C I T Y O F B O U L D E R
TRANSPORTATION ADVISORY BOARD
AGENDA ITEM

MEETING DATE: October 13, 2014

CLIMATE COMMITMENT TRANSPORTATION EMISSIONS REDUCTION UPDATE

PRESENTER/S:
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EXECUTIVE SUMMARY

As part of the 2014 Transportation Master Plan (TMP) update, staff and consultants conducted extensive analysis of the transportation sector related greenhouse gas (GhG) emissions and evaluated strategies for achieving deep greenhouse gas emissions over the next twenty years. This effort is part of a larger city-wide initiative to evaluate and implement a new Climate Commitment goal. The provisional guidance from Council is to identify and develop strategies capable of achieving a minimum 80% reduction in GhG emissions below 1990 levels by 2050.

As part of the TMP process, vehicle miles travelled (VMT), VMT per capita and single occupant vehicle (SOV) mode share targets were updated in coordination with the city's new GhG goal. During this process, it was also recognized that additional transportation energy source change strategies--and their associated metrics and targets--would need to be developed. Given the need for additional research and evaluation that extended beyond the timeframe of TMP adoption, this process has been ongoing.

This memo provides an update on the progress made to-date in development of these additional elements. Based on the feedback received from the Transportation Advisory Board (TAB) at the October 13 meeting and from the City Council Study Session on November 12, staff will continue to refine strategies, targets and measures for consideration as part of the larger Climate Commitment strategy development process. This information can then be incorporated into the broader TMP measurable objectives and included in the future "dashboard" on-line reporting system.

TAB ACTION REQUESTED

Review and discuss transportation related GhG analysis progress to-date and provide input to share with City Council at the November 12 City Council Study Session as part of the broader Climate Commitment strategy development process.

BACKGROUND

As part of the analysis conducted to update the Transportation Master Plan (TMP), substantial effort was invested in conducting an extensive analysis of transportation related emissions and options for implementing deep GhGemissions reductions congruent with the larger city goal of reducing emissions by 80% or more within the next 20-30 years. This analysis resulted in four major assessment elements.

1. A thorough analysis of Boulder' transportation GhG emissions by seven categories:
    a. Resident
    b. Non-resident employees
    c. Students
    d. Visitors
    e. Transit
    f. Freight
    g. Local Airport
2. Analysis of GhG reduction potential of existing and anticipated TMP related programs and initiatives intended to reduce vehicle miles travel and promote alternative modes of travel.
3. Analysis of the remaining GhG emissions necessary to achieve an 80% reduction by 2050 objective including the impact of federal CAFE fuel economy standards on achieving this goal.
4. A comprehensive assessment of the GhG reduction potential of the public transit program including emission projections based on a doubling of transit service and different fleet vehicle characteristics.

Based in part on this analysis, the TMP established new VMT, VMT per capita, and SOV mode share objectives for 2035 that are intended to help achieve a portion of the GhG emissions reductions as well as a wide range of other co-benefits in support of the city's Sustainability Framework and community values.

The next stage of work on the city's transportation emissions reduction effort is to formulate clear objectives, metrics, targets and associated strategies to achieve emissions reduction associated with the energy sources utilized in travel. The overall goal of these efforts will be to identify options to significantly reduce the carbon intensity of energy used in travel, transit and transport. This document describes the work conducted to-date in three areas related to this goal:

1. Refinement of GhG inventory and analysis
2. Metric and target Development
3. Energy Source Change Strategy Development

STAFF ANALYSIS

Refinement of GhG Inventory and Analysis of Emissions Reduction Targets

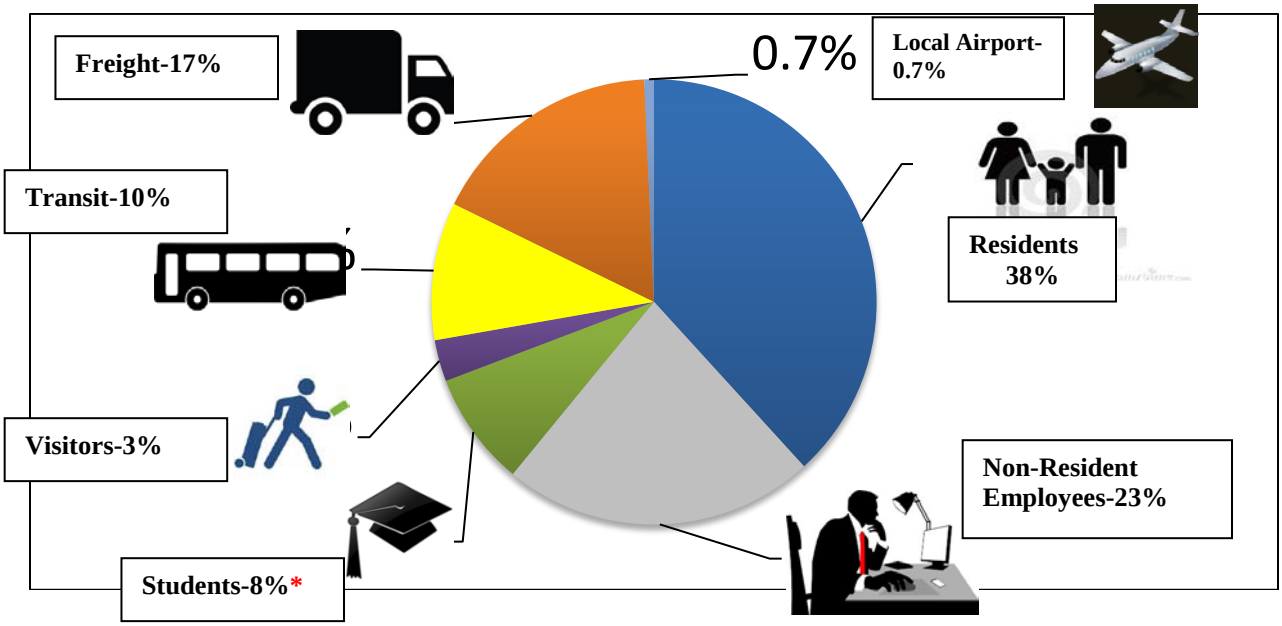
A significant focus of efforts during the TMP GhG emission analysis was the development of a much more accurate and locally-based emissions data gathering and analysis process. In previous inventories, the total transportation related GhG emissions were calculated based solely on the Boulder Valley VMT estimates generated by the regional Denver Region Council of Governments (DRCOG) transportation model. In the system developed for the most recent TMP analysis, staff and consultants utilized the extensive data available through a variety of sources including travel surveys and local traffic counts to create a much more locally accurate picture of transportation emissions. As part of this process, the staff also utilized the International Council for Local Environmental Initiatives (ICLEI) Local Government GhG emissions reporting protocol. This for the first time incorporated a more accurate recognition of the impact of inter community travel--particularly employment related travel e.g. in and out commuters--by counting emissions associated with one-half the entire length of the commuting trip. A similar provision was also integrated related to freight and transit. The summary of this analysis by the seven major categories of travel identified are shown in Table 1 and Figure 1 below:

Table 1
Summary of Transportation-relate GhG Emissions by Travel Sector

	Annual VMT	*% VMT*	*Annual GHG (MT)*	*% GHG*
Resident	323,769,600	51%	118,809	38%
Non-Resident Employee	192,192,000	30%	70,526	23%
Student	70,200,000	11%	25,760	8%
Visitor	25,550,000	4%	9,376	3%
Transit	10,435,000	2%	31,110	10%
Freight	18,250,000	3%	52,980	17%
Boulder Personal Aircraft			2,188	0.7%
Annual GHG (Metric Tons)			**310,749**	100%

From Fox-Tuttle-Hernandez Analysis 2014

Figure 1
Boulder Transportation GHG Emissions by Sector



* Refers to students over 18 driving single occupancy vehicles

Transportation Emissions Reduction Targets

As part of the analysis of the GhG emissions reduction potential of programs and measures being implemented as part of the updated TMP, staff utilized the EPA's "Commuter Model" to assess the emissions reductions that could be achieved through implementation of aggressive single occupancy vehicle (SOV) mode share reduction strategies targeting both residents (including students) and non-resident employees. The mode share targets analyzed and incorporated as part of the VMT reduction goals in the TMP update are included in Table 2 below.

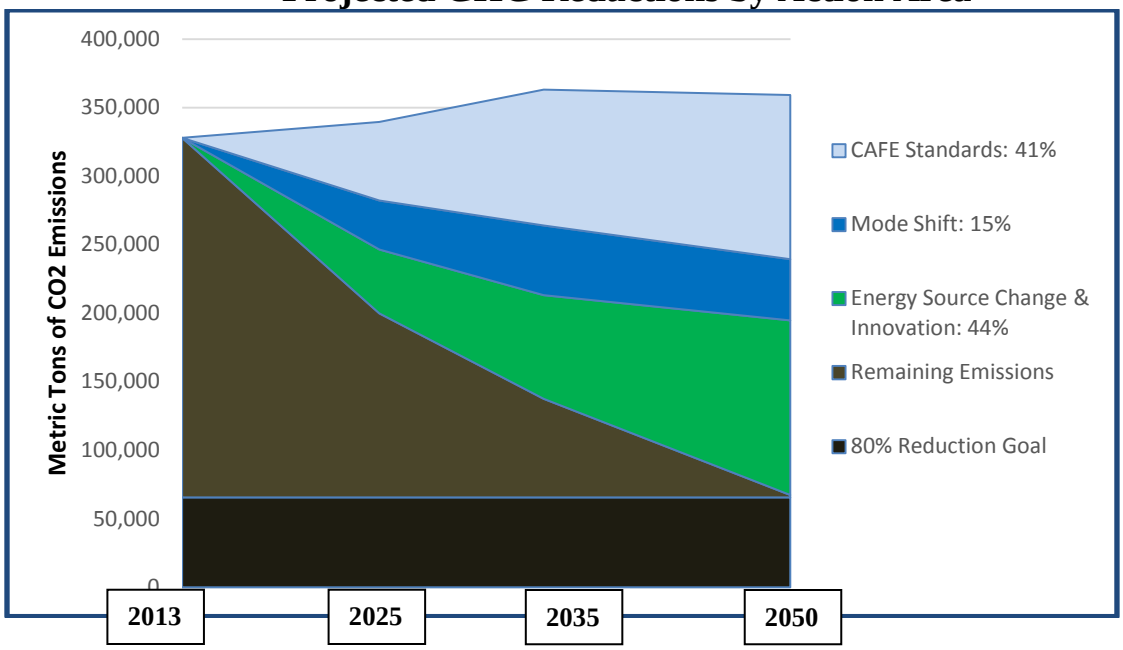
Table 2
SOV Mode Share Targets

Travel Sector	2013	2025	2035	2050
Residents- All Trips	36%	30%	25%	20%
Non-Res Employee-Work Trips only	80%	70%	65%	60%

This shift from SOV trips assumes a significant increase in use in other modes, particularly transit. This was congruent with a more than doubling of transit utilization that was projected by Nelson Nygaard as part of their analysis of the preferred transit system development outlined in the TMP update. The transit analysis is discussed in more detail in the Strategy Development section below.

