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# STRENGTHENING THE ABILITY OF PUBLIC TRANSPORTATION TO REDUCE OUR DEPENDENCE ON FOREIGN OIL

## HEARING

BEFORE THE

## COMMITTEE ON BANKING, HOUSING, AND URBAN AFFAIRS UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

ON

THE ADEQUACY OF THE FEDERAL GOVERNMENT'S ROLE IN PROMOTING TRANSIT AND IN MAXIMIZING THE ENERGY EFFICIENCIES OF PUBLIC TRANSIT SYSTEMS

TUESDAY, SEPTEMBER 9, 2008

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# C O N T E N T S

## TUESDAY, SEPTEMBER 9, 2008



## WITNESSES

# STRENGTHENING THE ABILITY OF PUBLIC TRANSPORTATION TO REDUCE OUR DEPENDENCE ON FOREIGN OIL

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**TUESDAY, SEPTEMBER 9, 2008**

U.S. SENATE,
COMMITTEE ON BANKING, HOUSING, AND URBAN AFFAIRS,
*Washington, DC.*

The Committee met at 10:11 a.m., in room SD–538, Dirksen Senate Office Building, Senator Robert Casey, presiding.

Senator CASEY. The Committee will come to order.

I am honored this morning to be sitting in Senator Dodd's place. He had an emergency he had to attend to, and I am grateful for the opportunity to chair this hearing and grateful for the members who are here with us. I will do a brief opening and then I will turn to Senator Shelby and other members.

## OPENING STATEMENT OF SENATOR ROBERT P. CASEY

Senator CASEY. Today, we are examining ways to strengthen the ability of transit to reduce our dependence on foreign oil, and there are, as we know, two great economic challenges facing our country today. One is the challenge created by the collapse of the subprime mortgage market and the ripple effects it has had throughout our economy. And the second, of course, is the dramatic impact that the high cost of energy has had on our economy. For those of us on this Committee, it is our good fortune—or some might say misfortune—to have a central role to play in addressing each of these challenges.

With respect to the challenge cause by increasing energy costs, this hearing could not be more timely. The cost of energy has increased precipitously over just a short period of time. Three years ago, the President signed the surface transportation reauthorization bill known as SAFETEA. At the end of 2005, the price of gasoline was around $2 a gallon. In recent weeks, in most parts of the country the cost of gasoline has exceeded $4 a gallon. While prices have abated somewhat in recent days, they are still exceptionally high by historic standards.

Perhaps the greatest indication of the impact of these high energy prices are having on American families is that they are changing Americans' behavior. Today, for the first time in 27 years, our people are driving less. As we will learn just this morning from our first witness, people in record numbers are relying upon public transportation to go to work and live their daily lives. So while some people are waiting, the American people are not waiting for Washington to change.

So we will explore a lot of these issues today, and I am going to cut short my statement to turn it over to the Ranking Member, Senator Shelby, and then we will go from there. Senator Shelby.

**STATEMENT OF SENATOR RICHARD C. SHELBY**

Senator SHELBY. Thank you, Mr. Chairman. I will try to be brief.

I believe we all agree that the role of public transportation in conserving energy is an important issue and one that has gained greater attention of late with gas prices on the rise, as you mentioned. Mobility has always been an important part of the American way of life and one that we have come to expect. Our communities, the economy, and much of our lives are organized around our ability to travel easily and efficiently, from home to work and to school, to shop, to play, to receive medical care, or simply to travel for pleasure. However, as more vehicles take to the roads, traffic congestion is having an increasingly debilitating effect on our ability to travel, whether for necessity or for fun.

These increasing delays not only diminish our overall quality of life but place an actual strain on our pocketbook. In fact, according to the Texas Transportation Institute, congestion has cost the U.S. economy $78 billion in the form of 4.2 billion hours of travel delay and 2.9 billion gallons of wasted fuel for American consumers. Just think about it. While we can attempt to build more roads and bridges to accommodate greater numbers of vehicles, public transportation is an important alternative. Public transportation can efficiently and effectively transport commuters to and from their destinations while using less fuel, creating less pollution, and taking a significant amount of stress and congestion off our roadways.

The majority of Americans continue to have few choices but to pay at the pump to get where they need to go; but for those who do have access, many have seized the opportunity to save money on fuel by taking public transportation, resulting in the highest ridership numbers that have been reported in 50 years.

Last week, the average price of gasoline in the U.S. was $3.68, down slightly from the month before, and yet ridership numbers seem to be holding steady. But we must find a way to maintain these ridership numbers long term despite the price of fuel.

I believe that we must recognize the ability of public transportation to alleviate congestion and reduce energy consumption by giving it greater focus as we continue to debate ways to increase supply, reduce demand, and diversify our fuel sources. I also believe that the public must be able to see, feel, and realize the advantages of public transportation in their daily lives, or they will never take advantage of the services. In fact, we can have the most fuel-efficient, environmentally friendly public transportation systems around. But if riders do not believe that it is benefiting them directly, they will not utilize the systems.

Ultimately, this must be a collaborative effort, one that enlists the efforts of the agencies in making their systems more efficient, their rides more pleasant, and the overall experience more positive and the efforts of Congress in supporting these endeavors. This cannot be seen as just another opportunity to collect more from the

Federal Government and deliver the same to the American public. This is an important topic, I believe, and I look forward to hearing the thoughts of our panelists regarding actions that Congress, and specifically this Committee, can take to increase the efficiency and effectiveness of public trans systems big and small across the country.

Thank you, Mr. Chairman.

Senator CASEY. Senator Shelby, thank you very much.

We will go now to other Members of the Committee in the order of appearance. That is the rule, as we know. Now, according to my list here, Senator Reed is next.

**STATEMENT OF SENATOR JACK REED**

Senator REED. Thank you, Mr. Chairman.

I just want to emphasize very briefly what Chairman Casey and Senator Shelby said. With increased prices of gasoline particularly, many people are using mass transit, but the mass transit system cannot accommodate this increased demand, and that is causing huge problems. In my home State of Rhode Island, our public transit agency estimates that they have to put more buses on, yet with higher diesel prices, higher prices for everything else, they cannot afford to do that, so at this moment they are thinking about cutting service, which means that people cannot get to work, seniors cannot get to appointments, and we also understand the huge ramifications for environmental policy with congestion, as Senator Shelby mentioned, and just environmental degradation. So we have to do something, and I am pleased that my colleague Senator Clinton, I think, will talk about temporary operating assistance, which is important, particularly in this fuel crisis, and also long-term capital investments for energy-efficient transportation vehicles and systems, not just buses but systems—GPS systems that can move buses more efficiently; special lanes on roads that can get buses through. All of that is essential to building a system.

I also think and hope that as we consider supplemental appropriations bills—Senator Burr has included $900 million in investments in public transportation—we can get that through, and thank you, Mr. Chairman, very much.

Senator CASEY. Thank you, Senator Reed.

Senator Corker.

Senator CORKER. Out of respect for the witnesses, I have no opening comments and sort of hope that will be the norm.

Thank you.

[Laughter.]

Senator CASEY. Senator Corker, you are already more popular than you were a minute ago.

Senator Carper.

**STATEMENT OF SENATOR THOMAS R. CARPER**

Senator CARPER. Breaking with the norm, let me—Mr. Chairman, the price of gasoline went to $4 a gallon earlier this year, and Americans started looking for ways to save money. Some of us bought the smaller, more fuel-efficient cars. Most people, though, tried to find ways to buy less gas. I believe the cheapest, cleanest gallon of gasoline is the one that we never have to buy.

So how have people avoided filling up their tanks? They have worked with their employers to allow them to telecommute. They have started carpooling. They have been getting onto trains and buses wherever they are available. In the Northeast corridor, our ridership on Amtrak—in fact, nationwide, ridership on Amtrak is up some 11 percent; revenues are up about 14 percent over the last year.

The biggest growth, though, has not been in the Northeast corridor. The biggest growth has been in other densely populated corridors, including corridors between Chicago and St. Louis, Chicago and Kansas City, Kansas City and St. Louis. Even the Carolinian, which runs from New York down to Charlotte, has shown dramatic increases in ridership, along with a number of routes on the West Coast.

Transit ridership, as we know, is breaking records all over the country, and, again, that is not just in the Northeast. But the biggest increases in rail travel were, I am told, in Seattle; Harrisburg, Pennsylvania; Oceanside, California; and the biggest gains in ridership in buses were down in Gainesville, Georgia, and Pompano Beach, Florida.

Now, this is good news for lowering our dependence on foreign oil. Each year, public transportation uses about 1.4 billion gallons of gasoline. That is almost 4 million gallons of gasoline a day. Some may say that is bad news. Actually, I think it is good news for the American people and for our families. The American Public Transit Association has found that people can save some $1,800 per year by taking transit. Americans understand that transit saves money. Recent studies show that one-third of Americans who live near rail transit use it regularly, and that is terrific. What is not so terrific is that less than one in every 20 Americans lives within a half-mile of trail transit. Less than one in 20 Americans has a way to save money on gas when costs spike. We can do better than that, and we need to.

