2012; Harrington and McConnell 2003). Even if 15 percent of the population replaced their standard

commuting pattern with telecommuting, consumption reduction is estimated to be roughly 1.4 percent of the baseline (Harrington and McConnell 2003). Carpooling and other ridesharing strategies generally reduce petroleum consumption by two to five percent (Davis et al 2013). Compared to the national average of 9.7 percent, approximately 14 percent of Hawaii commuters are in a carpool (US Census 2010). In a statewide study of travel behavior responses to higher gas prices, Miyashiro et al (2010) found that carpooling was the third most used coping strategy for Hawaii commuters (15.1 percent of respondents said they joined a carpool). This shows that Hawaii commuters are open to carpooling and advocating for such programs could contribute to decreased VMT, although it is possible that the high number of carpoolers indicates a saturated market. Since the carpooling increase was in response to an increase in gas prices, implementing pricing strategies in concert with carpooling incentives is likely to be a more effective method of reducing VMT than simply relying on carpooling strategies (Cambridge Systematics 2009).

Although politically unpopular, pricing strategies have proven to be the most effective in reducing petroleum consumption (Moore et al 2007; Knittel 2012). Empirical studies validate HCEI's plan to quantify the "true cost" of commuting to drivers through parking costs to employees (Spears and Handy 2013). While many studies saw modest VMT reduction as a result of parking pricing, i.e., less than two percent if only modest price increases, Shoup's (1997) analysis of workplaces in Southern California that offered cash incentives for employees who did not commute or park at their place of work found that the program reduced VMT by 12 percent (Spears and Handy 2013).

The final VMT reduction strategy discussed in the HCEI discusses studying public transit demand and evaluating alternatives (HCEI 2011). Such policies have reduced VMT by one to three percent nationally when implemented singularly (Davis et al 2013). Similar to carpooling,

Hawaii commuters use public transportation at a higher rate than the national average (6.6 percent versus 5.0 percent respectively); as such policies to increase public transit use are likely to produce results in Hawaii (US Census 2010; Miyashiro et al 2010).

Technology and Efficiency Strategies

Davis et al (2013) found that vehicle efficiency improvements can reduce overall consumption by 10 to 20 percent if implemented individually. However, increases in fuel economy that occurred after the implementation of CAFE standards did not discourage automobile use when coupled with decreasing fuel prices; highway petroleum consumption in the US instead increased by 59 percent (Morrow et al 2010).

The HCEI aims to increase the overall efficiency of the fleet by promoting efficient standard vehicles, EVs, HEVs, and biodiesel switching for trucks (HCEI 2011). Literature suggests that HEVs and the continued innovation within the sector are absolutely crucial to reducing petroleum consumption since the vehicles are already cost competitive with standard vehicles over their lifecycle (Aguirre et al 2012; Knittel 2012). This is also the only strategy that directly addresses freight vehicles; in an island context it is the appropriate place and method to do so (Cambridge Systematics 2009). The technology and efficiency strategies in the HCEI have demonstrated the ability to reduce petroleum consumption, particularly when used with complementary strategies present throughout the initiative (HCEI 2009; Davis et al 2013; Cambridge Systematics 2009).

Vehicle and Fuel Diversification Strategies

At present, a technological breakthrough is required to make EVs cost competitive with standard vehicles (Knittel 2012). The infrastructural development programs and incentives highlighted in the HCEI enhance this strategic objective as they provide a crucial building block

for the industry forces capable of creating such a breakthrough (HCEI 2011). However as charging stations primarily rely on a grid fueled by burning petroleum, other HCEI strategies (electricity, alternative fuels, end use efficiency) must produce a grid less dependent on petroleum for EVs to fully realize their potential (HCEI 2011; Knittel 2012). Finally, EV sales currently represent one percent of annual vehicle sales in Hawaii, roughly equivalent to 500 vehicles per year (DBEDT 2012). In order to achieve the HCEI benchmarks shown in Table 3, EV sales would need to increase by 800 and 2000 percent by 2015 and 2020, respectively (DBEDT 2012). This is an unlikely scenario.