Southwest Energy Efficiency Project (SWEEP) then used the projected GhG reductions associated with TMP related programs to assess the remaining reductions that would be necessary to achieve the 80% emissions reduction goal. As part of this assessment, SWEEP also factored in the impacts of the implementation of the federal Corporate Average Fuel Efficiency (CAFÉ) standards to determine what level of reductions the full implementation of these standards would contribute towards Boulder's emissions reduction goal. The results of this analysis are shown in Figure 2.

Figure 2
Projected GHG Reductions by Action Area



From Southwest Energy Efficiency Project 2014 Analysis

An important insight generated by this analysis was the significant share of GhG reductions that will still need to be accomplished after the reductions provided by both TMP related mode shift actions and the vehicle efficiency improvements resulting from the implementation of CAFÉ standards.

One of the promising areas for further reductions is in the adoption of new high efficiency vehicle technologies that go well beyond the minimum miles per gallon (MPG) set as part of the CAFE standards. This would include both the growing set of hybrid vehicles (HV) as well as the now expanding set of options in both plug-in hybrid electric vehicles (PHEV) or fully electric vehicles—plug-in electric vehicles (PEVs).

<u>Further Refinement of Data Gathering Systems</u>
Two additional data gathering elements are now being developed or considered to continue to improve the accuracy and specificity of both transportation emissions data and other transportation behavior evaluation.

Make and Model Identification within Surveys—Given the significantly different emissions impacts depending on the type of vehicle being driven, the most recent version of the Boulder Valley Employee Survey will incorporate a new set of questions designed to determine

the emissions characteristics of the vehicles being used. This will enable a much closer tracking of trends related to vehicle uses, particularly low emission or electric vehicles.

Digital data gathering—As part of efforts to utilize and integrate the significant information opportunities related to personal communication devices, i.e. smart phones, Transportation staff are seeking to partner with software developers to create individualized travel management and information applications that would enable users to optimize their use of multiple modes of transportation and provide transportation planners with much more accurate information on travel patterns and travel mode utilization. Staff hopes to start testing these applications as part of the 2015 travel diary survey of Boulder residents.

Next Generation Emissions Tracking and Management

Another important insight derived from the in-depth analysis of Boulder's transportation greenhouse gas emissions was the limits imposed by the current methods and metrics for assessing transportation GhG emissions. These limitations are especially prominent in two areas—measurement of gains being made in non-vehicular mobility, and the role of vehicle energy efficiency and energy source in determining emissions per vehicle mile traveled (emissions per VMT).

Emissions and Mobility

The current methodology for determining transportation emissions is based entirely on vehicle miles traveled. Consequently, while efforts to reduce VMT would be reflected in reduced GhG emissions, this reduction could have been accomplished through either eliminating the trip or replacing a carbon-intensive travel mode with one that is either less carbon intensive or has no fossil-fuel based emission impact e.g. bike, walk. Current emissions calculation methods create an inherent focus on trip reduction and provide no way of recognizing or tracking those reductions that are coming through mode replacement or increased efficiency. This significantly undervalues the significant accomplishments that cities like Boulder have made in the substantial expansion of low-no carbon transportation/mobility options.

To address this limitation and provide a new way of both tracking and incenting low/no-carbon mobility development, a new metric is proposed that can quantify emissions in relation to total personal mobility. The two components of this new metric are the total person miles traveled (PMT) and the total GhG emissions. This metric is a companion to the VMT per capita but provides an even broader view of the progress in reducing emissions in relation to the total mobility of the community.

PMT measures the number of miles a person travels in any given period taking into account the distance traveled in not only vehicles, but also by foot, bike or transit. The metric also provides a more holistic understanding of the impact of investments in our transit, pedestrian, bicycle and TDM programs. One way of measuring change is to track and analyze the number of gallons of fuel that are used to travel the aggregate PMT for Boulder residents, non-resident employees and students. Another second option is to measure PMT per unit of GhG emitted, such PMT per lbs of CO_2 equivalent. According to the Modal Shift Report, the average PMT for a Boulder resident is 18.8 miles per day. Of those 18.8 miles, approximately 11.2 miles are traveled in vehicles and the rest in a combination of transit, foot and bike trips. Additional analysis of existing data is needed to determine the PMT of non-resident employees and students as well as the total number of gallons of fuel used during vehicle trips.

While PMT could decrease as a result of changes in land use that create more "15 minute" neighborhoods, for example, the overall ratio of PMT to gallons of fuel used to move that distance will increase not only as trips are shift away from vehicles but also as those fewer vehicle trips are less carbon intensive.

Staff will continue to measure total and VMT per capita for residents and non-resident employees as well as analyze the carbon intensity of VMT by tracking changes in local MPG estimates for Boulder's fleet of vehicles (described in more detail below). The addition of the PMT to carbon generated metric would provide a useful measure to track the carbon intensity of Boulder's entire mobility system.

Emissions and Efficiency

As noted earlier, increasing vehicle energy efficiency can have a significant impact on total transportation emissions. A related option is to change the fuel source of vehicles to energy that has lower or no-carbon emissions impacts. To date, the city's transportation program has not included objectives, strategies, targets or metrics associated with the promoting the adoption of more efficient or alternative fuel vehicles. As a first step in developing objectives and strategies in this area, staff recognized the need to develop a set of metrics that could be used to quantify the impact of actions that might be taken to effect vehicle efficiency or energy source change.

Given that this metric is focused on vehicle use, the ideal metric would be closely related to existing vehicle usage metrics. The Southwest Energy Efficiency Project has proposed that one of the most common and standardized metrics of vehicle efficiency—miles per gallon—could be modified for use as an overall fleet efficiency metric that could encompass both petroleum-based transport and emerging alternative fuel sources including electricity and hydrogen. This new metric—miles per gallon equivalent (MPGe)—could then be the basis of developing strategies and targets for significantly reducing the GhG emissions within the projected fleet at any target year.

Target Development

With the projections for levels of VMT that will be achieved after implementation of TDM and transit development strategies, we can then calculate what level of fleet efficiency—carbon released per mile travelled—would need to be achieved in the remaining light duty vehicle fleet to achieve the additional emissions reduction targets for each milestone year.

The table below summarizes both the current projected efficiency targets based on the federal CAFE standards, and what the MPGe would need to be under two different scenarios to achieve the city's transportation GhG emissions goals. The calculations for the "Current Trajectory" include the reductions already projected for VMT reductions utilizing TDM and other TMP based strategies.

Table 3
Vehicle Efficiency Targets to Achieve 80% GhG Emissions Reduction by 2050

	2014	2025	2035	2050
Current Trajectory MPGe w-CAFÉ standards	22	27	34	39
Action Scenarios				
Scenario 1. MPGe needed to meet 80% GhG Reduction—VMT reductions to 2035	22	43	61	88
Scenario 2. MPGe needed w-VMT reductions continuing to 2050	22	38	53	74

This analysis demonstrates that in addition to the existing VMT reduction objectives, significant increases light duty vehicle MPGe will also be necessary. As part of the transportation GhG analysis conducted during the TMP update, the Southwest Energy Efficiency Project reviewed policy and program options for achieving further vehicle emissions reductions beyond those anticipated as part of federal CAFÉ standards. Their full analysis is included as Attachment A.

Using the MPGe standard creates a clear, measurable and recognizable metric that is easily integrated into the existing fleet efficiency standards but is flexible enough to incorporate new considerations including different levels of carbon intensity of electricity source and different modes of clean energy such as hydrogen or as yet unforeseen transportation energy alternatives.

Next Steps in Transportation Emissions Reduction Strategy Development

In the analysis being presented to City Council in mid-November, the Climate and Energy teams will present an analysis demonstrating that achieving levels of deep greenhouse gas reduction that are now considered essential to stabilize local and global climate will require a complete transformation of <u>all</u> fossil-based energy systems.

As nearly a quarter of the city's GhG emissions, transportation and its associated energy sources must be included in this analysis of energy systems transformation. The preceding summary of analysis conducted by the climate and transportation teams during the TMP update process provides the foundation for this next stage of efforts to reduce Boulder's transportation GhG emissions through both its well developed transportation demand management (TDM) and multi-modal transportation programs <u>and</u> new initiatives that can begin to address the carbon intensity of the remaining vehicles used in transportation.

The following summarizes a set of additional efforts in development that are targeting emissions reduction through vehicle efficiency and energy source modification.

<u>Electric Vehicle Charging Infrastructure and Adoption Assessment</u>
Drawing from this analysis, the city has partnered with Boulder County, University of Colorado (CU) Boulder, Boulder Valley School District (BVSD) and UCAR to coordinate a

County wide analysis of electric vehicle charging infrastructure issues as well as other key factors in electric vehicle adoption. The Southwest Energy Efficiency Project will be conducting this analysis for this consortium. The study was initiated October 1st with a projected completion date of February 1st, 2015.

The study has three major focus areas:

Charging Infrastructure – A critical factor in support of broader adoption of electric vehicles is the availability of charging infrastructure. SWEEP conducted a preliminary analysis of County wide charging infrastructure in 2011. This study will update both the public charging station analysis and add analysis of home, workplace and public charging infrastructure.

Multi-Modal Linkages -- In the public infrastructure analysis we will give special attention to the potential for creating multi-modal linkages by examining the possibilities of charging infrastructure at park-and-rides and "edge" parking facilities with "last-mile" mode options.

Workplace EV Adoption – One of the strategies for accelerating adoption of EVs in sectors with the greatest GhG emissions reduction impacts is in the potential for workplace commuting. This is also one of the travel categories most difficult to move out of single occupancy vehicles. As part of the analysis, SWEEP will identify issues and opportunities for the city of Boulder to implement an EV commuting pilot project with its own employees. Boulder County, CU, BVSD and UCAR are interested in similar opportunities. This sort of group adoption could create a much more rapid expansion of EV usage, particularly in the longer travel categories with the most emissions reduction potential.

<u>Employee Commute Pilot Project</u>

As noted above, the SWEEP assessment will help the study partners evaluate the potential for implementing electric vehicle commuting opportunities for its employees. Given the high proportion of each organization's employees that commute in to Boulder for work, employee commuting represents one of the largest sectors of GhG emissions for each of these organizations. The Boulder employee commute pilot will examine both the potential for alternative vehicle options <u>and</u> other travel/trip reduction methods such as vanpool expansion (including the potential for electric vans), telework options, and other forms of employee commute alternatives that reduce single occupancy, low efficiency vehicles.

<u>Boulder Energy Challenge Transportation Pilot Projects</u>

As part of the Boulder Energy Challenge, three projects were selected that have a focus on transportation emissions.

eGo Car Share—Boulder's highly successful Energy Smart Program has become a national model for effective adoption of energy efficiency measures based in large part on the energy advisor element of its approach. Similar ideas of more personalized assistance in travel planning have been considered or tested on a limited scale in other areas. In the project funded by the Energy Challenge, eGo Care Share will implement a pilot advisory model that includes both direct person-to-person support, enhanced web and personal device applications, and a gamification element to incent new and more efficient behavior.

Lightning Hybrids—Lightning Hybrids has developed an after-market regenerative braking system for medium-to-heavy duty transit and freight vehicles that can cut energy usage by as much as 30%. In this funded pilot, they will install one of their systems on a VIA transit vehicle and assess the overall energy savings over the course of a year of

operations. Given the significant contributions of both transit and freight to the city's overall transportation GhG emissions, this is an exciting opportunity to test new technology that could have a substantial impact on emissions in this category.