When we consider energy legislation, global climate change legislation, and our next transportation bill, we need to take this into consideration and make sure that most Americans have safe, convenient access to transit. If we do so, we will go a long way in helping families save money, reducing our reliance on foreign oil.

If I could, Mr. Chairman, I just want to share a "gee whiz" fact with everybody here today. There has been a migration of Americans back toward our coasts, and today some 55 percent of Americans live within, I believe—is it 75 miles?—within 50 miles of one of our coasts. And what this does is it certainly provides opportunities for densely populated corridors which rail is able to serve well. It also provides better opportunities for transit with those kinds of density.

Thanks very much.

Senator CASEY. Senator Dole.

## STATEMENT OF SENATOR ELIZABETH DOLE

Senator DOLE. Thank you, Mr. Chairman, Senator Shelby. I want to thank you for holding this important hearing on how functional transit programs can play an important role in our effort to combat rising energy prices, and I will just prepare you that I have a rather long statement, so hold on here.

In North Carolina, there has been a concerted effort across our larger communities to develop more efficient mass transit systems, which I believe has been largely successful. When I served as Transportation Secretary during the Reagan administration, I strengthened the criteria that the Federal Transit Administration, FTA, uses to evaluate proposed transit projects. It is absolutely necessary that FTA have the expertise on hand to judge projects fairly and objectively. I firmly believe that any transit project built with Federal tax dollars must be thoroughly examined and rigorously tested to guarantee that the numbers add up and the ridership figures are solid.

I recall a crisp May morning in 2005 when I and many other State and local leaders drove in the golden spike to mark the beginning of construction and to celebrate the signing of the full funding grant agreement for the Charlotte light rail system. At that time there was no way to fully comprehend how the city of Charlotte and its surrounding areas would embrace light rail. In November 2007, the line officially opened for public use, and I am pleased to report that as of July it has serviced over 430,000 trips, averaging over 16,900 trips a day during a typical work week. In total, there were over 2.3 million trips taken on the Charlotte Area Transit System, the CATS System, with an average of more than 90,000 daily rides during that same month. These statistics far exceeded initial projections, and CATS is now slated to reach ridership levels that were not supposed to be achieved until the year 2025. Congratulations to Director Keith Parker and Charlotte Mayor Pat McCrory for the resounding success of this transit program.

Likewise, in the Raleigh-Durham-Chapel Hill area, the local transit authority has also witnessed increased reliance on the public transportation assets. In fact, the American Public Transportation Association estimates that a person in the Triangle can save more than $8,000 per year by taking public transportation. In just the past year, ridership on the Triangle Transit—that is the regional bus service—has increased 14 percent to nearly 1 million riders. While Triangle Transit has experienced setbacks in the development of its own light rail proposal, I am pleased they have gone back to the affected local communities and various civic and business leaders to try to develop a more robust light rail proposal for the Triangle area.

While I am pleased to see these two urban areas in my State effectively utilize transit systems, we must not forget that our rural areas also demand viable transportation solutions. Indeed, from the largest metropolitan area to the smallest towns, updating our infrastructure would positively impact the lives of all Americans. In addition, improving our current system of roads and bridges will lead to a more efficient system, and I look forward to Congress working toward a new transportation reauthorization bill, as has been mentioned earlier, next year.

I am proud to join Senator Wyden and Senator Thune as an original cosponsor of the Build America Bonds Act. This legislation would provide $50 billion in new transportation infrastructure funding through a one-time bonding program. Funds generated from the bonds would be available to all States, and these additional dollars would empower States and local governments to compete and complete significant new infrastructure projects across all modes of transportation, and that would include roads, bridges, transit, and rail. Unlike other proposals, our bill does not create a new Federal bureaucracy or a panel of individuals that could be influenced by politics to cherry-pick the projects that are to receive funding.

As we discuss these important public transportation issues, we must not and cannot have this conversation without discussing the fundamental supply and demand principles of our dependence on foreign oil. Americans will continue to drive their cars and fuel our economy using oil for the foreseeable future. Not everyone can purchase a new hybrid, and not everyone will have access to public transportation. So it is important that the United States have a comprehensive energy policy that is not dependent on Chavez's Venezuela or Ahmadinejad's Iran or Putin's Russia. Let us put those dollars to work here at home. To free the United States from the stranglehold of high gas prices and dependence on foreign oil, I believe we must pursue a comprehensive strategy based on improving conservation, investing in alternative sources, exploring for more energy, and ensuring market fairness. Indeed, mass transit systems which help conserve valuable energy resources play an important part in this comprehensive strategy.

We must put every option on the table, everything and the kitchen sink, to achieve energy independence, less energy through conservation, and more energy to the market by making better use of America's vast resources. We must get to work to achieve bipartisan, common-sense solutions. That is what the American people expect, and that is what this Congress needs to deliver.

I have joined with the bipartisan group of Senators to deliver an energy plan that will help transition our vehicles to non-petroleum-based fuels, commit the U.S. to conservation and efficiency, and increase responsible, environmentally sound production of new energy. Securing our energy independence is one of the greatest challenges facing our Nation. It is critical to our economic future. It is critical to our national security. And our commitment to all options, including the one the Chairman has highlighted today—public transportation—must be on the table. As I have said previously, we need to throw everything, and the kitchen sink, on the table to secure our energy independence.

Thank you, Mr. Chairman.

Senator CASEY. Thank you, Senator DOLE.

Senator Schumer.

## STATEMENT OF SENATOR CHARLES E. SCHUMER

Senator SCHUMER. Thank you, Mr. Chairman. I would like to thank you and Senator SHELBY for holding this hearing, and I want to acknowledge, of course, my good friend and colleague from New York State, who is here today.

As Chairman of the Subcommittee on Housing, Transportation, and Community Development, I would like to start by saying transportation needs have reached a critical point in the Nation's history, and as has been mentioned before, the skyrocketing price of oil is putting financial strains on all modes of transportation.

The gas pump is not the only place where the American traveler in struggling. The infrastructure that carries America is sorely in need of a shot in the arm. And so we are at a confluence here. We need to do more for road infrastructure, transit infrastructure, and we have an energy crisis. And so right now, related to this bill, as we speak, on the floor of the Senate we are trying to infuse $8 billion into the Highway Trust Fund, which is short. If we do not do that in the next few weeks, our States will get only 64 cents on every dollar for ongoing projects. Ongoing projects. And that means at a time of recession, workers will be laid off; our need to increase our infrastructure, make it better—we saw what happened with the bridge collapse—is gone.

And so we have proposed filling that trust fund. And what do our colleagues on the other side of the aisle say? Take it out of the Mass Transit Fund. I agree with my colleague from North Carolina. We need both. And it is wrong to rob Peter to pay Paul, and yet that is exactly what is happening here as we speak.

So the irony is, as we are all praising the need for mass transit, some are deciding to rob the cradle by taking money out of mass transit and putting it into regular transit, regular highways. That is a huge mistake, and I hope we do not do that. I hope we can, rather, fill the Highway Trust Fund without sacrificing mass transit. That is very, very important, and I hope my colleagues on the other side of the aisle would agree with me on that.

Now, in the long run, we need to rebuild our mass transit infrastructure. In my city, the MTA reports that subways, buses, and railroads provide 2.6 billion trips each year to New Yorkers. That saves us energy every time they take that. And in our city, which I guess is the capital of mass transit in the country, ridership has increased 4 to 11 percent in the last 9 months alone. People are leaving the cars and going into mass transit because of the high price of gasoline.

The riders that we have in the New York metropolitan area, which is really four States—Connecticut, New Jersey—my colleague from New Jersey is here; our Chairman from Connecticut; and Pennsylvania as well, where Senator CASEY comes from. Now Pike County is part of the New York metropolitan area, and people take mass transit. I just met a police officer who retired and moved out there, but he has another job, and he takes the bus. He takes a commuter bus in from Pike County. It only takes an hour and 15 minutes. Pretty good. He used to live on Staten Island.

But in any case, we need to do this. So our infrastructure is really important, and we have to build our mass transit infrastructure. We have waited too long. It not only works in large cities like New York. It works in medium-size cities like Buffalo and Rochester and Syracuse and Albany, and smaller cities. So it is now needed across the whole country, and that is why the Saving Energy Through Public Transportation Act, introduced by my colleague Senator CLINTON—I am a proud cosponsor of it—is so important. And I hope that we can all get behind this legislation so we can move forward and improve mass transit without taking that money away from the Highway Trust Fund, just as the Highway Trust Fund should not take the money out of mass transit. The 80–20 break has been regarded as fair all along. This crisis should not make us change that at a time when we need more mass transit as well as fixing our highway infrastructure.