Fuel Diversification

Alternative fuels make up the largest component of the HCEI's transportation petroleum consumption goal (Kelly 2011). The HCEI aims to increase the incorporation of alternative fuels into the transportation sector by maintaining existing E10 regulations, supporting infrastructure for alternative fuels, and exploring incorporating marine and aviation sectors into transportation goals via alternative fuel use (HCEI 2011). The regulations currently reduce petroleum consumption by 10 percent; placing hope in a sector already reducing consumption is sound (US DOE 2013). Investing in an infrastructural backbone will encourage the technical innovation necessary to further improve alternative fuels. Additionally, exploring the incorporation of marine and aviation transportation assets into the goals is a valid exercise as these components currently account for more petroleum consumption than the ground transportation sector (DBEDT 2013). The initiative mentions the hydrogen fueling facilities at Joint Base Pearl Harbor-Hickam as an "accomplishment to date;" perhaps the initiative should explore the Navy's "Great Green Fleet" maritime and air alternative fuel initiative as a partnering opportunity for the

marine and aviation sectors (HCEI 2011; US Navy 2013). For more detailed information on the “Great Green Fleet,” see US Navy (2013).

The HCEI addresses local fuel production separately as the issue’s complexity is broad enough that it merits separate consideration. Knittel (2012) and Whitaker et al (2010) demonstrate that although biofuels reduce petroleum consumption it is important to look at the issue holistically, factoring in the perspective of environmental and social sustainability. There is disagreement across the state about the amount of agricultural lands available and what they are actually being used for; if crops for fuel replace crops for food, the potential to negatively impact food security and local resilience exists (Gomes 2009).

HCEI Strategies and Elements Not Included

Several strategies with a minimal ability to reduce petroleum consumption in Hawaii were not included as part of the HCEI transportation plan. For example, the plan omits freeway capacity expansion and ITS strategies greater than those already present in Hawaii. While the initiative does include commuting strategies such as carpooling and vanpooling, car- and bike-sharing programs are not addressed (HCEI 2011). However, the Hawaii Energy Policy Forum (HEPF) is making a concerted effort to change the state rental car surcharge taxes so as to allow for easier access to car-sharing services (HEPF 2014). Additionally, the City and County of Honolulu approved the Oahu Bike Plan in 2012, which includes plans for bike-share programs across the island by 2015 (HHF 2012).

There are several strategies not addressed in the HCEI Road Map that could significantly contribute to reducing petroleum consumption. The HCEI did not advocate for any pricing measures beyond those related to parking. While politically difficult and potentially regressive, no single strategy reduces VMT and associated petroleum consumption greater than those that

increase the cost of driving (Morrow et al 2010; Cambridge Systematics 2009). Additional pricing strategies could contribute toward the overall reduction goals. Although the strategy of identifying VMT reduction and transit alternatives is in the plan, the HCEI did not make mention of land use planning or the Honolulu Authority for Rapid Transportation (HART) heavy rail project that is currently underway.

While the City and County of Honolulu is currently planning for TODs along the rail corridor in order to focus development near transit, thus increasing ridership and decreasing VMT, the HCEI as published makes no mention of these plans (DPP 2013; HCEI 2011; OMPO 2011). Additionally, the aforementioned Oahu Bike Plan includes projects that will increase the safe and efficient transportation of bicycles on Oahu (HHF 2012). Land use plans that encourage multi-modalism have the potential to significantly reduce VMT; these strategies should be addressed in the HCEI transportation plan (Brandes et al 2010).

Finally, the in-progress heavy rail project also has a high potential to increase transit ridership and decrease VMT (Calthorpe 2013; HART EIS 2012). If rail ridership levels match those projected in the environmental impact statement and observed in similarly developed cities, 30,000 vehicles will be removed from the road each day (HART EIS 2012). Peter Calthorpe (2013) modeled four scenarios for Oahu's growth and development based on the Oahu Regional Transportation Plan and potential development patterns using the RapidFire comprehensive modeling program. Although the projections are limited to reductions by new households, Calthorpe's analysis shown in Table 8 illustrates the significant potential of rail and TOD to reduce VMT on Oahu (Calthorpe 2013).