Snugg Home—Snugg Home has developed a financing package for homeowners that enables them to bundle the purchase of a photovoltaic electric system, an electric vehicle and a home retrofit at a cost comparable to what they would pay for a car payment and energy costs (including gasoline) and pay off the entire package within 5 years. If successful, this could offer local residents a significant opportunity to both save money and make a major contribution to local GhG emissions reductions in both electricity, natural gas, and petroleum usage reduction.

Transit Fleet Improvements

As part of the GhG emissions analysis conducted during the TMP update, Nelson Nygaard conducted an extensive assessment of the GhG impacts of different transit scenarios being considered in the TMP. Their full analysis is included as Attachment B of this document. Table 4 provides a summary of this analysis for both the base year, 2013, and target year 2035.

Table 4
Nelson Nygaard Analysis of Transit GhG Emissions 2013 & 2035

Current Year (2013 Base)

Comparisons to Current Scenario Base Emissions								
Fuel Type	Metric Tons of CO2e Emissions/ Year	Difference from Diesel Fleet (A)	Difference from Hybrid Electric Fleet (B)	Difference from Electric and HEV (Current Mix) (C1)	Difference from Electric and HEV (Low Carbon) (C2)	Difference from Full Electric (Current Mix) (D1)	Difference from Full Electric (Low Carbon) (D2)	% Change From to Current Year Diesel Fleet
A. Diesel	25,530	0	9,910	9,890	15,040	9,870	20,830	N/A
B. Hybrid Electric (HEV)	15,620	-9,910	0	-20	5,130	-40	10,930	-39%
C1. Electric/ HEV (Current Energy Mix)	15,640	-9,890	20	0	5,150	-20	10,950	-39%
C2. Electric/ HEV (Low Carbon Energy Mix)	10,490	-15,040	-5,130	-5,150	0	-5,170	5,790	-59%
D1. Full electric (Current Energy Mix)	15,660	-9,870	40	20	5,170	0	10,970	-38%
D2. Full electric (Low Carbon Energy Mix)	4,700	-20,830	-10,930	-10,950	-5,790	-10,970	0	-82%
Fleet VMT/YEAR	8,703,000							

2035 Transit Scenario

Comparisons to 2035 Scenario Base Emissions									Current Base
Fuel Type	Metric Tons of CO2e Emissions/ Year	Difference from Diesel Fleet (A)	Difference from Hybrid Electric Fleet (B)	Difference from Electric and HEV (Current Mix) (C1)	Difference from Electric and HEV (Low Carbon) (C2)	Difference from Full Electric (Current Mix) (D1)	Difference from Full Electric (Low Carbon) (D2)	% Change from 2035 Diesel Fleet	% Change from Current Year Diesel Fleet
A. Diesel	39,870	0	17,960	17,940	22,010	17,900	33,280	N/A	56%
B. Hybrid Electric (HEV)	21,910	-17,960	0	-20	4,050	-60	15,320	-45%	-14%
C1. Electric/ HEV (Current Energy Mix)	21,930	-17,940	20	0	4,070	-40	15,340	-45%	-14%
C2. Electric/ HEV (Low Carbon Energy Mix)	17,860	-22,010	-4,050	-4,070	0	-4,110	11,270	-55%	-30%
D1. Full electric (Current Energy Mix)	21,970	-17,900	60	40	4,110	0	15,380	-45%	-14%
D2. Full electric (Low Carbon Energy Mix)	6,590	-33,280	-15,320	-15,340	-11,270	-15,380	0	-83%	-74%
Fleet VMT/YEAR	15,064,000								

* Current mix of electricity: 60% coal with scrubbers, 22% natural gas, and 18% wind and other 'green sources'

** "Low carbon mix" is an average CO2e (24.8g) output of bio-mass (18g), Solar PV (46g), Solar CSP (22g), and wind (12g), adjusted for CO2 equivalency. Source: Moomaw, W., et al, 2011: Annex II: Methodology. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, et al [eds.]], Cambridge University Press, Cambridge, New York, NY. http://srren.ipcc-wg3.de/report/IPCC_SRREN_Annex_II.pdf

As noted earlier, the significant TMP's efforts to reduce VMT and improve community mobility anticipate a more than doubling of transit usage over the next 20 years as well as increases in walking and biking. An important finding in this analysis was the limited emissions reduction benefits that this transit expansion would provide if the transit fleet continues to rely on diesel driven vehicles and supports the importance of transitioning the transit vehicle fleet to other fuel sources to enhance emission reduction benefits.
Nelson Nygaard's analysis does demonstrate that with existing and available technology in transit vehicles, these benefits could be significantly enhanced. GO Boulder staff and other partners, including Via, are continuing to research opportunities to explore and pilot these new technologies including a recent presentation and tour by Proterra Electric Bus company and exploring the potential for introducing these types of vehicles into Boulder's transportation system.

BOARD ACTION REQUESTED

Review and discuss transportation related GhG analysis progress to-date and provide input to share with City Council at the November 12 City Council Study Session as part of the broader Climate Commitment strategy development process.

Attachments:

- **A.** Policy Options for Expanding the Use of Electric and Efficient Vehicles
- **B.** Nelson Nygaard Transit Fleet and GHG Reduction Analysis

ATTACHMENT A
Policy Options for Expanding the Use of Electric and Efficient Vehicles

Report prepared for the City of Boulder by:
Southwest Energy Efficiency Project
Will Toor
Mike Salisbury
April 24th, 2014

Introduction

In order to achieve deep reductions in transportation GHG emissions, both demand reduction strategies to reduce vehicle miles traveled (VMT), significant improvements to fuel economy, and a move towards much lower carbon fuels will be required. This section will focus on the latter two strategies.

As discussed in the accompanying analysis, the light duty fuel economy standards that have been adopted by the federal government will be a significant driver towards greater fuel economy, and to a lesser extent towards vehicle electrification. We will explore additional strategies that could be employed at a local level. We focus on efficiency and on electrification. There are other potentially important approaches. It is certainly possible that truly low carbon biofuels will be developed, available at scale, which could make biofuels a very important tool, especially in the heavy duty vehicle sector, where electrifications is more challenging. It is also possible that fuel cell technologies will become affordable and practical on a large scale, and that low carbon sources of hydrogen will become available, making hydrogen an important fuel. However, both of these are speculative enough that we do not further discuss them at this point.

One challenge for any local effort aimed at increasing the efficiency of the vehicle fleet is federal pre-emption: The Energy Policy and Efficiency Act and the Clean Air Act pre-empt state or local governments from setting fuel efficiency standards and greenhouse gas (GHG) emission standards different than those set by the federal government. The one exception is for the State of California, which does have the ability to set standards that go beyond the federal standard. Other states may not independently set standards, but do have the authority to adopt the California standards. The city can use financial incentives, social marketing, business partnerships, and infrastructure investments to try to shift the vehicle fleet, but may not directly regulate. This is quite different than other sectors, such as buildings, where the city has more direct regulatory authority.

As the accompanying emissions analysis demonstrates, over the long term vehicle electrification combined with cleaner generation will provide the greatest emissions reductions. In the short to medium term, very high efficiency hybrid vehicles

provide the greatest emissions reductions, unless the EVS are powered by renewables rather than by the existing grid mix. Thus, in this section we will discuss both strategies that are focused on electric vehicles and strategies that are focused on more efficient hybrid vehicles.

Consumer surveys[1] show that the top two concerns prospective buyers of EVs have is the vehicle's price and its range. Therefore policies that directly address these two concerns are most likely to have an impact on purchasing decisions. Other concerns expressed by consumers such as maintenance costs, performance and reliability indicate that education can still play an important role in promoting EVs because these concerns are not well founded.

In this section, we will discuss a number of potential strategies that the city can use to encourage more widespread adoption of lower emission vehicles. Some are relatively simple to implement; others could involve significant costs or political challenges, and one case may require state legislation to expand local authority.

We will group these into financing strategies, public vehicle fleets, support for vehicle charging, social mobilization/education, and potential utility roles.

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1 http://www.harrisinteractive.com/NewsRoom/HarrisPolls/tabid/447/ctl/ReadCustom%20Default/mid/1508/ArticleId/1216/Default.aspx

Summary of Policy Options

Policy	Time Frame	Difficulty	Potential GHG Impact
Financial Incentives			
Feebate	Short-Medium Term	High (may require state approval, administratively challenging)	High
Rebate for EVs	Short Term	Medium (needs funding)	Medium
Financing to convert tax credit to rebates	Short Term	Medium (program design challenges)	Medium
Incentives for Public Charging	Short Term	Medium (needs funding)	Medium
Public Fleets			
Performance Contracting	Short Term	Low	Low due to small size of fleets – but shows public sector leadership
Transit Electrification Pilot	Short Term	Medium	Low – but paves way for future larger scale
Maximize use of CMAQ rebates for transit electrification	Short Term	Medium	Medium

Building Codes/Parking			
Building Codes	Long-Term (may not take a long time to adopt, but results are not quick)	Low-Medium (depending on how aggressive with existing stock)	Low
Requirement for Existing Buildings	Short-Medium Term	Medium (could be significant resistance from building owners)	Medium
Workplace Charging	Short	Low	Low-Medium

Social Mobilization			
Targeted Efforts with Employers	Short Term	Low	Low
Broadening Energy Smart	Short Term	Low	Low
Support for Bulk Purchases	Short Term	Medium	Medium
Targeting Larger Vehicles	Short Term	Low	Medium
EV/PV promotion Pilot	Short Term	Low	Low – but could pave way for larger scale EV/PV programs that would have larger impact
Utility Strategies			
Utility rebates for EVs, charging	Medium term	Medium	Medium
EV rates or appropriate time of use rates for EV charging	Medium term	Medium	Low – but could be important to managing load at high EV penetration
Battery Buyback by Utility, or Battery ownership by utility, leased to customers	Medium-Long Term	Medium-High	Medium-High

Time Frame: Length of time it would take for policy to be implemented and begin providing results. Short term: 1-3 years; Medium 3-10 years; Long Term: 10+

Difficulty: This is based on both the difficulty of getting the policy adopted and the administrative challenges

Strategies involving financial incentives

The first three strategies involve different variations of offering rebates for highly efficient vehicles. The programs range from rebates, which are relatively easy to implement (but require a funding source) to more complicated feebates and vehicle trade-in programs, which can be set up to be self-funding, which are expected to have greater climate benefits but are more complicated to administer.

Fee-bate for EVS and efficient vehicles

The use of "feebates" to incentivize the purchase of high efficiency vehicles has been implemented in Denmark, France, the Netherlands and Norway. Similar policies have been discussed at both the federal level and in a number of states, but have not been implemented anywhere in the United States. However, it may be more politically feasible to implement such a program at the local level. This might require legislation allowing a local option feebate program, implemented at the city or county level.

Under this approach, the city would assess a fee on new vehicles that achieve less than average fuel efficiency, and use that revenue stream for offer incentives to purchase or lease of a new high efficiency vehicle. This program is designed to pay for itself by providing rebates for efficient vehicles, less administrative costs, which do not exceed the impact fees collected from the purchase of new inefficient vehicles. This approach imposes no barriers to the freedom of consumers to purchase any vehicle for sale, so does not trigger federal pre-emption, but would require purchasers of the least efficient vehicles to bear an additional cost to help reduce the burden they place on all consumers as they increase the overall demand for motor fuels and the resulting emissions, drive the price of fuels higher, and reduce our energy security.