Thank you, Mr. Chairman.

Senator CASEY. Thank you, Senator SCHUMER.

Senator Menendez.

**STATEMENT OF SENATOR ROBERT MENENDEZ**

Senator MENENDEZ. Thank you, Mr. Chairman and Senator SHELBY, for having this hearing, and I want to echo what my colleague from New York said very much so. We have a lot of synergy between our two States. And if you look at some of the mass transit systems and the PATH System, which is a subway system between New Jersey and New York, you see record ridership taking place at this time. But you also see mass transit agencies facing record challenges as fuel and other operating costs rise. And it is interesting to see that across the landscape of the country, at a time where there is greater demand for mass transit, there are also mass transit agencies cutting back on some services because of the challenges they face.

And so we have a tremendous opportunity to build upon a system that moves people effectively and efficiently in, generally speaking, a non-polluting fashion and takes cars off the road, reduces our demand on foreign oil, and at the same time does something about our collective challenges on global warming. There are few entities that can do all of those things in one fell swoop, and that is certainly our opportunity in mass transit that we have dramatically underfunded over the years. And now we face the consequences of that underfunding. It is time to reinvest in a way that helps us in all these challenges.

I would like my full statement to be included in the record, Mr. Chairman, but I would make two final points so we can move on.

One is that some people think that mass transit is for those who simply cannot afford the opportunity to own a car, and they are so wrong. In my home State of New Jersey, we have an incredible number of train stations where the average income of a rider is well over $70,000 a year. So this is not just a question about low-income individuals or those who cannot afford a car to be able to achieve the opportunity to get to work having to use mass transit. No. People of higher incomes and middle income, upper middle income, see it as a real way in which not only is it a savings to them, but their quality of life is better because they do not have to physically drive at the end of the day.

And, third, I am proud of what I was able to do as an example—and I welcome colleagues to come visit it—when I was in the House, as a member of the Transportation Committee, where we had a high-speed, non-polluting light rail system along the Hudson waterfront that creates the connections to opportunities to work, to recreation, and by virtue of creating this light rail line, has spurred enormous economic investment. What was an abandoned railroad yard is now the location of multi-million-dollar homes, businesses, and financial institutions. A good deal of that took place by virtue of the investment we made in mass transit. It took a lot of people off the road, gave them access to employment opportunities, trans-Hudson crossings, and created the intermodality that we really need in this process.

The final point I would make is that, in a post-September 11th world, I think this is more than about just economic realities and about meeting environmental challenges and also meeting our challenges on energy. This is also about creating multiple modes of transportation so that God forbid we face an event like that which took place on September 11th, of which the anniversary is coming upon us, that, in fact, we can have different ways of getting people out of a major incident.

On that fateful day, when the PATH system was closed, when the tunnels were closed, when the bridges were closed, it was an alternate means of transportation. The ferry system that moves tens of thousands of people between New York and New Jersey, they got people out of downtown Manhattan into New Jersey and triaged to hospitals across New Jersey. So it has even that dimension as well.

I think when we look at all of this, it makes a compelling case for the type of legislation Senator Clinton has talked about, as well as some that the Chair and the Ranking Member have talked about. And I look forward to actually moving in this direction in a way that can help us achieve these goals.

Thank you, Mr. Chairman.

Senator CASEY. Senator Menendez, thank you very much.

Now we will move to our witnesses, and our first witness is Senator Clinton. We are honored by your presence, Senator Clinton, not only as a colleague but as someone who cares deeply about the issues that bring us together today. And I think it is very difficult, especially in the setting of a hearing like this, to encapsulate your whole biography. And I will not try, but I think everyone in this room knows the contributions you have made to this country, starting as an advocate many, many years ago, in your work as First Lady both in Arkansas and for the United States and for all of America; your work in the Senate advocating for those who do not have a voice, not only from New York State but for the whole country; your historic campaign where you brought light to a lot of the darkness that is faced by so many Americans; and I think in particular today, the issues that we are discussing here—how we reduce our dependence on foreign oil, how we adequately invest in transit. And I think you have an understanding—and your record demonstrates this—not only the people that ride the bus, places in Philadelphia—I remember the 33 bus, the bus I was on many years ago. I think you have an understanding of what those families are up against in their daily lives, as well as the complex challenges of funding those transit systems.

So for your work here in the U.S. Senate and for what you have represented for American families, we are honored by your presence here, and we are grateful that you took the time to provide testimony, and the floor is yours.

## STATEMENT OF HILLARY CLINTON, U.S. SENATOR FROM THE STATE OF NEW YORK

Senator CLINTON. Thank you very much, Chairman Casey. That was way too kind. But I appreciate the attention that you and Senator Shelby and the Members of this Committee are paying to this issue because I do think this is a win-win-win for all of us. This is an opportunity for the Congress to come together in the short term, the medium term, and the long term to address the multiple challenges that we are confronting in a very productive and positive way. So I thank you for your commitment to this.

You have already heard a lot of the reasons from the opening statements of the Members of this Committee as to why we are here. The kind of challenges that we are facing from our energy and security perspective with respect to global warming and carbon emissions, to the congestion on the roads, to the difficulties that so many people are having today affording the transportation for the mobility that Senator Shelby referenced.

So what do we do about it? And we need to start solving problems in America. And no matter who is elected President in January, we are going to need a Congress that is committed to finding solutions. And as I listened to Senator Dole talking about what she had done when she was in a previous administration, that is the kind of tangible progress that Americans are looking for, where they actually can see and touch and feel and experience what Senator Menendez did on his side of the river.

So I hope that this Committee will work with the rest of the Senate in moving us toward the long overdue recognition that mass transit, public transit, has really the answer to a lot of the problems that we face today.

In the first quarter of this year alone, riders took more than 2.6 billion trips on public transportation, nearly 85 million more than during the same time last year. And, of course, as my colleague Senator Schumer pointed out, New York City is the epicenter of mass transit. But that is no longer the case that it is just a New York City issue or just a New York/New Jersey issue. Across the country, in small towns, in rural areas, we are seeing more and more public transportation being provided and the need and the desire for even more than that becoming a public concern.

You know, more and more transit systems, though, are facing the squeeze. These networks were already in need of investment just to keep running, let alone to meet the skyrocketing demand. They have to pay the high fuel costs as well. With these increased numbers, the equipment and the mechanical problems also increase. The MTA in New York is thinking about putting on subway cars with no seats in order to jam more people in.

So there is a recognition that we had pre-existing problems that the good news of people taking more public transit has some consequences that are causing our transit systems to worry about whether they can continue to provide the services that are being demanded.

Now, what we see is a sense that public transit has never fulfilled its promise. Again, I think Senator Shelby sort of hit it on the head when he talked about what people expect from public transit. If we are going to get them in the doors, how do we keep them coming? How do they have a good experience? How do they believe that this is a worthwhile commitment for them to make every day as they commute to work or go on about their daily business? So it is time to make public transportation a public priority. It is a public good. It has the opportunity of solving all of these problems that we have been discussing.

That is why I have introduced the Saving Energy Through Public Transportation Act of 2008. This legislation authorizes $1.7 billion over 2 years to help mass transit systems across the country expand and prepare for the massive rise in consumers' switching from the driver's seat to seats on commuter rail lines and bus routes.

Now, what happens in New York is that a number of people still have cars. We are not a car-less society in New York. But they put those cars to one side for the daily activities. They use them for special occasions. They use them to go visit relatives, to go to some occasion that really does require them getting in the car and getting on the highway. But many people are now saving money; I think Senator Carper said $1,800 a year. And as Senator Dole said, it is $8,000 if you forego the second car or if you leave it garaged and you are not using it as much as you did before.

So this proposal will meet the growing demand for affordable, convenient public transportation in cities, suburbs and rural areas. But I want to recognize that this is what I consider to be a medium-term solution. We have the short-term problems because of the shortfall in the Highway Trust Fund. We know that it is approaching bankruptcy. The Mass Transit Fund is facing a solvency crisis. So before we leave, we have got to fix that. That is the short-term necessity.

Now, the National Surface Transportation Policy and Revenue Study Commission estimates that $225 billion each year is required to meet the country's transportation infrastructure needs. That is everything that we do. We are currently spending at about 40 percent of that level, so we are falling further and further behind.

So that is why when we consider a new surface transportation bill, we have got to cast aside business as usual. We have got to think outside the proverbial box. We have got to bring every region of our country together looking for the long-term solutions, and that will include a comprehensive infrastructure policy.

So, Mr. Chairman, I am excited that we are looking at this in the perspective that I think it should be considered: as a great opportunity, an opportunity to enhance our security, to lessen our dependence on foreign oil, to begin to meet our obligations with respect to global warming, to create jobs, millions of new good jobs—which we desperately need a source of new jobs right now—and to save money for folks, and begin to chip away at that congestion which is becoming a bigger and bigger problem no matter where you live today in America.