Table 8: Projections for Growth on Oahu (Calthorpe 2013)

Scenario	Residential Land Consumption (sq mi)	% saved	VMT per new HH per yr	% saved
Rail not built / trends toward urban sprawl continue	21	baseline	12717	baseline
Rail built / most growth occurs beyond the rail corridor	16.8	20	10654	16.2
Rail built / most growth occurs in TODs according to current city plans	10.8	48.6	6952	45.3
Rail built / 85% growth along rail corridor	7.1	66.7	5354	57.9

Levels of Governance

The strategies omitted are typically implemented at different levels of governance than the state level (Godschalk et al 2006; Moore et al 2007). Land use and transportation plans can be implemented at the state level however they are typically implemented at the regional or city level (Godschalk et al 2006). Pricing strategy implementation varies, though regulated cost of fuel increases are rare below the federal level (Poumanyvong et l 2012; Morrow et al 2010). However, strategies such as telecommuting, carpooling, and parking fees are also typically implemented below the state level (Godschalk et al 2006). As the HCEI is a non-statutory set of recommendations and goals with targeted strategies implemented at different levels of governance, including the omitted strategies in the road map would be beneficial.

Accomplishing the Goal: Challenges and Modeling the Probability

Although it is generally aligned with current state and county plans, the HCEI is a multi-tiered public and private collective and therefore lacks any statutory authority for implementation and enforcement of the strategies outlined in its transportation plan (Kelly 2011). Efficiency goals are positively affected by regulatory standards on new vehicles, they cannot similarly impact poor efficiencies in older cars on the road, i.e. the average vehicle on the road is nine years old (US DOT 2008). Although the HCEI contains strategies to improve the technical

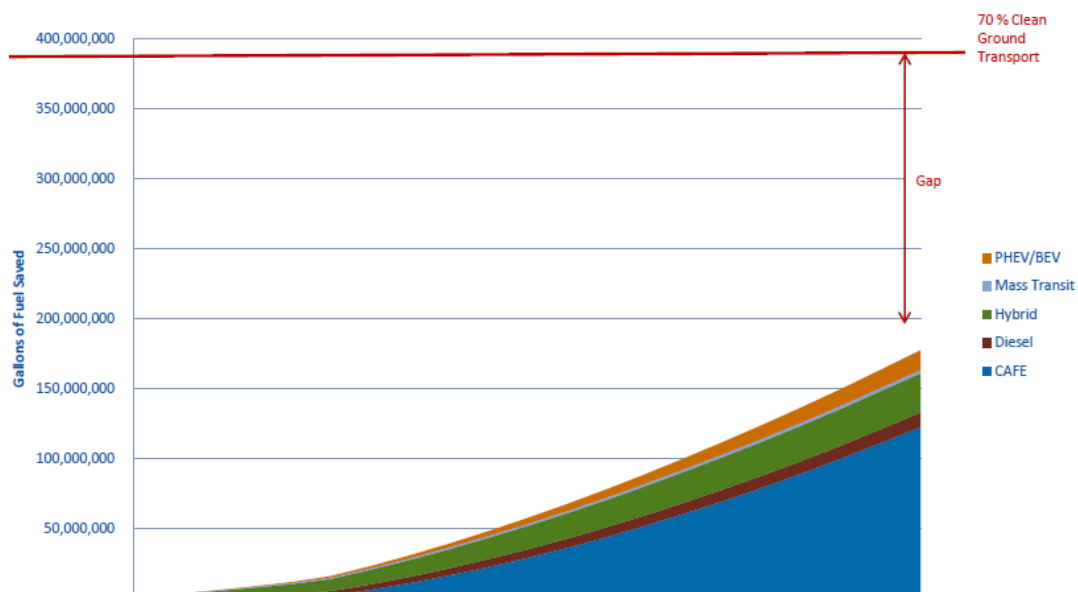
innovations necessary for increased market power of EVs and alternative fuels, the necessary innovation is yet to be realized (HCEI 2011; Knittel 2012). These challenges illustrate that achieving the goal of 70 percent reduction will be difficult.