Under this approach, fees would be assessed to approximately half of the vehicles sold - those with below average fuel economy. For Boulder, this would be approximately 1750 vehicles per year, and the revenue would go to support the purchase of approximately 1750 more efficient vehicles. The fees would be assessed on a sliding scale – with the size of the fee increasing as the vehicle efficiency gets worse, and rebates would be awarded on a sliding scale, with the largest rebates available for the purchase of electric vehicles.

In its simplest version the fee/rebate would be set as:

Fee (rebate) = Rate x (emission rate-benchmark), where the benchmark is set at the average carbon emissions per mile of new vehicles.[2]

Example:

For 2015, the average combined fuel efficiency under the CAFÉ standards will be 32.7 mpg. This corresponds to tailpipe emissions of 271 gms CO2/mile.

Based on the European examples, a typical rate might be $20/(gm/mile)

A zero emission vehicle would be eligible for a rebate of $20*271=$5400

A Toyota Prius getting 50 mpg, with emissions of 178 g/mile, would be eligible for a rebate of $20 x(271-178)= $1881

By contrast, a Subaru Outback M6 getting 24 mpg and emitting 370 gms/mile would pay a fee of $20* (370-271)= $1970

There are many ways such a program could be structured. There could be separate programs for different categories or footprints of vehicles, so for example small cars would be compared to small cars, light trucks to light trucks.

The level of emissions reduction depends on program design. A number of studies have been conducted of potential programs in California and Connecticut have estimated potential reduction in the emissions from an average new car that range from a low of 18 gms/mile up to a high of 1/3 of new car emissions, or about 90 gms/mile.

Program Cost

The only cost for this type of program would be the administrative costs, as the ongoing rebates would be paid by the fees.

Impact

Using Boulder's current VMT level of 2.4 million daily VMT, each year the feebate program will reduce the carbon intensity of the new vehicles added to the fleet. For 2025, after 10 years, 35000 vehicles, or approximately half the fleet, would be impacted. Since the program is targeted at vehicles registered in Boulder, only resident and student GHG would be impacted.

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[2] Bunch and Green, 2012, Potential Design, Implementation, and Benefits of a Feebate Program for New Passenger Vehicles in California, University of California, Davis, Institute of Transportation Studies

Reduction at -18 gms/mile	5,800 MT/year, a 1.4% reduction
Reduction at -90 gms/mile	25,000 MT/year, a 7% reduction

However, it is also important to realize that the impact of vehicle strategies on total GHG emissions will be greater than shown here, since these numbers do not capture reduced emissions on longer trips outside of the Boulder area.

By 2050, the impact would grow, as the entire resident fleet would be impacted.

Reduction at -18 g/mile	10,000 MT, a 2.8% reduction
Reduction at -90 g/mile	50,000 MT, a 14% reduction

Challenges
While there is no federal pre-emption, legal analysis would be required of the ability of a home rule municipality to implement such a program under Colorado law. Unlike many of the other strategies, which would likely have support from the auto industry, this strategy would likely be opposed by this industry. Administratively, it would be very difficult for the city to administer, since motor vehicle registration is managed at the county level, so in practice such a program would likely need to be implemented at a county level. This would require legislative authorization.

Vehicle Trade-In Program plus Feebate: "Cash for Clunkers"

Some type of Cash for Clunkers program could be considered. This could work for both light and heavy duty vehicles and would bring more climate benefits than Prius owners switching to EVs, by focusing on replacing less fuel efficient vehicles in the fleet..

A vehicle trade-in or Cash for Clunkers program would operate similarly to the feebate program except that to qualify for the rebate one would have to trade in a relatively inefficient vehicle, perhaps one in the bottom 10% of efficiency, to receive a rebate on a new highly efficient vehicle. Because it ensures that the vehicles receiving a rebate are replacing low efficiency vehicles there is a clearer climate benefit. With the rebate and feebate programs it is not sure that a current Prius owner is just using the rebate to purchase a new Prius, which would have no net climate benefit, for example.

This would entail some additional administrative challenges as far as certifying the trade-ins and disposal of the clunkers, but the primary challenges would be the same as for the feebate option.

Rebates for purchase of electric vehicles

Currently, there is a significant upfront cost premium for purchasing an electric vehicle, driven primarily by the cost of the batteries. While the lifecycle cost may be lower than a conventional vehicle, due to reduced fueling and maintenance costs, the upfront cost is a significant barrier to EV adoption. Over the longer term, this price premium is expected to come down, as the cost of batteries declines.

In order to help address this issue in the near term, both the state and federal governments offer significant tax credits for EVs. The federal credit is currently $7,500, and the state credit is up to $6,000. The city could also offer a local incentive in the form of a rebate at time of purchase. Time of purchase rebates have a greater impact for the same level of incentive than a tax credit, so a rebate in the $1,000 to $2,000 level might be expected to have an impact on adoption rates, even though this is substantially smaller than the combined state and federal credits.

There are approximately 3500 new vehicles purchased per year. Boulder vehicles are fairly evenly split between passenger cars and light trucks. In the near future, EVs are likely a real option primarily for the passenger cars. Note that based on the current vehicle fleet, in the decade since hybrid vehicles have been introduced, market share has grown to about 5%, with 1.3% of the fleet Toyota Priuses. Nationally, EV sales are growing faster than hybrid vehicle sales soon after hybrids were introduced, so it may not be unreasonable to expect a baseline of 5% EVs in the Boulder fleet by 2025, or about 3400 vehicles. This would require that about 340 EVs a year be added to the fleet, or just under 10% of new vehicles sales over the next decade.

If Boulder offered a $2,000 rebate for electric vehicles, it might be possible to push this to a higher share of new vehicle sales.

Passenger car adoption rate	Vehicles/year	Annual Cost	2025 EV fleet
5%	175	$350000	1750
15%	263	$525,000	2630
25%	620	$1.24 million	6200
50%	1750	$3.5 million	17500

Note that these are very aggressive scenarios. The Energy Information Administration in the 2014 Annual Energy Outlook only projects total sales of battery electric vehicles and plug in hybrids together at 1% of new vehicles sales in 2025. The most aggressive national forecast [3]projects 2025 EV sales at

[3] Edison Electric Institute, April 2013, Forecast of On-Road Electric Transportation In The United States, 2010-2035

approximately 10% of new LDV sales, the equivalent of approximately 20% of passenger cars. Currently the highest adoption rate in the country is in the state of Washington, where 1.6% of new vehicles sold in 2013 were EVs. Colorado is in the top ten states, with 0.4% of new 2013 vehicles. California is aiming to reach 15% of new vehicle sales by 2025.

Such rebates could also be used to incentivize the purchase of extremely fuel efficient conventional vehicles.

This would be a relatively straightforward program - there are no legal challenges, and the number of transactions is small enough that the administrative burden should ne manageable. However, it would require a significant ongoing funding mechanism, and could raise equity concerns that these rebates might be going largely to wealthier households that are more likely to buy new cars.

Financing program to convert tax credits to time of purchase incentive

The current tax credits for EVs are significant – up to $13,500. However, the impact of tax credits is much less than the impact of point of sale incentives. One approach the city could take is to create an upfront rebate, but tie it to recapture of the same amount from the tax credits – essentially to finance the tax credits.

For customers who are leasing, the dealer is generally able to take the $7,500 federal credit, and apply this upfront to lower the cost of the lease. This is not possible given the current structure of the state tax credit.

It would be theoretically possible to create a rebate program, but have the cost, or a portion of the cost, paid for by capturing a portion of the tax credits received by the customers. There are clearly significant administrative challenges, and some level of financial exposure, but this potentially a lower cost way to create an upfront rebate incentive.

A variant to this would be to work to amend the state statute, to allow dealers to take the credit in the case of leasing, and pass the savings on to the lessees. This would allow the private sector to use the tax credits to lower the upfront cost , at least for those consumers who choose to lease.

Public Vehicle Fleets

While most of the vehicles in Boulder are privately owned, public sector leadership can be very important in developing broader public awareness and support. In addition, because some of the public sector vehicles are larger vehicles that are driven many miles, the emissions impact can be significant, as for transit vehicles.

Use of performance contracting

Last year, legislation passed in Colorado to expand the allowable uses of performance contracting by government agencies to include financing efficient vehicles, with the upfront costs paid back through fuel savings, in much the same way that upfront costs of building energy improvements are financed through performance contracting. The City of Boulder is working with McKinstry to acquire 30-35 electric vehicles in what we believe will be the first such contract in the state. This could provide a model for large-scale fleet replacement by other large public agencies (Boulder County, BVSD, the University, the national labs) as well as other private institutions that are large enough for performance contracting to work. Historically, the Colorado Energy Office has actively supported performance contracting; there could be an opportunity for the city to partner with the Energy Office to actively promote its use for vehicles.

This could be used both for passenger vehicles, but also for medium and heavy duty vehicles as more options become available in these sectors. To give a sense of the scale, the BVSD has approximately 250 buses and 150 light duty vehicles; Boulder County has approximately 60 heavy duty vehicles and 440 light duty. Among all of the fleets, the total might be on the order of 1,000 light duty vehicles, and several hundred buses or trucks.

Transit electrification

This strategy would require working with the major providers of transit service – the BVSD, RTD, and VIA. Currently, the vast majority of these buses are diesel vehicles. A number of manufacturers are now making electric buses for transit agencies, including ProTerra and BYD, and one company 9transTeach) is manufacturing electric school buses. In the United States the use of electric buses is largely in a pilot phase, with a handful of transit agencies in locations including LA, New York and Nashville trying out small numbers. However, in China the market has expanded to thousands of electric buses.

A program in Boulder would likely need to begin as a pilot effort with one of the transit agencies, to try a small number of electric buses and address operational

issues, including how recharging would take place. This would also allow cost data to be collected; electric bus manufacturers have argued that the higher upfront costs of the vehicles will be outweighed by much lower fuel and maintenance costs, but local experience will likely be required for transit operators to take this seriously. Given the smaller scale, and the pre-existing relationship between the City and VIA, it might be the most likely candidate for a pilot project.

There is a window of opportunity over the next our years. The Colorado Energy Office and the Regional Air Quality Council will be administering a $15 million fund for replacing trucks and buses in the metro area with alternative fuel vehicles, including both electric and CNG vehicles. With many other rebate programs (such as the Xcel DSM and Solar Rewards programs), Boulder has had a much higher uptake rate than the statewide average. The city could have a focused campaign to maximize the use of these truck and bus funds, in order too kick start pilot or larger scale electrification.

Support for EV Charging

Access to charging infrastructure is another barrier to more widespread adoption of electric vehicles. Most daily travel is well within the range of a typical electric vehicle, but it is important for vehicle purchasers to be comfortable that they can make longer trips. Evidence to date suggests that most charging will take place at home, with workplace charging the next largest slice of the pie. In addition, it may be important to have fast charging locations available at destinations outside of Boulder that are important to Boulder residents.

In addition, if the city is successful at achieving high levels of market penetration, the nature of workplace and public charging needs will change. For example, there may be many employees who commute and park all day in a single private parking lot, or municipal parking structure. Meeting this demand may require large banks of charging outlets. In order for this to be practical, future charging needs may require larger numbers of level 1 chargers, which are significantly less expensive to install than the faster charging level 2.

There are a number of potential actions Boulder could take to enhance the charging network.