So it is exciting to be part of this, and I thank you and look forward to working with you as we meet this challenge.

Senator CASEY. Senator Clinton, thank you very much for your presence here today, and you are welcome to stay, but I know you have to go. Thank you very much.

I wanted to turn to our second witness, Bill Millar. I think we will go from left to right—oh, I am sorry. Let me just interrupt for 1 second. Senator Tester came in, and I want to make sure that we give Senator Tester some time for an opening statement.

**STATEMENT OF SENATOR JON TESTER**

Senator TESTER. Mr. Chairman, thank you. And before Senator Clinton leaves, I want to tell you that I appreciate your remarks, Senator Clinton. I think those remarks work well in New York City as well as they do in Big Sandy, Montana. So thank you very much.

Mr. Chairman, I would be remiss if I did not point out the fact that it is good to see you in that slot and that you and Senator Shelby could pass for brothers.

[Laughter.]

Senator TESTER. And that is meant as a compliment to both of you.

Normally, on Tuesdays from 10 to 12:30, I preside on the floor, and I wanted to take a moment to go away from that position. And Senator Pryor was good enough to substitute for me for the purpose of making some statements at this Committee meeting.

I think this is a very important topic. I want to welcome all of the folks who are going to testify here today. I have got to go back and preside once I am done making my statement. I will scrutinize your testimony, but I appreciate your being here.

The fact is that this is a very critically important issue for all the reasons that Senator Clinton talked about, but in Montana—and, by the way, Senator Dole, I understand you approached it from a rural perspective in some of your comments. I appreciate that. I think that, as I said earlier, as we struggle with gas prices in rural America, in places like Montana, we see people using more public transportation. But they have some of the same challenges that we have. Their energy prices have gone up, a Missoula provider, 37 percent in the last year. They are seeing their ridership go up, but by the same token, they are seeing increased pressure that is already on overburdened transit districts. Whether that is maintaining their fleet and keeping their fleet up to snuff or whether that is moving to hybrid or more economical diesel buses or buses that can run on vegetable fuel or whatever, we need an investment in infrastructure in our transit districts if we are going to get our hands around this energy problem. This is another piece of the puzzle, the way I see it.

And so as we go forth here today, I think it is important that we talk about what necessary investment is—what necessary investment is in urban areas as well as in rural areas. You know, I jumped on the Metro here in Washington, D.C., the other day—and I come from a State of 950,000 people. That is the whole State. Arguably, that is about as many people as in the greater Washington, D.C., area. And I jumped on that Metro, and I thought to myself, "What if each one of these folks were driving a car right now?" The fact is it saves a lot of energy. It is better for the environmental. And that particular system—and I am more familiar with it than others—is a very good system for moving people around this District. So it works.

But I think that in the end, folks are going to be looking to mass transit—bus systems, in particular, in my neck of the woods—for more and more use. Whether it is getting their groceries or getting to work, it does not matter. I think hopefully, as this conversation moves forward, that we will consider absolutely the urban benefits, but let us also consider the rural benefits, because I think they are real and I think they need to be pursued.

Thank you very much, Mr. Chairman. I appreciate the opportunity to make that statement.

Senator CASEY. Senator Tester, thank you very much, and we appreciate your coming over in the midst of presiding.

The Committee is pleased to welcome Bill Millar back before us. Bill has been President of APTA for 12 years, has testified before this Committee many times, is one of the Nation's premier leaders in mass transit policy. We are grateful that he is joining us today and sharing the great news of record increases in transit ridership.

Mr. Millar, we appreciate your being here, and the floor is yours.

**STATEMENT OF WILLIAM W. MILLAR, PRESIDENT, AMERICAN PUBLIC TRANSPORTATION ASSOCIATION**

Mr. MILLAR. Thank you, Mr. Chairman. It is a pleasure to return before the Committee, and I appreciate the you and Mr. Shelby have sponsored these hearings, and I am so pleased to be back with you.

I do want to show you the good news of public transit. We have seen sweeping changes in the way Americans are traveling. The burden of $4-a-gallon gas has caused people to think about where they can economize and yet not give up their basic freedoms of mobility that are so important to each and every one of you.

I am going to be sharing with the Committee some brand new statistics that we are releasing today on a number of the issues that are relevant to this discussion.

First, the second quarter—that is, April through June of this year—we have seen about a 5.2-percent increase in the use of public transportation; some 140 million times more Americans used public transportation in that period. Thinking about that another way, that is every day a million and a half times more that are using public transportation than just a year before. And we remember the year before was a record, and the year before that was a record. So we now have an on going trend here.

No doubt about it, the higher gas prices have been part of this, but it is also part of a long-term trend of improving public transportation in communities that did not have the type of systems they now have. For example, as Mrs. Dole has alluded to in her testimony, it shows the good work that this Committee has been doing for many, many years in trying to improve the investment in public transit.

They may have come to public transit to avoid high gas prices, but we are seeing that they are staying because they are finding it convenient and it meets their lifestyle. And even though gas prices have retreated somewhat in the last few weeks, some anecdotal data that we have recently gathered from our members shows that even in August, after gas prices had already fallen again, the people who came to public transit are staying. I have every reason to believe that by the end of this year we will have yet another record ridership.

We heard from several Senators about the amounts of money that can be saved by using public transit. Our absolute latest data, using information from the AAA and other reliable sources shows that you can now save over $9,500 per year on average in an urban area in America by using public transportation. It certainly helps out as people are facing record food prices, record energy prices. By taking public transit, they can certainly save a great deal.

Several of you have mentioned the energy savings of public transit, and that is certainly important. The opportunity to save many thousands of gallons in individual households, that all adds up. Right now, over 4.2 billion gallons of gasoline per year is saved by Americans who take public transit today. That is 11 million gallons a day. That is 3 times the amount of oil that we import from a country like Kuwait. So it is a significant savings, and certainly more can be done.

Now, our transit systems are working hard to meet the challenges that arise with so many new customers. A recent survey we have done showed, though, that 85 percent were experiencing capacity problems on a portion of their system, and 39 percent actually report turning away customers. Now, that is not something we want to do, but you can only squeeze so many people on the bus or the train.

Typically, we might look to State and local resources to help us along, but we are finding that the States are seeing declines in their own motor fuel taxes, which often are used for transit. We are seeing the States are seeing declines in things like mortgage transfer taxes. Local governments are seeing declines in property taxes as housing values fall. And so there simply is not that local or State revenue. In fact, over 58 percent of our members responded by saying that their State and local revenue was either declining or, at best, being held even this year compared to last year.

It brings us to the need for additional assistance at the Federal level. We certainly believe that we need both short-term and long-term investment. I want to heartily endorse the comments about we have got to save the Highway Trust Fund first, and then we need to move into getting additional revenue for public transit. We strongly support Senator Clinton's bill. We believe that that will help transit systems to meet their fuel bills, to avoid fare increases and, worse, service cuts. But we also are interested in money that could buy additional buses or allow us to speed up projects that could happen sooner. And Senator Reid had sponsored the Reid substitute during the energy bill of a few weeks back, and so we think that combining Senator Clinton's ideas with those of the Reid substitute could make money available for the immediate problem, but as well as getting additional equipment.

We look forward to working with the Committee on how best to do this. It is certainly an irony that, at a time when transit ridership is at its peak, 35 percent of our members are in the process of cutting service. Americans cannot use what they do not have. If we are forced to cut back with the service, then they simply will not have a choice. They will be further held hostage at high oil prices, and I am sure that is not something that anyone wishes.

I know I am over my time limit, so let me just wrap up by saying thank you, Mr. Chairman, Mr. Shelby, all the Members of the Committee. We look forward to working with you as you wrestle with these important problems.

Thank you very much.

Senator CASEY. Thanks so much.

In the interest of time, I will do introductions of all our witnesses, so if there are Members that may have to leave before the introductions—or I should say after the introductions. But, Senator Dole, I know that in addition to the introductory comments for each witness, I know that you wanted to introduce Mr. Parker, Keith Parker. Is that correct?

Senator DOLE. Yes. Thank you. I am pleased indeed to introduce Keith Parker, who is Director of Public Transit for the city of Charlotte and the Chief Executive Officer of the Charlotte Area Transit System, the CATS system. CATS is one of the fastest-growing transit systems in the country, with approximately 1,200 employees, direct and contracted, and with an annual budget exceeding $131 million. CATS provides about 70,000 passenger trips per day on buses, paratransit vans for citizens with disabilities, and linked light rail.

Keith arrived in Charlotte in 2000, serving as chief operating officer and deputy director for CATS. In 2004, he was appointed assistant city manager for the city of Charlotte, focusing on community safety and corporate communications. Prior to his arrival in Charlotte, Keith was the chief executive officer for the Clark County Transit Authority in Vancouver, Washington. He also served as assistant general manager for the Greater Richmond Transit Company in Richmond, Virginia.