The National Renewable Energy Laboratory (NREL) sponsored an analysis of the HCEI transportation plan in which a business as usual, probable, and best case scenario were evaluated (Kelly 2011). In the probable scenario, the following factors are used to model predicted reductions (Kelly 2011):

- 1) Full attainment of CAFE standards
- 2) 27 percent bus ridership increase
- 3) 13 percent adoption of HEVs
- 4) 5 percent adoption of EVs
- 5) 9 percent adoption of Flexible Alternative Fuels
- 6) 50 percent adoption of light trucks in the vehicle fleet

As shown in Figure 2, this scenario produced a marked reduction in petroleum consumption, however only 30 percent of baseline consumption instead of the HCEI's 70 percent the HCEI goal (Kelly 2011).

Figure 2: HCEI Probable Scenario Fuel Savings (Kelly 2011)



Conclusions

This paper provides an overview of planning strategies to reduce petroleum consumption in the transportation sector and comments on the demonstrated effectiveness of strategies, both individually and in concert. Literature suggests that strategies to reduce VMT through increasing the cost of motorized transportation, land use planning, increases in vehicle fuel efficiency, and increasing accessibility to alternative modes are the most effective in reducing consumption of petroleum (Cambridge Systematics 2009; Grossman and Lovaas 2012; Morrow et al 2010; Knittel 2012). As technical improvements in alternative fuels and vehicles continue to mature, the role that these strategies play in reducing consumption will continue to grow with that maturation (Knittel 2012).

The Hawaii Clean Energy Initiative's goal of 70 percent petroleum consumption reduction contains strategies proven to reduce consumption and those with the potential to reduce consumption as technical improvements increase. As these technologies are as yet unproven, it is impossible to accurately project with certainty that the overall consumption reduction goal will be met (HCEI 2011). Although ridership and population growth uncertainties are present in projecting any future consumption reduction from HART and land use strategies, an inclusion of these strategies, more robust pricing recommendations, and an increased partnership with the marine and aviation petroleum sectors could further aid in accomplishing the HCEI's goals. These plans are currently present in many city and county general plans and while such strategies are typically implemented at levels other than the state, referencing current efforts could increase ownership of the goals across the state.

Although technological advancements have revolutionized how the world lives and works, digital communications cannot replace the need for the physical movement of people and

goods. These technical innovations have in fact increased demand for such movement, and as such reducing consumption of oil is imperative for the environmental, economic, and social security of the United States and the world (US EIA 2013).

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Appendix 1: Table 1 Sources

		Consumption Reduction Factors			
		VMT Reduction	Technology and Fuel Efficiency	Vehicle / System Operations	Fuel Diversification
Strategies	Pricing	X	X	X	X
	Land Use / Smart Growth	X		X	
	Public Transportation	X		X	
	Commuting Strategies	X	X	X	X
	Alternative Fuels / Vehicles		X	X	X
	Regulations	X	X	X	
	Operations / ITS		X	X	
	Freight	X		X	X

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Appendix 2: *Moving Cooler* Strategy Bundle Summaries (Cambridge Systematics 2009)

Strategy Bundles: six bundles designed to bring together strategies that emphasize common themes or comprehensive approaches

- Near-term / early results – broadly in short term
 - Pricing strategies: parking pricing, congestion pricing
 - Public transportation strategies: increased frequency/LOS, fare measures
 - Commuting strategies: car-sharing, employer based measures
 - Regulatory Strategies: urban parking restrictions, speed limit reductions
 - Systems Strategies: eco-driving, incident, road weather, signal control, and traveler information management
 - Multimodal Freight strategies: container permits, LCV permits, truck stop electrification
 - Costs: \$676-945B implementation; \$3.2-4.8T vehicle cost savings. Net savings = \$64-96B annually
 - GHG Reduction: 14% aggressive, 17% maximum
 - Gallon reduction: 10% aggressive, 13% maximum
- Long-term / maximum results – maximized efforts without regard to cost , scale, or timeframe
 - Pricing strategies: parking pricing, congestion pricing, inter-city tolls
 - Land Use and Smart Growth/Nonmotorized strategies: combined land use, pedestrian, bike
 - Public transportation strategies: increased frequency/LOS, fare measures, urban transit expansion, intercity rail expansion, high speed passenger rail