Building Codes
A number of jurisdictions have begun to adopt building codes that mandate either pre-wiring for EV charging, or mandate that a certain number of spaces in new parking facilities are wired for charging. Adopting building codes that include language supporting the provision of charging in new commercial and residential structures is important to enabling a charging network. Establishing capacity for

charging during construction (or during planned renovation) costs significantly less than retrofitting, as retrofitting often requires retrenching, rewiring or upgrades to electric panels. For commercial installations, retrofitting can cost an additional $1,100 per station for surface lots and $800 for parking garages.[4] For residential single-family homes, the Vancouver Electric Vehicle Association estimates that, on average, the cost of retrofitting for Level 2 charging is at least $900 more than preparing that home during new construction.[5]

Building codes will utilize three primary mechanisms to promote charging adoption: a) require that all buildings install the electrical capacity for a certain level of charging, b) require a minimum number of EVSEs per parking space, or c) require that all businesses of a certain size provide EVSE.

Several local governments throughout the US and Canada have already enacted these regulations, as shown below.

	Single Family Residential	**Multi-Family Residential**	**Commercial**
Boulder County, Colorado[6]	240 volt outlet or upgraded wiring or conduit for future installation .		
Vancouver, British Columbia[7]	Conduit for future dedicated outlet for EV charging in the parking area	Conduit for EV charging in the parking area; 20% of parking spaces accommodate EVSE	
Los Angeles, California[8]	A 240 volt outlet or sufficient panel capacity and conduit for future	A 240 volt outlet or sufficient panel capacity and conduit for 5% of	Enough 240 volt outlets for 5% of total parking spaces

[4] Electric Vehicle Charging Infrastructure Recommendations to Fairfax County. Available at : http://www.mitre.org/work/tech_papers/2011/11_2916/11_2916.pdf

[5] EV Infrastructure Costing Worksheet. Available at http://www.veva.bc.ca/home/index.php

[6] 2012 Boulder County Building Code Amendments. htttp://www.bouldercounty.org/property/build/pages/buildingamends.aspx

[7] http://vancouver.ca/sustainability/EVcharging.htm

[8] Sections 99.04.106.6 and 99.05.106.5.3.1 http://ladbs.org/LADBSWeb/LADBS_Forms/PlanCheck/2011LAAmendmentforGreenBuildingCode.pdf

	installation	parking spaces	
State of California[9]	Conduit from service panel to the parking area.	3% of all parking spaces would have the capacity to support future charging.	Capacity and conduit for 1-4 future chargerss, depending on the number of spaces.
Hawaii[10]			Places with at least 100 parking spaces will have one charging location near the building entrance.

Requirements for existing buildings
Boulder has adopted requirements for energy upgrades for existing residential rental property (Smart Regs). The city could consider adding an EV charging requirement for existing multifamily residential, and could consider EV charging requirements in a future commercial energy conservation ordinance. Because most of the projected 2050 building stock in Boulder has already been built, regulatory requirements for existing parking areas may be an important strategy.

Financial Incentives for installing charging:
The city could also provide financial incentives for installation of EV charging. For example, Nevada Energy, for example, provides incentives to businesses of 50% of the cost of installing charging stations. An order of magnitude estimate might be $10,000 per site for purchase and installation of a level 2 charging stations, so a city incentive of 50% would be apprioximately$5,000 per station

Workplace charging
The greatest need beyond residential charging is likely for workplace charging. Workplace charging not only makes it easier for commuters to use electric vehicles, but also serves as an important marketing tool, making EVs visible to other employees. This can lead to additional demand, and the need for a bank of EV charging locations. Because many employees will park for many hours at a time, inexpensive level 1 chargers could be a good application for providing multiple charging locations at a worksite, or in a publically owned parking lot or parking structure used by regular commuters. The city could provide matching funds to

[9]Sections: A4.106.6, A4106.6.1, A4.106.6.2 A5.106.5.3 and A5.106.5.3.1 http://www.iccsafe.org/cs/codes/Errata/State/CA/5570S1002.pdf
[10] http://www.capitol.hawaii.gov/session2012/Bills/SB2747_.htm

encourage installation of workplace charging, and could tie this to a phased-in regulatory requirement, perhaps requiring that charging be installed when parking areas are resurfaced.

The city could also consider a workplace charging challenge, in which businesses receive recognition for efforts to expand charging for their employees. This could be a standalone effort, or incorporated into existing efforts such as the Partners For a Clean Environment (PACE) program administered by Boulder County Public Health.

City partnership effort to install chargers at key destinations outside the city
While many EVs are likely to replace second cars in two-car households, thus allowing the other vehicle to be used for longer trips, high levels of EV penetration will require people to be confident that they can use the EV for longer distance trips outside the city. The use of PHEVs can certainly help to address this concern, allowing most urban trips to be driven on electricity while using gasoline for longer trips. In addition, over time lower costs and higher energy density in batteries may also help address this concern. But another important strategy may be to place charging at destinations that are important to Boulder residents. While we would need to do additional analysis to understand more about out of city destinations for Boulder travelers, given the strong outdoor recreation culture in Boulder, we would anticipate that recreational destinations such as the Eldora Ski Area, major trailheads in the Indian Peaks and Rocky Mountain National Park might be appropriate locations. The city could either directly invest funds, or could serve in a role that helped to organize projects and seek funds from sources such as the Electric Vehicle Infrastructure Fund administered by the state energy office.

Social Mobilization Approaches

The city could create a focused effort to promote the adoption of both electric vehicles and more efficient gasoline or diesel vehicles by the community. There are a number of programs the city, the county, and other local partners have developed to impact public behavior in related areas, including GO Boulder's programs to promote alternative modes of transportation, and the Energy Smart program's effort to get residences and businesses to make home energy upgrades, and the partners For a Clean Environment (PACE) program that works to promote environmentally responsible practices in local businesses.. These programs have combined financial incentives, infrastructure improvements, and thoughtful community based social marketing efforts. The Electrification Coalition has also taken a mobilization approach in the communities that they have identified. Such an effort would require funding for dedicated staff or a community partner, and could require integrating elements around efficient vehicles into existing workplans.
We would strongly recommend that vehicle efficiency and electric vehicles be incorporated into the mission, programs, and messaging of these existing programs.

A number of elements that would be possible include'

Targeted efforts with employers, including events at large employers with EV drive-along opportunities
Evidence suggests that anyone who actually rides in an electric car is far more likely to buy one than someone who has not been in an EV. The city could work with employers to organize opportunities for their employees to try out EVs; this could be linked to efforts to promote workplace charging. The existing network of Employee Transportation Coordinators could be used to work with businesses on efficient and electric vehicles in addition to the current work focused on commute mode choice.

Broadening Energy Smart
Energy advisors who are working with residents on home energy improvements could also provide advice on efficient vehicles. This could be particularly effective if there are even small rebates or financing available that the advisors can connect customers to.

Support for bulk purchase of EVs, EV charging, or EV and PV together
As the Solarize program in Portland focused on solar PV has demonstrated, there can be significant uptake if there is a focused effort among a particular group (it could be a neighborhood or an employer) to promote a clean technology, and to provide a time limited opportunity to buy at a preferential rate.

This approach could be used to promote the purchase of electric vehicles, combined with installation of home chargers. It could also be combined with bulk purchase on PV in order to incentivize people to move towards transportation with close to zero net emissions.

This could be piloted among city employees, as a relatively manageable size for an initial effort. This could be an opportunity to develop partnerships with private sector entities that the city has not previously had a close relationship with, such as auto dealers of car manufacturers. This could be an opportunity to pilot the use of rebates paid back by tax credits on a small scale. If successful, such a program could potentially be expanded to other large employers in the city.

Appendix 2 describes in somewhat more detail how a pilot project for City of Boulder employees might be implemented.

Targeting users of larger vehicles
The analysis of the Boulder fleet showed that Boulder has a higher percentage of light trucks than the national average. This may reflect the wealthier population, or the strong emphasis on outdoor recreation. At this point, the EVs that are available

are really replacements for smaller passenger vehicles. One effort could focus on encouraging Boulder residents to consider the most fuel efficient larger vehicles that are available.

For example, the Prius V actually has as much cargo capacity as a small SUV. It is not clear that this is widely known, but for many applications that are currently served by minivans and small SUVs, a Prius V could provide the same service at 40 mpg, as compared to the current average new light truck at 22 mpg.

Utility Role

There could be a major role for the electric utility to play in the expansion of use of electric vehicles, whether the utility service is provided by Xcel Energy or a new municipal utility. A municipal utility may be more able to experiment and develop innovative programs such as the battery storage ideas listed below.

From a financial perspective, there is a real value to utilities associated with electric vehicles. Because EVs increase consumption of electricity, and most of the new demand comes during off peak hours when power is cheap, greater sales are available to cover the fixed costs of the system. It should be possible to capture at least some of this value for investment into expanding the number of electric vehicles. This is the logic, for example, that led Nevada Energy to offer rebates covering half the costs of commercial charging.

Potential utility roles in the short term could include offering rebates for purchase of EVs or installation of charging, and structuring time of use rates to incentivize EV charging at off peak hours..

Over the longer term there are very interesting possibilities involving the use of EV batteries for storage. One that has drawn significant attention is the potential for use of EVs as highly distributed storage through “Vehicle to Grid” energy transfer.

However, another that has great opportunity is the use of EV batteries for stationary storage after the end of their useful life in the vehicle. Estimates are that the current generation of EV batteries will typically last on the order of 10 years or 100,000 miles before their capacity to hold a charge drops to about 80% of the original capacity. That reduces the range to the point that the batteries are no longer useful for vehicle applications, but they still could have many years of use for stationary storage.

There could be an interesting opportunity to both develop storage and increase the uptake of EVs by committing to the purchase of the batteries at the end of their useful life; or acquiring the batteries up front, and essentially renting them to customers for use in their vehicles until they are ready to be used for stationary

storage. Current estimates suggest that the residual value of the EV batteries could be $6,000, although this may come down if battery improvements make lower cost batteries available by the time current batteries are useful for resale.

To give a sense of scale here, a Nissan Leaf has a 24 kwh battery pack. After the capacity has declined to 80%, there will be about 19 kwh storage capacity in the remaining batteries. So the batteries from 50 Leafs would allow about 1 MWH of storage. At high EV penetration rates, there could be significant storage capacity available from used EV batteries.

ATTACHMENT B
Nelson Nygaard Transit Fleet and GHG Reduction Analysis
Revised Appendix to TMP

INTRODUCTION

This document describes the methodology and results of analysis of greenhouse gas (GhG) emissions reductions possible through changes in the transit system, including transition to cleaner fuel/energy sources for the transit fleet. It is organized into the following sections:

- Analysis Scenarios
- Methodology
- Results
  - Transit Fleet Emissions (for current year and 2035 scenarios and several fuel/energy alternatives
  - Net Transit GhG Emissions (accounting for VMT avoided by riding transit)
- Key Findings

ANALYSIS SCENARIOS

Transit Scenarios

Various transit vehicle fleet scenarios were analyzed to show the range of GhG reduction possible through fleet change. Scenarios included two time horizons:

- **Current Year Boulder County Transit System.** GhG emissions from current transit vehicle miles traveled (VMT) in Boulder County were estimated based on the current fleet of diesel transit vehicles and several fuel/energy alternatives.
- **2035 Transit Scenario.** A future-year transit scenario was adapted from the transit scenarios analyzed as part of the TMP.[11] It represents a substantial increase in service investment and transit VMT by 2035. GhG emissions were estimated using a similar set of fuel/energy alternatives as was analyzed for the current system.