Keith has displayed a strong commitment to all the communities in which he has worked. He served as the fundraising chair for the city of Charlotte's Arts and Science Council Campaign and most recently served as the public service fundraising chair for the United Way. And I hope you were very good to the Red Cross during those days. He is on the board of directors for Partners in Out-of-School Time—it is called POST—and 100 Black Men of Charlotte.

Keith earned a bachelor's degree in political science and a master's degree in urban and regional planning from Virginia Commonwealth University. He also earned a master's degree in business administration from the University of Richmond. He is a graduate of the Senior Executive Leadership Institute through the University of Virginia and received certification from the American Institute of Certified Planners. In 2004, Keith was recognized as a Forty Under 40 Award winner in the Charlotte Business Journal as one of the region's most promising young leaders.

So, Keith, thank you very much for being here today. We greatly appreciate your time and all the great work that you are doing in Charlotte.

Senator CASEY. Thank you, Senator.

Next we have Andy Darrell, who is the Vice President of the Environmental Defense Fund, where he works as the Director of the New York Region and as the National Vice President of EDF's Living Cities program. He serves on New York Mayor Michael

Bloomberg's Sustainability Advisory Board. We are very pleased to have him with us today.

In addition to Mr. Darrell, we have Dorothy Dugger, who is the General Manager of the Bay Area Rapid Transit, or BART, system. She was elected to be BART's first female chief last year where she previously served as BART's Deputy General Manager. Prior to her work with the Bay Area Rapid Transit, Ms. Dugger spent a decade at the Port Authority of New York and New Jersey. We are happy to welcome her here today.

From my home State of Pennsylvania, Dave Kilmer, who is from the Red Rose Transit Authority in Lancaster, Pennsylvania. Dave has been a champion for small and medium-sized transit agencies, both in the Commonwealth of Pennsylvania and across the country. As General Manager of Red Rose Transit, a lot of the challenges he faces are a microcosm of the challenges confronting transit authorities across the country. So we are happy for his work in Pennsylvania and Lancaster County.

And last, but not least, Rob Puentes, a Fellow at the Brookings Institution Metropolitan Policy Program. Mr. Puentes is a leading author who has studied many transportation and land-use issues, published many papers, and testified frequently before Congress on these issues.

So with all of those introductions, we will turn to Mr. Darrell for his testimony right now. Thank you.

**STATEMENT OF ANDREW H. DARRELL, VICE PRESIDENT, ENVIRONMENTAL DEFENSE FUND**

Mr. DARRELL. Thank you, Chairman Casey and Ranking Member Shelby and Members of the Committee, for the opportunity to speak with you today. I am proud that my comments today are also endorsed by the Environmental and Energy Study Institute, the Southern Environmental Law Center, and the American Planning Association.

It is no secret that over the past year, Americans have felt a powerful financial wallop from rising gas prices. Transportation is the second largest expense for the average American household, second only to shelter—and, in fact, ahead of food.

As a result of the high gas prices, yes, Americans are driving less. According to the Federal Highway Administration, the past year has brought the steepest decline in vehicle miles traveled across the country since the data was first recorded in 1942.

Now, some of this shift means less travel. But Americans, as we have heard today, are also turning to transit like never before. This map that I have attached to the testimony that I handed in to all of you shows the—each green dot on this map shows a community across the country with a rise in transit use. And what is extraordinary to me about this map—and I live in New York City where you sort of expect people to use transit. What is extraordinary to me about this map is how spread out across the country these green dots are.

Let me just give you a few examples of the rise in transit use: Southern Florida, a 42-percent rise in commuter rail use; Charlotte, a 34-percent jump in transit ridership; Minneapolis, 20 percent; Caspar, Wyoming, 23 percent; Boise City, 40 percent; Omaha, 8 percent; Denton County, outside of Dallas, 53 percent. In my home town of New York City, we have 300,000 more subway trips every day.

So these trends are revealing sort of a basic truth: Americans are looking for an affordable and a sustainable way to get to work. And the question is: Are our transit networks, is our Government able and prepared to meet that demand? At a time when Americans are turning to transit, can we embrace that demand?

So far, the answer is that our transit networks are trying really hard. They are innovating, but they are struggling. Let me give you some examples of budget gaps that we are seeing in transit networks around the country: Minneapolis, a $15 million gap; Nashville, a $3 million gap; Charlotte, $4 million; Southern Florida, $18 million; Denver, $19 million; Seattle, $70 million. And I cannot even tell you about the many billion dollars of capital gaps we have in New York City.

To respond to that demand, what are transit networks doing? There is an extraordinary amount of innovation going on in transit across the country, especially in communities that we do not automatically think of as transit centers.

In Charlotte, North Carolina, a new light rail system opened last November with projected ridership, I believe, around 9,000. As reported in the local papers there, by April ridership had reached, I believe, 18,000, surpassing projections for the year 2025.

In Kansas City, Missouri, the new bus rapid transit network has cut trip times by 25 percent. It is not surprising that with a system like that, you are seeing ridership increase.

In communities like Maplewood, New Jersey, and Hialeah, Florida, van networks pick up suburban commuters on their local streets and drop them off at the train station so that commuters can leave their cars at home and still get to work.

In Alabama, the city of Montgomery piloted three new bus routes in 2000. Today that system has expanded to 16 routes and services almost 400 percent more trips.

And in Chattanooga, Tennessee, ridership is up 14 percent this year as citizens can choose from really an extraordinary variety of transit choices: commuter bus routes with Wi-Fi, park-and-ride lots, free downtown shuttle buses with emissions-free electric engines, on-demand van pool servicing rural parts of Hamilton County.

So innovations like these make transit a truly practical alternative to high gas prices. And from the point of view of the environment, where I come from professionally, from the point of view of public health, air quality, climate change, this turn to transit is a good thing. This is what the environmental community wants to see happening, and Americans are doing it right now, are asking for the service to be able to do the right thing on behalf of the environment.

The transportation sector accounts for 30 percent of the Nation's greenhouse gas emissions, and in many large metropolitan areas, over 70 percent of the added air cancer risk comes from traffic. Exposure to traffic pollution is linked to an extraordinarily wide range of diseases, from asthma attacks to heart diseases, stunted childhood lung development, cancer, even, we are seeing in studies now, lowered IQ in children.

So expanding transit is, of course, also essential to reducing dependence on foreign oil. Two-thirds of oil in the United States goes to transportation, with the largest share consumed by cars and trucks. Overall, a typical public transit rider, somebody who has access to a transit alternative in their community, consumes on average one-half of the oil consumed by someone who does not have that alternative, mainly because they can choose to integrate transit into their daily routines.

We are really seeking help in four areas for transit systems across the country: one, emergency grants to expand transit service right now to meet rising demand; support for the innovation that we are seeing in communities across the country, especially in more rural and suburban communities; help so that transit systems can get the most out of their existing networks by increasing efficiency, upgrading things like signalization that are not the most exciting things to talk about but are fundamentally important to be able to move more buses and more trains through a system; helping them invest in clean fuel buses, hybrid buses to cut the cost of the diesel in their fleets; and then, of course, helping communities expand access to transit, for example, by making transit easier to reach from residential areas through these local van pools and encouraging residential development near transit hubs.

I just want to close by noting that, in addition to this emergency help, of course, we also need the long-term strategy. And I am so encouraged to hear the comments that have been made today about the upcoming transportation bill and the opportunity that is there between the climate bill and the transportation bill to frame a transportation policy for the country that embraces this demand for transit that we are seeing across the country.

Thank you very much.

Senator CASEY. Thank you very much.

Ms. Dugger.

**STATEMENT OF DOROTHY W. DUGGER, GENERAL MANAGER, SAN FRANCISCO BAY AREA RAPID TRANSIT DISTRICT**

Ms. DUGGER. Thank you, Chairman Casey, Ranking Member Shelby, Members of the Committee, for the opportunity to testify on this timely topic.

While California is certainly no stranger to the vulnerability of energy markets and rising energy prices, this past year has pushed the State with the Nation's highest gas prices to even new heights. Since we began service at BART 36 years ago this week, BART has always played an important role in the mobility of the Bay Area. But in today's context, our service is becoming an even more attractive transportation option for people who are trying to combat rising gas prices.

With over 360,000 average weekday riders, or more than 104 customers served each year, our ridership, too, has seen the same growth that you have heard about this morning—5.5 percent. This year for the second consecutive year, that is about double our normal rate of growth. In July, we saw 9-percent growth in our off-peak passenger ridership, and on our newest service to San Francisco International Airport, 37-percent growth. Thank you, Senator Shelby, for your leadership in helping us deliver that important and well-used addition to our system. Clearly, more people are choosing transit and not just to go to work.