- Commuting strategies: HOV lanes, car-sharing, employer based measures
- Regulatory Strategies: urban nonmotorized zones, urban parking restrictions, speed limit reductions
- Systems Strategies: eco-driving, incident, freeway management, road weather, signal control, and traveler information management, VII, bottleneck relief, highway capacity expansion
- Multimodal Freight strategies: rail capacity improvements, container permits, LCV permits, truck stop electrification
- Costs: \$2.6-5.1T implementation; \$4.8-7.7T vehicle cost savings. Net savings = \$56-64B annually
- GHG Reduction: 18% aggressive, 24% maximum
- Gallon reduction: 11% aggressive, 15% maximum
- Land Use / Transit / Nonmotorized transportation – urban area focused strategies that increase density, encourage mode shifts, and increased walking / biking
 - Pricing strategies: parking pricing, congestion pricing
 - Land Use and Smart Growth/Nonmotorized strategies: combined land use, pedestrian, bike
 - Public transportation strategies: increased frequency/LOS, fare measures, urban transit expansion, intercity rail expansion, high speed rail
 - Commuting strategies: HOV lanes, car-sharing, employer based measures
 - Regulatory Strategies: urban parking restrictions, urban nonmotorized zones
 - Systems Strategies: signal management, traveler information
 - Multimodal Freight strategies: urban consolidation centers

- Costs: \$1.4-2.4T implementation; \$3.3-5.7T vehicle cost savings. Net savings =\$82-143B annually
- GHG Reduction: 9% aggressive, 15% maximum
- Gallon reduction: 5% aggressive, 9% maximum
- System and Driver efficiency – reduce speeds, improve efficiency, maximize existing capacity, reducing congestion
 - Pricing strategies: congestion pricing
 - Public transportation strategies: increased frequency/LOS
 - Commuting strategies: HOV lanes, car-sharing, employer based measures
 - Regulatory Strategies: speed limit reductions
 - Systems Strategies: eco-driving, incident, road weather, signal control, and traveler information management, freeway management, VII, capacity expansion, bottleneck relief
 - Multimodal Freight strategies: container permits, LCV permits, truck stop electrification, urban consolidation centers, rail capacity and marine system improvement, weigh station bypass
 - Costs: \$1.9-3.3T implementation; \$2.2-2.7T vehicle cost savings. Net savings =\$9-15B annually
 - GHG Reduction: 11% aggressive, 12% maximum
 - Gallon reduction: 7% aggressive, 8% maximum
- Facility pricing - pricing and incentive strategies that induce travel behavior changes coupled with transit service and highway capacity expansion
 - Pricing strategies: parking pricing, congestion pricing, intercity tolls

- Public transportation strategies: increased frequency/LOS, fare measures, urban transit expansion, intercity rail expansion, high speed rail
- Commuting strategies: HOV lanes
- Systems Strategies: traveler information management, capacity expansion, bottleneck relief
- Multimodal Freight strategies: rail capacity and marine system improvements, LCV permits, truck stop electrification
- Costs: \$2.4-4.5T implementation; \$1.1-1.7T vehicle cost savings. Net savings =\$28-41 annually
- GHG Reduction: 3% aggressive, 4% maximum
- Gallon reduction: 2% aggressive, 3% maximum
- Low cost – most cost effective strategies
 - Pricing strategies: parking pricing, congestion pricing, residential parking permits, intercity tolls
 - Land Use and Smart Growth/Nonmotorized strategies: combined land use, pedestrian, bike
 - Public transportation strategies: fare measures
 - Commuting strategies: car sharing, employer commuting measures
 - Regulatory Strategies: urban parking restrictions, speed limit reductions
 - Systems Strategies: eco-driving, freeway management, incident management, traveler information, VII
 - Multimodal Freight strategies: container permits, LCV permits, truck stop electrification, weigh station bypass, urban consolidation centers

- Costs: \$599-634B implementation; \$3.5-5.1T vehicle cost savings. Net savings
=\$72-112B annually
- GHG Reduction: 15% aggressive, 18% maximum
- Gallon reduction: 9% aggressive, 12% maximum