Fuel/Energy Alternatives

These scenarios were analyzed under several transit fuel/energy alternatives, intended to reflect a range of options:

- **A. Full Diesel Bus Fleet.** The diesel analysis assumes a complete fleet comprised of “clean” diesel vehicles. The current year scenarios use the existing fuel economy numbers for “clean” diesel buses. The 2035 scenarios use a more conservative 18.4% increase in 2035 transit fleet fuel economy based on the U.S. Energy Information Administration’s (EIA) Annual Energy Outlook Reference Case for Heavy Diesel.[12]

[11] EIA 2014 Energy Outlook, Freight Transportation Energy Use, Heavy Diesel Fuel Efficiency, Reference Case, 2013-2035. See Figure D-3 for methodology details.
[12] EIA 2014 Energy Outlook, , Freight Transportation Energy Use, Heavy Diesel Fuel Efficiency, Extended Policies Case, 2013-2035. See Figure D-3 for methodology details.

- **B. Diesel Hybrid-Electric Bus Fleet.** The diesel hybrid-electric scenario assumes a fleet comprised entirely of hybrid-electric transit buses for all routes. Hybrid-electric buses have been adopted by RTD on a number of routes and are a familiar technology for transit operators and maintenance personnel. The vehicles combine a small conventional diesel hybrid electric engine to charge an electric propulsion system plus regenerative braking. Fuel economy numbers are drawn from the Federal Transit Administration's (FTA) Altoona test results with more aggressive assumptions (23.4%) for transit fleet fuel efficiency improvement by 2035 based on the EIA Extended Policies Case for Heavy Diesel. [13] This case assumes that policies mandating increased efficiency for heavy vehicles will be extended into the future. The Extended Policies case includes an assumption that efficiency standards do not "sunset" as currently legislated.
- **C. Electric and Hybrid-Electric Mix**. Employing a mix of full-electric and diesel hybrid-electric transit vehicles, the Electric and Hybrid-Electric Mix alternative models full-electric buses on local routes and diesel hybrid-electric buses on regional routes. Short ranges limit the current electric buses. Emissions numbers are drawn from the Altoona test results for diesel hybrid-electrics and full-electric buses, plus a source emissions calculation using the existing Xcel Energy – PSCo power supply mix and a low carbon power supply mix for illustrative purposes. A more aggressive fuel efficiency improvement is assumed for these vehicle types.
- **D. Full-electric Bus Fleet.** The all-electric bus fleet scenario suspends existing range limitations to test the greenhouse gas savings achievable through a fully electric bus fleet, today and in the year 2035. Current year numbers for electric vehicle GhG emissions reflect source emissions from the current Xcel Energy – PSCo power supply mix[14] and a low-carbon power supply mix for illustrative purposes. Future-year electric vehicles GhG emissions similarly include a sensitivity test of the current power supply mix and a potential low-carbon energy supply mix. A more aggressive fuel efficiency improvement is assumed for these vehicle types.

These alternatives were developed with several considerations in mind:

- The projected 40%improvement in light-duty vehicle (LDV) fleet fuel efficiency by 2035 represents an aggressive conversion based on federal standards, and assumes continued penetration of hybrid technology in the LDV fleet.
- Federal standards for heavy-duty vehicles are still evolving and there is no specific EIA projection for buses. Different rates of increased efficiency were assumed for different bus technologies. Innovations likely will increase standard diesel-powered transit vehicle efficiency (i.e., Alt. A). However, a hybrid-electric fleet (i.e., Alt. B), reflects continued adoption of hybrid technology as many transit agencies are doing today and is a more appropriate comparison to light-duty vehicle efficiency trends. The other alternatives (C and D) test more aggressive moves to cleaner transit vehicles, represent by a blended hybrid-electric and electric transit fleet or an all-electric transit fleet.
- It is assumed in Alt. D that a full-electric fleet could be supported by battery technology for all types of routes by 2035, however it should be noted that other market-driven technologies (see sidebars on the following pages) will influence the efficiency and GhG benefits for the technologies included in this analysis. These technologies may supplant the options considered

[13] FTA Altoona testing, average R1015 (New Flyer XDE40) and R1007 (Orion VII EPA 10); average of measured, Manhattan NY, Orange County CA, and UDDS scenarios; EIA 2014 Energy Outlook.
[14] Xcel Energy PSCo, 2012 Owned and Purchased Energy, accessed online: http://www.xcelenergy.com/About_Us/Our_Company/Power_Generation/Power_Generation_Fuel_Mix_-_PSCo

with alternatives that have comparable emissions benefits. For example, hydrogen fuel cells are an evolving technology that could be a viable future path to reducing transit fleet emissions.

Leading Edge Transit Technology

Electric Bus

What: Manufactured by Proterra and BYD in the United States, electric buses are ready for fleet integration today. Electric buses from Solaris and other manufacturers do not meet Buy America requirements.

Benefits: Quiet, smooth operations. Fast acceleration and regenerative braking work well for transit. On-route charging possible with contactless overhead infrastructure.

Negatives: Expensive, vehicles cost between 25-50% more than conventional buses. Shorter range, often only 50 miles. Infrastructure upgrades for on-route charging are expensive. Depending on source of electricity, carbon footprint may remain large.

Case examples: Proterra used by Foothill Transit in the San Gabriel Valley of California and San Joaquin RTD. Long Beach, California awaiting delivery of BYD buses.

Proterra ecoliner, charging while in-service during a stop in San Joaquin, California.

Source: wikipedia

Proterra ecoliner, Foothill Transit, San Gabriel, Calif.

Source: flickr user lucian400

Hydrogen Fuel Cell Hybrid Bus

What: Electrically propelled buses using proton exchange membrane fuel cells to convert hydrogen gas to energy. Hydrogen fuel cell buses offer performance and range similar to diesel vehicles without noxious emissions.

Benefits: Only water vapor and heat emissions. Quick refueling, sometimes using existing compressed natural gas facilities. Not as range-limited as electric buses.

Negatives: Expensive, a five-year pilot in Whistler, British Columbia was five-times more expensive than diesel. More frequent maintenance. Difficult and expensive to get renewable hydrogen. May be energy-intensive to extract hydrogen for use.

Case examples: Ten pilot programs are taking place around North America including Cleveland's RTA, AC Transit's HyRoad, and SunLine Transit Agency in Riverside County, California.

Cleveland RTA's hydrogen fueling station.

Source: NASA.gov

Hydrogen-powered Credo E-Bone concept bus designed by Peter Simon. Composite body used to reduce weight.

Source: green.autoblog.com

Emerging Transit Technology

Electric School Buses

Conversion of school buses to electric is an ideal use of electric vehicle technology:

- School bus routes are often short
- Buses spend most of the day in depots and not in use
- Frequent stops help charge batteries through regenerative braking
- Current school buses emit heavy tailpipe emissions in residential neighborhoods.

Air Resource Board of California's ZEBRA demonstration school bus.

Source: wikipedia

Advances in Materials

- Lightweight vehicle construction materials such as carbon fiber and composites allow transit vehicles to be more fuel-efficient.
- Recyclable materials such as steel, aluminum, and some plastic reduce the overall environmental footprint of transit vehicles.
- Transit vehicles constructed with recycled post-consumer waste materials may reduce the environmental impact of the vehicles.

Alcoa Aluminum produces the all-aluminum space frame for the BYD electric bus. Total body weight is reduced by 40%, nearly one ton, versus steel.

Source: Alcoa.com

e-Bus Rapid Transit (e-BRT)

Siemens Mobility is developing an integrated e-BRT vehicle system that incorporates electric propulsion, short charging sequences at stops, and an electronic guidance system. The system uses an advanced version of ultra rapid energy transfer, which may take as little as 20 seconds.

Using a retractable pantograph-like arm, the Siemens e-BRT will draw intense 20 second charges at each stop.

Source: siemens.com

METHODOLOGY

This section provides details on the methodology and assumptions used in this analysis.

Fleet Emissions

Overview

The following steps were used to compute the existing metric tons of CO2 emitted from transit vehicles for each current and future-year fleet scenario:

STEP 1: Calculate fuel consumption.

$$Total\ vehicles\ miles\ traveled\ \div Average\ Fuel\ Economy\ (mpg) = Gallons\ of\ fuel\ used$$

- The number of total transit vehicle miles traveled (daily weekday and weekend) was compiled for each route, from RTD's 2012 Service Recap report (August 2012). For the future year scenario, transit VMT was based on a refined version of the 2035 scenario developed for the TMP.
- The gallons of fuel consumed was calculated based on fuel efficiency assumptions for the predominant vehicle type used for each route, e.g., 30- or 40-foot transit bus or over-the-road (OTR) coach. These assumptions were drawn from a variety of government sources, primarily the EIA database and calculations for RTD vehicles in operation from FTA Altoona testing fuel economy numbers.

STEP 2: Calculate CO_2 equivalent emissions (CO_2e).

$$Gallons\ of\ fuel\ used\ \times CO_2\ emissions\ per\ gallon = Daily\ CO_2\ emissions$$

- CO_2 emissions for the fleet scenarios were calculated by applying a carbon-equivalent emissions factor per gallon of fuel (or fuel-equivalent energy) consumed per transit vehicle miles traveled. All CO_2 calculations were divided by 0.988 to yield a CO_2-equivalent (CO_2e) value.

STEP 3: Calculate electric vehicle CO_2 equivalent emissions (CO2e).

For electric vehicle types, a source emissions factor for the power mix was applied, representing a more accurate and "tunable" CO_2e emissions factor than using only the diesel fuel emissions equivalent number. The CO2e calculation for electric buses was calculated using the FTA's Altoona average diesel fuel economy equivalent and the kilowatt hours (kWh) per mile averages from the ProTerra bus trial. Scenarios with the existing mix of coal, natural gas, and "low carbon" sources and a future scenario with 100% "low carbon" sources calculates the source emissions from power generation for the electric fleet.

Detailed Assumptions

Assumptions and metrics are detailed in the following tables. Figure D-1 lists emissions factors that identify the quantity of CO2 emitted per unit of fuel or energy consumed.

Figure D-1 CO2 Emissions Factors

CO_2 emissions from a gallon of diesel	10,180 g/gallon of CO_2	U.S. EPA, Greenhouse Gas Emissions from Typical Passenger Vehicles, http://www.epa.gov/otaq/climate/documents/420f11041.pdf
Average Emissions from *Coal* burning power plants, with scrubbers	1,001 g/kWh of CO_2	http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11
Average Emissions from *Natural Gas* burning power plants	469 g/kWh of CO_2	http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11
Average Emissions from *Wind/ low carbon energy* power	28.6 g/kWh of CO_2	http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11

CO2 emissions from electricity generation vary based on the sources used to generate the electricity. Figure D-2 describes current and future energy source profiles, including a future "low-carbon" energy mix.