During this past year, however, we have also seen increases in our energy costs, about 16 percent this year. BART is 100-percent electric with two-thirds of our power provided by renewable, hydroelectric power. So we are not quite seeing the shock of diesel prices that some of my colleagues do, but, nonetheless, our costs are increasing as well.

We use approximately 400 million kilowatt hours annually to power our trains and stations. About 75 percent of that is for train operations, which is enough to power 11,000 homes for a year.

In order to reduce our own energy costs, BART is partnering with our local utility, Pacific Gas and Electric, and has identified eight strategies to reduce energy consumption by retrofitting our existing fleet of rail cars. I would like to highlight just one of these technologies this morning and ask that the full report be submitted for the record.

Our fleet is equipped with regenerative braking, a design that redirects electricity generated from the vehicle braking back into the third rail for immediate use by a nearby or passing train. The new technology that we have looked at would install a storage device onboard each vehicle that would store the electricity generated from that braking for use in its own future propulsion.

If these ultra-capacitors were installed on all of our 669 rail cars, we estimate that we could reduce our energy consumption by about 25 percent. That translates into a savings of about $8 million a year, almost 83 million kilowatt hours.

Retrofitting our entire fleet is not inexpensive. It would cost about $94 million, an amount that would be realized, however, through energy savings over about 11 to 12 years. The resulting energy and emissions benefits, however, would be immediate.

If we were able to fund all of the efficiency retrofits that are identified in the report I have submitted, we would save almost 130 million kilowatt hours of electricity each year or 43 percent of the power currently necessary to run our service.

These technologies are not unique to our system. They could be applied on a national level in a relatively short period of time. But it will take a strong Federal partner and increased investment to make this possible.

However, the largest contribution that BART, and other transit operators around the country, as we have heard this morning, can make to reducing our dependence on foreign oil is to provide good transit service—service that is safe, reliable, convenient, and frequent enough to serve the growing numbers of people who are seeking an alternative to driving.

Eighty percent of our customers at BART tell us they have another way to make the trip that they are choosing to make on BART, and most of those say that other mode is an automobile. With an average trip length of 14 miles and a 96-percent on-time performance rating, I believe we are providing an attractive alternative to driving, and I think our customers are telling us that. In fact, during rush hour, our customers are traveling at the equivalent of 249 miles per gallon. And according to a recent U.S. PIRG study, riders on our system saved about $522 million in fuel costs by riding BART and avoided consuming almost 200 million gallons of gas.

As you have heard from Mr. Millar and others, we are not unique. Transit agencies across the country are facing record ridership increases as people are driving less due to high gas prices. This trend will continue, and coupled with an aging and growing population, we and other large rail operators will soon be facing a capacity crisis. In fact, today we are removing seats from our cars to make more room for standees during the peak periods. And successful transit-oriented development, another important energy efficiency and resource preservation strategy, is also creating new demand for service. The future success of this model will depend on transit agencies being able to serve these developments with robust, reliable service.

If transit is to continue to be a viable alternative to driving and meet our country's growing mobility demands, we must address our core capacity needs. Like the energy efficiency technologies I mentioned, the return on investment for expanding our ridership is significant and quantifiable.

Mr. Chairman, the question of whether people will get out of their cars and ride transit I think has been answered. The new question is: Will we be able to meet this growing demand?

I look forward to working with this Committee, APTA, and our industry partners to achieve the funding levels necessary to meet this challenge, both through current legislative efforts that are underway as well as the coming authorization bill.

Thank you very much. I am happy to take questions.

Senator CASEY. Thank you very much.

Mr. Parker.

## STATEMENT OF KEITH PARKER, CHIEF EXECUTIVE OFFICER, CHARLOTTE AREA TRANSIT SYSTEM

Mr. PARKER. Thank you. Let me first thank Senator Dole for the gracious introduction and to again personally thank her for the tremendous advocacy she has had for the Charlotte Area Transit System, along with Senator Burr, and their staffs, in helping us bring real transportation options to the Charlotte region. On behalf of the Charlotte Area Transit System, thank you very much.

I have to say, sitting at this table, it is a tremendous day. As a father of two girls to sit at a table with Senator Clinton, next to Ms. Dugger, and be introduced by Senator Dole, wow, what a great story for me to go home and tell my daughters.

But let me thank you, Mr. Chairman and Ranking Member and other Members of the Committee, thank you for giving us this opportunity to offer some comments about the transit phenomenon that is going on in Charlotte.

According to a recent survey, Charlotte is the best place to live in America. Another survey indicates that Charlotte has the best housing market in the United States, and yet another indicates that we have the lowest downtown vacancy rate of any of the other cities of comparable size in the country. Not surprisingly, this type of success brings many people to want to join us and become residents of the Charlotte area. In fact, we are expecting about a 50-percent increase in our population over the next two decades—about the equivalent of bringing the entire city of Pittsburgh and dropping them within our borders.

Now, unfortunately, Pittsburgh will not be bringing its roads with them when they come to join Charlotte. To deal with our growth, the visionary citizens of Mecklenburg County about a decade ago decided to pass a half-a-percent sales tax to expand mass transit in the area. The investment has proven to be quite wise. During that time our ridership has increased about 100 percent, and in the past year we have seen ridership increase about 41 percent in comparing July 2007 to July 2008. Public transit users in Mecklenburg County are saving about 26,000 gallons of fuel a day by using mass transit.

To deal with our ridership growth, of course, we have to expand our capacity. We are increasing the number of buses on the road, trying to make a big commitment to hybrid vehicles. We would like to order only hybrids, but, of course, they have about a 50-percent premium on them. And like most transit systems, we have to make the tough balancing choice of more green technology versus meeting the immediate demands of an ever increasing ridership public.

While we are very proud of the overall success of the bus system, the segment that has received the greatest attention in Charlotte has been the introduction of LYNX Light Rail. Again, we thank Senator Dole for her advocacy on that project. This new transportation option has truly transformed the city of Charlotte and the way people get around. Since opening late last year, it has become an icon in the our city, with one of our local newspapers writing in a headline, "Is it the year 2025 yet?"—wanting to know would we actually reach our year 2025 ridership goals in our first year of actual service.

We have seen tremendous ridership, and we have seen people now taking LYNX Light Rail not just to get from place to place but as a part of the overall experience of their trip. When they go to the circus, when they go to the basketball game, when they take their kids shopping, they add the LYNX trip because they just enjoy it more. It has become truly a part of the whole overall quality of life for the city of Charlotte.

The success has made Charlotte a real hot spot in the minds of public transit users around the country. In about 6 months, we have seen visitors from all over the country and beyond come out to see Charlotte, to hear about the $1.8 billion in new investment that has emerged around the transit line. People from places like Tampa, Atlanta; Mobile, Alabama, which sent a group of over 110 citizens recently, to come out and share with the experiences we are seeing in Charlotte.

They also like to hear about the fact that we are raising tens of millions of dollars in new personal property tax revenues that are being generated by these new developments. Those property taxes are being used to hire new police officers, new school teachers, and new firefighters.

The thing I like to talk to our visitors about mostly, though, is the ability of light rail to truly transform neighborhoods. In the city of Charlotte, we do a quality-of-life study every other year. The most recent one was just completed in the past 3 weeks. In 2006, they looked at about 173 different neighborhoods. And they look at everything from crime to dropout to teenage pregnancy to home values. And one of the neighborhoods that rated the lowest was the Wilmore neighborhood. In the 2 years since the 2006 study, the Wilmore neighborhood has seen dramatic decreases in crime, has seen its teenage pregnancy rate plummet. And these are people of modest incomes. They have seen people whose houses were worth $92,000 just 2 years ago, their average home value is now at $195,000. And it just so happens that the Wilmore neighborhood is on the LYNX Light Rail line. Charlotte's investment in light rail has truly transformed the neighborhoods that surround these light rail lines.

In fact, if you look at all those 173 neighborhoods again and you look at the core area where most of Charlotte's growth has occurred, only three other neighborhoods have shown real growth in terms of their stability and so forth of the Charlotte neighborhoods looked at. All three of those neighborhoods just happen to be on the light rail line.

Public transportation truly is about getting people from one place to another, but also it is about transforming communities. It is about making investments and watching those investments pay off.

Thank you for your time. Again, thank you, Senator Dole, and we can entertain any questions.

Senator CASEY. Thank you.

Mr. Kilmer.

**STATEMENT OF DAVID W. KILMER, EXECUTIVE DIRECTOR, RED ROSE TRANSIT AUTHORITY, AND CO–LEADER, THE 100 BUS COALITION**

Mr. KILMER. Good morning, Chairman Casey, Minority Ranking Member Shelby, and Members of the Committee. I appreciate the opportunity to discuss this issue with you today.

As you know, I am one of the small systems in the country. We average 36 peak buses and carry 8,000 people a day, which is kind of small in comparison to my colleagues at the table, but at the same time, we have the same issues. Fuel costs for us went up 67 percent this year, from $1.92 a gallon to $3.24 a gallon for diesel fuel. That added $500,000 to our budget, which was huge for a small system like us.

At the same time, we experienced record ridership gains that we have not seen in over 20 years. We had a ridership increase of 4.4 percent, which is huge for us. And if it was not for the passage of the technical corrections bill this year, which I would be remiss if I did not thank this Committee for your work in doing that, we would have had to cut service. But, instead, we actually expanded service. We added night and later-evening service on a lot of our routes to try to meet the need for the residents of Lancaster County.

One of the main issues facing small systems is the ability to replace old vehicles. Many of us are operating vehicles that are well beyond their useful life, and as they get older, they are more costly to maintain. And whether I am talking to my colleagues in Lubbock, Texas; Lancaster, California; Oklahoma City; Martin County, Florida; or even Winston-Salem, North Carolina, all of us are looking at ways to get new buses, and particularly hybrid buses. It has been shown that in Seattle Metro they save 40 percent on their energy costs by operating hybrid vehicles. If Red Rose operated all hybrids right now, I could save about 150,000 gallons of diesel fuel a year. And for the members of the 100 Bus Coalition, which are about 150 systems, that could translate into about 25 million gallons of fuel just for us small systems in savings a year by the use of hybrid vehicles.

Another big issue facing us is facility improvements. We are operating in a facility that is now about 30 years old. Many of the operating systems are antiquated, and they are not very energy efficient. And it keeps our costs increasing trying to maintain the facility. Right now, we have money to do the design and engineering to try to renovate our facility, and some of the things that we are looking at, just because it makes good business sense, is looking at ground source heat to replace a conventional oil-operated heater, coupled with putting solar panels on the roofs of our maintenance and storage buildings; plus the use of skylights in our storage areas, maintenance areas, and office so we can reduce our lighting needs and reduce our electric costs.

Also, one of my pet things is to include a waste oil burner. We generate about half of what we use in heating oil just by the normal oil changes of our buses. And while we are getting paid 50 cents a gallon for someone to remove it just because of the high cost of oil, on the other hand, I am paying $3.60 for heating oil. So if you do the math, we could have a huge savings if we were able to do some of these energy-efficient things.

But they all need to be coupled together because, taken by themselves, they cannot provide all of our needs. And we estimate that we could reduce the energy consumption of our facility by over 60 percent if we had the money to do these measures.

This is common to a lot of the small systems. All of us are operating old facilities that are in need of renovations. And if we can make these improvements, we could have an immediate impact on the amount of energy that is being consumed by our transit systems.

Right now, with our current funding levels, it would take me 4 to 5 years to save up enough money to do our facility renovations, and I would not be able to do anything with our buses. I would have to save up even more money later on to replace our old buses with hybrid buses.

So on behalf of Red Rose and the 100 Bus Coalition, I want to thank the Committee for considering our issues, and we look forward to working with you in the future on this issue and with the authorization for a new transportation bill.

Senator CASEY. Thanks very much.

Mr. Puentes.

**STATEMENT OF ROBERT PUENTES, FELLOW, AND DIRECTOR, METROPOLITAN INFRASTRUCTURE INITIATIVE, BROOKINGS INSTITUTION**

Mr. PUENTES. Thank you very much, Senator Casey, Senator Shelby, members of the Committee. Thank you very much for having me here today.

Mr. Chairman, I support the transit provisions in the substitute to the energy bill, as they are consistent with Brookings' research and the policy work on transportation reform we have already done and for the many excellent reasons that we have heard articulated here today. Yet I believe there really is much more we have to do. The Nation needs a fundamentally new approach to transportation policy, again, for all the reasons we have articulated here today.

The broader system in the U.S. is no longer aligned with the big economic, energy, and environmental challenges facing the country. We have already discussed the perfect storm of energy and environmental sustainability that is looming, along with the high consumer anxiety about the escalating costs of transportation-related items such as gasoline.

With the U.S. set to add another 120 million people by 2050, these energy prices are likely to intensify. As a result of this growth, America will require an additional 213 billion square feet of homes, retail facilities, office buildings, and other built space. How and where we accommodate that growth carries far-reaching implications for the energy security of our country, our economic stability, and the health of our environment.

Unfortunately, as a program with its roots in the middle of the last century, the Federal Surface Transportation Program is outdated and out of step with the energy and environmental constraints of our time. For example, Federal transportation dollars continue to be distributed to its grantees based on archaic funding and distributional formulas. There is no reward for reducing the demand for driving, nor overall spending. In fact, at the same time Americans are seeking to drive less, Federal formulas actually reward consumption and penalize conservation.

Yet we are already seeing transformations of dramatic scale and complexity when it comes to how our transportation system is operating and how Americans are traveling. We know that most people cannot stop traveling, nor should they, but some can change how they travel. As we have heard, after years and years of steady increases, we have recently experienced the largest drops in driving that the Nation has ever seen, and without a doubt, some of this decrease is attributable to the skyrocketing gas prices which, although they have fallen in the last 2 months, are still one dollar per gallon higher than this time last year. Americans now consume 31 million fewer gallons of gasoline each day in 2008 than they did in 2005, and I agree that these are good trends.

But partly as a result, transit ridership is booming, as we have already talked about, and Amtrak ridership this past July was at its highest in any single month in its history. There is no doubt, again, that these trends are positive for our national quest for energy independence.

Unfortunately, the reality is that the availability and accessibility of public transportation across the country's 100 largest metro areas is seriously lacking. According to the American Housing Survey, only 55 percent of Americans reported that transit is even available to them. This absence of metropolitan travel options means tens of millions of Americans are tethered to their cars for their daily travel needs. Many simply have no choice but to spend $3, $4, or more for a gallon of gas.

At the convergence of these trends is the realization that a substantial market exists for a new form of walkable, mixed-use urban development around transit stops. We have already heard about the diverse real estate markets today in places like northern New Jersey, Charlotte, also Salt Lake City, Denver, Chattanooga, and many, many others.

Transit-oriented development has the potential to lower household transportation expenses, reduce environmental and energy impacts, and provide real alternatives to traffic congestion. Residents who live in transit-oriented housing typically use transit 2 to 5 times more than other commuters in the region.

However, many of these development benefits are not being realized. Such development requires synergy among many different uses and functions and almost always involves more complexity, greater uncertainty, a tighter regulatory environment, and higher costs than other forms of development.

The Federal Government in this regard can play a critical role in supporting the planning of such projects and corridors in order to catalyze the nearly $75 billion in public dollars that has been invested in rail transit over the past 11 years.

Mr. Chairman, I believe Federal policy can and should play a powerful role in helping metropolitan areas—and so the Nation—reduce energy consumption through targeted and prioritized investments in public transit and support of transit-oriented development. The cross-boundary challenges justify a more decisive Federal policy that helps metropolitan areas promote energy- and location-efficient development.

As Senator Clinton mentioned, we need short- and long-term strategies. In the short term, the provisions for energy funding and the program to boost the energy efficiency of transit systems are consistent with this overriding frame. The proposed Transit-Oriented Development Corridors Grant Program also provides an empowering model and a competitive process that supports innovative ideas for growing differently. Over the long term, the upcoming reconsideration of the surface transportation law provides the perfect opportunity for re-envisioning transportation policy, as my colleagues have already mentioned.

The Federal Government should establish a clear vision for transportation that includes energy and climate change concerns and levels the playing field between the modes so energy-efficient investments can become more feasible.

A national infrastructure bank, which has been championed by this Committee, is an important window through which the Federal Government can partner with States, metropolitan areas, and localities to implement this bold national vision. But, in addition, the Federal transportation formulas should be overhauled so funds are not distributed based on factors that potentially increase energy consumption and greenhouse gas emissions. And to take full advantage of development opportunities around transit stops, the Federal Government must correct the cost-effectiveness index that determines which projects receive New Starts funding. The energy, environmental, and agglomeration benefits that accrue to these projects should be sufficiently weighted.

As Senator Dole mentioned, we need to evaluate transit projects better. Addressing our Nation's energy problems will ultimately require innovation and creativity to link fragmented transportation, housing, energy, and environmental policies beyond anything that we have considered so far. So a sustainability challenge should be issued to unleash the innovation that is bubbling up in cities and metropolitan areas all across the country.

Mr. Chairman, in the end my message is simple: a sure-fire way of reducing our dependence on Federal Government oil is to lower consumer demand. And the best way to lower demand is to build more sensible communities that give families greater transportation options.

I look forward to this Committee's ongoing leadership, and I want to thank you again for the opportunity to appear before you today.

Senator CASEY. Thank you very much. We are going to move to questions now, and I will take just a portion of my time, and I want to get to my colleagues, and I might come back.