Figure D-2 Electricity Energy Source Profiles

Power Source Mix	Current Energy Mix		Low Carbon Energy Mix	
Type	%	g CO_2e/ kWh	%	g CO_2e/ kWh
Coal	60%	607.9	0%	0
Natural Gas	22%	104.4	0%	0
Wind, solar, and other low carbon sources	18%	2.2	100%	12.2
TOTAL	100%	705.94	100%	12.2

Figure D-3 identifies fuel economy assumptions. For 2035, a 12% improvement in diesel fuel economy is assumed in the analysis.[15]

Figure D-3 Fuel Economy Assumptions

	2013	% Improvement [2,3] 2013-2035	2035	
Diesel (clean diesel, B20, B100)	3.14	18.4%	3.72	Average of GREET and EPA EIA data. Assumed 2035 efficiency improvement based on EIA 2014 Reference Case for Heavy Diesel.[2]
Diesel HEV	5.74	23.4%	7.08	FTA, Altoona testing, AVG R1015 and R1007; AVG of measured, Manhattan, Orange CO, and UDDS scenarios. Assumed 2035 efficiency improvement based on EIA 2014 Extended Policies Case for Heavy Diesel.[3]
Electric Bus (MPGe)	20.84 [a], [b]	23.4%	25.72	FTA, Altoona Testing, Diesel Fuel Equivalent, Proterra electric bus, PTI-BT-R1305-P. Assumed same level of 2035 efficiency improvement as hybrid.
Coach Transit Bus	4.06	18.4%	4.81	FTA, Altoona Testing: AVG Blue Bird Express 4500 Commute, Arterial, CBD Phase Consumption (3.37) and AVG MCI 102D3 3-phases (4.75). Assumed same level of 2035 efficiency improvement as standard diesel.

Notes: (1) Electric Bus Fuel Economy drawn from EPA standard Miles per Gallon Equivalent (MPGe). More information: http://www.epa.gov/carlabel/electriclabelreadmore.htm. Actual MPGe number calculated by FTA Altoona Test Center. (2) 18.4% 2035 fuel efficiency improvement assumed for clean diesel, electric, and over-the-road coaches (3) 23.4% fuel efficiency improvement assumed for diesel hybrid-electric vehicles. (a) Electric bus assumed similar fuel efficiency improvements as heavy-duty diesel fuel efficiency improvement of 18.4% by 2035 (EIA). (b) Based on 1.81 kWh/mile.

[15] Diesel fuel economy numbers drawn from the average diesel bus fuel economy of the 2013 GREET (Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model) and 2012 Clean Air Task Force's Clean Diesel versus CNG Buses: Cost, Air Quality, & Climate Impacts Report (http://www.catf.us/resources/publications/files/20120227-Diesel_vs_CNG_FINAL_MJBA.pdf).
2035 emissions for transit buses is based on a 18.4% fuel efficiency improvement assumed for clean diesel, electric, and over-the-road coaches and a 23.4% fuel efficiency improvement assumed for diesel-hybrid electric vehicles; based on an EIA projection for all heavy-duty freight vehicles. Source: EIA Annual Energy Outlook 2014 with projections to 2040, http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf
This is inherently conservative as there is no specific EIA projection for buses, but innovations likely will increase standard diesel-powered transit vehicle efficiency beyond this level. A more aggressive electric light-duty vehicle scenario could be paired with either the third fleet scenario (balance of electric vehicles for local routes and hybrid-electrics for regional routes) or an additional all-electric transit fleet scenario that could be supported by improved battery technology by 2035 (or an alternative technology with comparable emissions benefits).

RESULTS

This section presents the potential transit fleet emissions reductions attainable with the fuel/energy alternatives for both current and 2035 scenarios. It then provides estimates of net GhG emissions, accounting for avoided VMT from transit riders.

Transit Fuel/Energy Source Shift (Boulder County)

Figure D-4 provides results of the alternative fleet energy source analysis. It should be noted that the results include only RTD routes, not University of Colorado (CU) or Boulder Valley School District (BVSD) operated services. The table lists CO_2 emissions estimates for alterative fleet scenarios for the current transit system and a 2035 Transit Scenario.

Current Year

The top portion of Figure D-4 lists CO2 emissions estimates for alterative fleet scenarios for a current-year transit system scenario including total emissions for each fuel/energy alternative and the difference from the base case (A). Base emissions are about 25,000 MT CO_2e and alternative fleet energy sources and fuel types could reduce transit emissions by 38% to 82%. Given the current electricity energy source mix for Boulder, fully electric transit vehicles do not achieve a significantly greater reduction in emissions compared to hybrid vehicles. However, a blended electric/hybrid-electric vehicle fleet (C2) or a full electric fleet (D2) would reduce emissions compared to a hybrid fleet (B) under the clean energy portfolio currently being considered as part of Boulder's formation of a municipal utility.

2035 Transit Scenario

The bottom portion of Figure D-4 lists CO2 emissions estimates for a 2035 transit fleet scenario.

- In 2035, assuming a significant increase in transit service, maintaining a predominantly diesel transit fleet would increase transit vehicle emissions to 56% from the current level, even with an assumed 18.4% increase in 2035 fleet diesel fuel efficiency (for standard diesel vehicles). This is due to the increase in the number of transit vehicle miles in the 2035 scenario.
- As described in the next section, the increase in transit vehicle emissions in (A) would be partially offset by emissions reductions from increased ridership and passenger vehicle-miles avoided. However, due to increased passenger vehicle fuel efficiency over time there would be a decline in the emissions reduced per passenger vehicle-mile converted to transit.
- A hybrid-electric (HEV) fleet (B) and a blended electric/HEV fleet (C1) or a full electric fleet (D1) with the *current energy source mix* would all achieve approximately the same reduction in transit fleet emissions—by 45% from 2035 base diesel fleet scenario (A) emissions.
- A blended fleet of electric and HEV vehicles with a *low-carbon energy source mix* (C2) would reduce emissions by 55% from base diesel fleet scenario (A) emissions.
- A full electric fleet with a *low-carbon energy source mix* (D2) would reduce emissions by 83% from base diesel fleet scenario (A) emissions.

Figure D-4 Annual Transit GHG Savings from Cleaner Fuel/Energy Adoption, MT CO_2e, Current and 2035 Fleet Scenarios

Current Year (2013 Base)

	Comparisons to Current Scenario Base Emissions							
Fuel Type	Metric Tons of CO2e Emissions/ Year	Difference from Diesel Fleet (A)	Difference from Hybrid Electric Fleet (B)	Difference from Electric and HEV (Current Mix) (C1)	Difference from Electric and HEV (Low Carbon) (C2)	Difference from Full Electric (Current Mix) (D1)	Difference from Full Electric (Low Carbon) (D2)	% Change From to Current Year Diesel Fleet
A. Diesel	25,530	0	9,910	9,890	15,040	9,870	20,830	N/A
B. Hybrid Electric (HEV)	15,620	-9,910	0	-20	5,130	-40	10,930	-39%
C1. Electric/ HEV (Current Energy Mix)	15,640	-9,890	20	0	5,150	-20	10,950	-39%
C2. Electric/ HEV (Low Carbon Energy Mix)	10,490	-15,040	-5,130	-5,150	0	-5,170	5,790	-59%
D1. Full electric (Current Energy Mix)	15,660	-9,870	40	20	5,170	0	10,970	-38%
D2. Full electric (Low Carbon Energy Mix)	4,700	-20,830	-10,930	-10,950	-5,790	-10,970	0	-82%
Fleet VMT/YEAR	8,703,000							

2035 Transit Scenario

	Comparisons to 2035 Scenario Base Emissions								Current Base
Fuel Type	Metric Tons of CO2e Emissions/ Year	Difference from Diesel Fleet (A)	Difference from Hybrid Electric Fleet (B)	Difference from Electric and HEV (Current Mix) (C1)	Difference from Electric and HEV (Low Carbon) (C2)	Difference from Full Electric (Current Mix) (D1)	Difference from Full Electric (Low Carbon) (D2)	% Change from 2035 Diesel Fleet	% Change from Current Year Diesel Fleet
A. Diesel	39,870	0	17,960	17,940	22,010	17,900	33,280	N/A	56%
B. Hybrid Electric (HEV)	21,910	-17,960	0	-20	4,050	-60	15,320	-45%	-14%
C1. Electric/ HEV (Current Energy Mix)	21,930	-17,940	20	0	4,070	-40	15,340	-45%	-14%
C2. Electric/ HEV (Low Carbon Energy Mix)	17,860	-22,010	-4,050	-4,070	0	-4,110	11,270	-55%	-30%
D1. Full electric (Current Energy Mix)	21,970	-17,900	60	40	4,110	0	15,380	-45%	-14%
D2. Full electric (Low Carbon Energy Mix)	6,590	-33,280	-15,320	-15,340	-11,270	-15,380	0	-83%	-74%
Fleet VMT/YEAR	15,064,000								

* Current mix of electricity: 60% coal with scrubbers, 22% natural gas, and 18% wind and other 'green sources'

** "Low carbon mix" is an average CO2e (24.8g) output of bio-mass (18g), Solar PV (46g), Solar CSP (22g), and wind (12g), adjusted for CO2 equivalency. Source: Moomaw, W., et al, 2011: Annex II: Methodology. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, et al [eds.]], Cambridge University Press, Cambridge, New York, NY. http://srren.ipcc-wg3.de/report/IPCC_SRREN_Annex_II.pdf

Net Transit GhG Emissions

This section presents net transit GhG emissions for the current and future transit fleet scenarios and fuel/energy alternatives described in the previous section.

Current

Figure D-5 shows 2014 City of Boulder GhG projections (from the Transportation GhG Workbook). For the current-year scenario, projections assume a complete fleet transition to modeled fuel source (in practice, a transition would likely be realized through phased fleet replacement, which is assumed in the 2035 scenario).

- **Transit Fleet VMT and Emissions.** Figure D-5 integrates transit fleet emissions scenarios from the above fleet analysis (Figure D-4); current year transit emissions are estimated at about 25,500 MT CO_2e for RTD and Via. See Row E (base) and Rows H to L (fuel/energy alternatives). These scenarios would reduce transit emissions (RTD/Via only) by between 39 and 82% (consistent with the above analysis).
- **Passenger VMT Avoided.** Figure D-5 integrates data from the Transportation GhG Workbook estimating over 35,000 MT CO_2e are avoided from existing transit in Boulder County (annual, including weekends).[16] These savings represent a reduction of 138% of RTD/Via transit emissions. See Row M.
- **Net GhG Emissions.** The final six rows of Figure D-5 (Rows N to S) show net emissions benefits from transit for the fuel/energy alternatives described above including GhG avoided from transit passenger vehicle trips avoided. These net reductions range from nearly 10,000 to 30,500 MT CO_2e relative to the current-year base scenario, or reductions of 38 to 120%. They represent a 4 to 13% reduction in the City of Boulder 2014 Transportation GhG forecast.

[16] A parallel analysis with a different methodology yielded similar results for weekday ridership only: There are currently about 8.9 million annual weekday rides on transit in Boulder County (based on the 2012 data used in the TMP analysis). If all these rides were converted to single- and multiple-occupant vehicle trips this would result in over 64 million additional vehicle miles traveled (VMT) annually. Assuming current average light-duty fleet fuel efficiency of 20.9 miles per gallon (MPG), these VMT would result in emissions of over 27,000 metric tons (MT) of CO_2 annually. This analysis assumed average vehicle occupancy of 1.3 and the average vehicle miles traveled (VMT) saved per ride applying data and methodology used in the Community-Wide Eco Pass Feasibility Study. Fuel efficiency assumptions were based on the EIA 2013 Reference Case that was current at the time this analysis was conducted.

Figure D-5 City of Boulder GHG Forecast, 2014, and Reductions due to Passenger VMT Avoided and Transit Fleet Fuel/Energy GhG Reductions

		Annual VMT	*% VMT*	*Annual GhG (MT)*	% Reduction of Transit-Related GhG Emissions (c)	% of Total City of Boulder 2014 Transportation GhG Forecast (d)
A.	Non-Resident Employee (a)	190,848,000	33%	70,033	-	29%
B.	Resident (walk/bike) (a)	301,105,728	52%	110,493	-	46%
C.	Student (walk/bike) (a)	70,200,000	12%	25,760	-	11%
D.	TOTAL WITHOUT TRANSIT	562,153,728	98%	206,286	-	86%
E.	Transit - RTD/VIA (b)	8,703,000	2%	25,500	-	11%
F.	Transit - CU/NCAR/BVSD (a)	3,269,500	1%	8,400	-	3%
G.	TOTAL WITH TRANSIT	574,126,200	100%	240,200	-	100%
	GHG REDUCTIONS (ENERGY OR RIDER VMT AVOIDED)					
H.	Reduction with Hybrid-Electric Fleet			-9,900	-39%	-4%
I.	Reduction with Electric/HEV with existing energy mix			-9,900	-39%	-4%
J.	Reduction with Electric/HEV with low-carbon mix			-15,000	-59%	-6%
K.	Reduction with Full Electric with existing energy mix			-9,800	-38%	-4%
L.	Reduction with Full Electric with low-carbon mix			-20,800	-82%	-9%
M.	Transit Riders VMT/GhG Avoided (a)			-35,200	-138%	-15%
	NET RTD/VIA TRANSIT GhG					
N.	w/ Diesel Fleet and Rider VMT Avoided			-9,700	-38%	-4%
O.	w/ Hybrid-Electric Fleet and Rider VMT Avoided			-19,600	-77%	-8%
P.	w/ HEV/Electric existing energy mix and Rider VMT Avoided			-19,600	-77%	-8%
Q.	w/ HEV/Electric low-carbon mix and Rider VMT Avoided			-24,700	-97%	-10%
R.	w/ Full Electric existing energy mix and Rider VMT Avoided			-19,500	-76%	-8%
S.	w/ Full Electric low-carbon mix and Rider VMT Avoided			-30,500	-120%	-13%

Notes: (a) From GhG Transportation Data Book (b) From fleet analysis or revised calculations. (c) Percentages are relative to the RTD/Via transit emissions only. (d) Percentages are relative to the total City of Boulder Transportation GhG Forecast.

2035 Transit Scenario

The Renewed Vision for Transit would increase operating and capital investment in local and regional transit services, such as improved local circulation between Boulder Junction and the University of Colorado campuses and additional service on regional routes between Boulder and other parts of Boulder County. A 2035 transit scenario was adapted from several transit scenarios that were developed as part of the TMP for comparative purposes. With this level of investment, transit ridership is projected to increase by over 100% by 2035.[17]

Figure D-6 provides estimates of net GhG reductions based on the 2035 transit scenario.

[17] This scenario is not constrained to TMP funding scenarios or the Transit Action Plans, however some elements of the original scenarios (see Transit Scenario Analysis Report) were not included. The additional investment in transit would result in a projected 19.3 million annual weekday transit rides by 2035. Ridership estimates were based on 2030 population and growth projections for the County, interpolated to 2035, and 2035 population and growth projections for the City, at the TAZ level.

- **Transit Fleet VMT and Emissions**. With a significant increase in the level of transit service, transit VMT and GhG emissions would increase (from 25,500 to nearly 40,000 MT CO_2e) if the fleet composition remains similar to today, even with an assumed 18.4% increase in transit fleet fuel efficiency in the baseline clean diesel case. The five fuel/energy alternatives analyzed in addition to the base case would decrease fleet emissions by 45 to 83%) relative to the 2035 base case and their share of transportation GhGs by between 6 and 12%. See Row E (base) and Rows H to L (fuel/energy alternatives).
- **Passenger VMT Avoided**. Emissions of about 40,000 MT of annual CO_2e would be avoided (Row M) due to increased transit ridership under the 2035 transit scenario. This estimate is based on assumptions for average VMT savings per ride[18], and reduces annual emissions by over 40,000 MT CO_2. (offsets base case transit emissions without substantial additional reductions). It assumes increased passenger vehicle fuel efficiency over time as more fuel-efficient vehicles are introduced and older, less fuel-efficient vehicles are retired; the EIA Annual Energy Outlook projects light-duty vehicle (LDV) fleet fuel efficiency of 34.1 MPG in 2035, compared to 20.9 MPG in 2012.[19] As a result, the emissions savings per passenger-mile served on transit will decline.

  However, the GhG benefits supported by transit reach beyond transportation, contributing to and supporting land uses and development that reduce VMT and have a smaller GhG footprint. Transit plays a key role in shaping built form and compact, walkable neighborhoods. Residents in walkable neighborhoods drive less not only by walking more but by using transit more often.
- **Net GhG Emissions**. The last six rows (N to S) of Figure D-6 show net GhG emissions. Given increased passenger vehicle fuel efficiency, a diesel fleet scenario would result in an increase in net transit emissions. However, a hybrid-electric, electric/HEV, or full electric fleet scenario with a low-carbon mix would provide net reductions of 18,300 MT CO2e to 33,600 MT CO2e annually relative to the 2035 base scenario, or reductions of 46 to 84% of transit emissions. This represents a 6 to 12% reductions in the City of Boulder 2035 Transportation GhG Forecast.

[18] The Community-Wide Eco Pass Feasibility Study methodology was applied to estimate the VMT per ride along existing transit corridor segments. For new corridor segments where VMT could not be inferred from existing route data, VMT was estimated based on 60% of the corridor segment distance for local trips and 80% of the corridor segment distance for regional trips. Transit was projected to result in savings of over 135 million annual VMT.
[19] EIA 2013 Reference Case that was current at the time this analysis was conducted.

Figure D-6 City of Boulder GHG Forecast, 2035, and Reductions due to Passenger VMT Avoided and Transit Fleet Fuel/ Energy GhG Reductions

		Annual VMT	% VMT	Annual GHG (MT)	% Reduction of Transit-Related GhG Emissions (c)	*% of Total City of Boulder 2035 Transportation GHG Forecast (d)*
A.	Non-Resident Employee	235,152,000	36%	86,290	-	31%
B.	Resident (walk/bike)	309,581,170	47%	113,603	-	41%
C.	Student (walk/bike)	94,500,000	14%	34,677	-	12%
D.	TOTAL WITHOUT TRANSIT (a)	639,233,170	97%	234,571	-	84%
E.	2035 Transit Scenario - Diesel (b)	15,064,200	2%	39,900	-	14%
F.	Transit - CU/NCAR/BVSD (a)	3,269,500	0%	8,400	-	3%
G.	TOTAL WITH TRANSIT	657,566,900	100%	282,900	-	100%
	GHG REDUCTIONS (ENERGY OR RIDER VMT AVOIDED)					
H.	Reduction with Hybrid-Electric Fleet			-18,000	-45%	-6%
I.	Reduction with Electric/HEV with existing energy mix			-18,000	-45%	-6%
J.	Reduction with Electric/HEV with low-carbon mix			-22,000	-55%	-8%
K.	Reduction with Full Electric with existing energy mix			-17,900	-45%	-6%
L.	Reduction with Full Electric with low-carbon mix			-33,300	-83%	-12%
M.	Transit Riders VMT/GhG Avoided (e)			-40,200	-101%	-14%
	NET RTD/VIA TRANSIT GhG					
N.	w/ Diesel Fleet and Rider VMT Avoided			-300	-1%	0%
O.	w/ Hybrid-Electric Fleet and Rider VMT Avoided			-18,300	-46%	-6%
P.	w/ HEV/Electric existing energy mix and Rider VMT Avoided			-18,300	-46%	-6%
Q.	w/ HEV/Electric low-carbon mix and Rider VMT Avoided			-22,300	-56%	-8%
R.	w/ Full Electric existing energy mix and Rider VMT Avoided			-18,200	-46%	-6%
S.	w/ Full Electric low-carbon mix and Rider VMT Avoided			-33,600	-84%	-12%

Notes: (a) From GhG Transportation Data Book, for 2035 (b) From fleet analysis or revised calculations. (c) Percentages are relative to the RTD/Via transit emissions only. (d) Percentages are relative to the total City of Boulder Transportation GhG Forecast. (e) Transit scenario estimate adapted for this analysis including an adjustment to account for weekend riders.

SUMMARY OF KEY FINDINGS

Key findings from this analysis include:

- Maintaining the status quo bus transit fleet (primarily diesel) would likely decrease the current net GhG emissions benefit from transit by 2035 due to increased transit service and increased passenger vehicle fuel efficiency. This would occur even with an assumed 18.4% efficiency improvement in standard transit vehicles. Based on the assumptions in this analysis, the benefit is small but still a net reduction in GhG emissions.
- Transitioning the transit fleet to cleaner fuel/energy sources will be necessary to increase net GhG emissions reductions from transit. This analysis evaluated several vehicle options ranging from current generation hybrid-electric and electric vehicles, including a blend of hybrid and electric vehicles. It also assumed continued fuel efficiency improvements in both standard diesel vehicles (e.g., lighter materials)

and more substantial efficiency improvements in hybrid vehicle technologies (e.g., from regenerative braking).

- With the current electricity energy source mix in Boulder, a conversion to electric buses offers little overall benefit in reducing GhG emissions—comparable to converting to hybrid-electric vehicles. However, shifting to an electric bus fleet does reduce local emissions of various air pollutants while generating emissions at the energy source, e.g., coal or natural gas power plant.
- The analysis included a low-carbon energy source mix, as could be achieved with the clean energy portfolio currently being considered as part of Boulder's formation of a municipal utility, and demonstrated the sensitivity of GhG emissions benefits to the energy source for electric vehicles. Changing from the current energy mix to a low-carbon energy mix of wind, biomass, solar, and thermal significantly reduces the overall GhG emissions of the fleet, reducing 2035 emissions to 26% of the current level (74% reduction) and to 17% of the 2035 scenario estimate (83% reduction).
- Advances in vehicle and fuel technologies (e.g., hydrogen fuel cells) will be market-driven and are likely to both enhance the efficiency of the vehicle types analyzed and make additional clean fuel/energy options viable in the future. An all-electric transit fleet scenario may or may not be supported by battery technology by 2035, and Boulder may or may not be able to transition to a cleaner energy source mix by 2035, however an alternative technology is likely to be available that can provide comparable emissions benefits to the alternative analyzed.
- Transit also provides indirect GhG benefits, contributing to land use development patterns that support reduced VMT and have a smaller GhG footprint. Transit plays a key role in shaping built form and compact, walkable neighborhoods. Residents in walkable neighborhoods drive less not only by walking and biking more but by using transit more often. Two statistics from T4America highlight the opportunity to reduce GhG emissions by influencing the character of the built environment:
  - Eliminating one vehicle and using public transit can reduce a two-car household's carbon footprint by 25 to 30 percent.
  - Residents of the most walkable areas of the country drive 26 percent fewer miles per day than those living in the most sprawling areas
- Pursuing transit, TDM, and land use strategies are all opportunities for the public sector to influence GhG emissions at a relatively low cost per net unit