In the interest of time, but also in the interest of repetition, which is important in Washington—to get your point across, you have to say the same thing a lot. I am just going to focus my initial part of questioning on the three individuals who are actually running a system right now, to focus very immediately in kind of a lightning round fashion—that is, for Mr. Kilmer, Mr. Parker, and Ms. Dugger—on what your immediate needs are right now in terms of what the Federal Government can do. Maybe give me your top two, if you can. We can get into longer explanations later, but I think it is important for us to hear kind of the priority list and then we can go from there. But in any order, maybe Mr. Kilmer. I know you spoke earlier of both hybrid buses as a need as well as facility improvements, but do you want to—I do not want to take your two. You identify them.

Mr. KILMER. You just said my two, in that order. Hybrid buses and facility needs I think will have the most immediate impact on saving oil and produce the best results across the country, particularly for the smaller systems.

Senator CASEY. How much would one hybrid bus cost you?

Mr. KILMER. Right now the costs are running about $500,000, and that is versus $320,000 for a conventional diesel-powered bus. We have a tough time trying to balance, I think what my colleague said, whether to buy three diesel buses and replace older ones or buy two hybrid buses, because running older buses is very costly.

Senator CASEY. We are getting some kind of interference here. We will wait until that stops.

Mr. KILMER. So, yes, we all want hybrids, but the increased costs make it very difficult for smaller systems to do that balancing act of the need to replace old buses and the need to get hybrids.

Senator CASEY. Thank you.

Mr. Parker.

Mr. PARKER. As was mentioned earlier, we are approaching our 2025 estimates in terms of ridership now, and as a result of that, we are reaching capacity on our light rail line in less than a year. What we are finding is about 8:15 in the morning, our largest park-and-ride lots are completely full already. We are turning away customers.

So one of the immediate needs for us would be the ability to expand. We need more property to either build more surface parking or to build upwards on our parking decks for the light rail line.

Senator CASEY. So, in essence, land.

Mr. PARKER. Yes. When we built the system, we built them within FTA guidelines, and as a result of that, we essentially built the system too small. That is the best way to describe it.

The other immediate need is more rail cars, and we are trying to place orders, but, of course, rail cars are in the neighborhood of 4 million bucks apiece. And we need probably another four to seven so we can run double-car trains at all times versus how we have to single and double now and then. And I apologize for the jargon.

Senator CASEY. No; that is OK. So just between your two systems, different States, different circumstances, there is a need for cars of one kind or another. That helps to keep us focused here.

Mr. PARKER. Yes.

Senator CASEY. Ms. Dugger.

Ms. DUGGER. I will make it a threesome: cars. Capacity is certainly our most immediate and longer-term challenge to extract the maximum efficiency out of the public investment that is the built system we have today. I think we can, with minimal investment in increasing the capacity of that system as opposed to building new expansions outward, we can even get more value out of that original public investment. And it is probably the most effective way that we can provide additional capacity in throughput on the existing system. As I said, we are taking seats out of our cars today to create more room for customers. A redesigned vehicle will give us some capacity opportunities, as well as energy efficiency opportunities in operating that fleet.

Senator CASEY. And you have got 100 percent electric.

Ms. DUGGER. That is correct.

Senator CASEY. And it is all hydro power.

Ms. DUGGER. About two-thirds of our power is supplied hydro today.

Senator CASEY. Interesting. I am going to move so we can keep our time here. Senator Corker.

Senator CORKER. Yes, sir, Mr. Chairman, thank you. And I appreciate the testimony of all of you, and thank you for mentioning Chattanooga so many times. I was mayor there from 2001 to 2005, and we really are proud of the use of electric buses in our downtown area shuttle service, the Wi-Fi, all the things we have done to really create a live-work-play environment. And while it is certainly not like some of the Northeastern cities that are more dense, we have come a long ways. It sounds like Charlotte is doing—is probably ahead of us, but doing much of the same.

I also funded, if you will, the public system there, and each year there were needs, and it certainly was interesting to hear of the diverse needs here at the table, much of it about capital. And, you know, I guess the thing that drove us in our city to do what we have done successfully was the words "sustainable development." I know that word is kind of not as much of a buzz word today, but I want to say that Senator Menendez mentioned something that I, too, was very excited about after 9/11, and that was a focus, hopefully, on trains being a mode of transportation throughout this country. It would be another way for this country to feel more secure. Our community has pursued heavily a mag-lev operation from Chattanooga to Atlanta, hopefully on up through the Midwest or Northeast.

So my point is I really do support the efforts that each of you are involved in. I understanding that communities are different, and sometimes it is that one passenger, if you will, the most expensive passenger at the end of a long run that depends most heavily on mass transportation, otherwise could not make a living. And I know we have to make choices as to services. You are constantly doing that in your own jobs.

Here is the question I would have. We are constantly looking—you heard us talking about the Highway Trust Fund and the Mass Transit, and there are other choices that we are constantly having to make here. We talk each year about Amtrak and whether it should be making a profit or not.

Is there a norm, if you will, that each of you look to as a system, if you will, that is running in a certain way that—or norms that you look to to really cause public transportation to be even more sustainability, if you will? I know that most operate with a subsidy. Most of you have capital needs. Is there something that we as policymakers should be looking to as a norm, as something we should sort of aspire to in mass transit to make it more sustainable in our country? Mr. Millar, I would appreciate you grabbing the mike, and since you represent the association, maybe you can best share that.

Mr. MILLAR. Thank you, Senator. We encourage our members in their communities to set their goals. As so many Senators have said today, as the testimony has shown, different communities have different needs. For some, the transit system is a basic lifeline, and that is the most important aspect. For others, it is to carry high volumes of urban commuters. And there are so many other ways to go.

So we encourage our members to set goals, then develop performance measures out of that. We do not find that there is a single norm that is really applicable to the systems across the country. But it is important that each system set its goals, set its performance measures so it can see how it is doing against its goals, and then report back to the public on how they are doing.

Senator CORKER. I know that each of you as you grow, it actually puts financial pressures on because you have capital needs, as you have mentioned. Are there systems in other places around the world that have been able to operate at no subsidy levels? Or is that just something we need to know is going to exist into the future?

Mr. MILLAR. In Western societies and industrialized societies, investment, as we would call it—you might call it "subsidy"—in public transit is the norm. In fact, for that government investment, you are actually buying things. You are buying cleaner air. You are buying more energy security. You are buying less traffic congestion. You are getting something back. The difficulty in transit is the costs all show up on our budgets, but the benefits show up throughout the society.

Now, there are places that have done more with recouping their costs through capturing some of these benefits directly for transit. For example, I was in Hong Kong a couple years ago. We always hear that the Far Eastern systems often run without subsidy. But what I learned was that instead of getting a subsidy from the general coffers of the government, they have been given great freedom to develop the real estate around their stations; and so instead of what we might call a typical public subsidy, they get it by being allowed to harvest for the transit system what in this country would normally go to private investors as private profit.

I do not think that we are likely to be ready to make a big move in America to stop private profit. I certainly would not advocate that. So we have to be very careful when we look for models elsewhere in the world. But there are certainly many things that could be done, and many systems are working to increase their return. But we have to be very careful as we make these international comparisons.

Senator CORKER. Yes, sir.

Mr. PUENTES. If I can just quickly, the one example or one anecdote, particularly in Western Europe, is the way that they think about transit systems and the way, the data, and the analytics that they use to measure the quality of those investments. I think in this country, we have not really done a good job in collecting information and then making the case for the benefits of transit or other kinds of transportation investments by linking it to other areas. I think in Europe, particularly in the U.K., the benefit and cost analysis that they do for transit investments and other investments includes things like energy consumption, greenhouse gas emissions, equity concerns. It includes all those things that we know that transit and transportation is connected to. We just have not done a good job in this country in analyzing those investments so we can make prioritized injections where we need to.

Senator CORKER. I think that is really an interesting comment. In most of the discussion around mass transit, there are anecdotal reasons given to do it, and that, you know, you just hit on the fact we do not actually look at it systemically and see what the true costs are. And I think that is—or what the true benefits are, which lessen the cost. I think that is a very interesting comment. You know, being—I know building, for instance, lots of new garages in a downtown area, parking garages, there is no return. I mean it costs a fortune. And yet, you know, public transportation can keep that from having to occur, if you will.

So I would say just in general to the association that it seems to me as we move ahead and look more at public transportation into the future, it would be very beneficial if some form of systemic looking at public benefits could be discussed—and I am talking about public benefits that actually public citizens typically would have to pay. I think that would be not just to society, if you will, but those public benefits that otherwise the government would have, I think that would be very useful to all of us as policymakers and I think very useful to all of you who are on the ground.

Mr. MILLAR. We would be very pleased to supply you with information, and with the permission of the Chair, perhaps I would distribute it to the Committee as well as to Senator Corker in particular.

Senator CORKER. Thank you, Mr. Chairman, and I thank all of you for your testimony.

Senator CASEY. Thank you, Senator Corker.

Senator Carper.

Senator CARPER. Well, this is a pretty good hearing, isn't it? We appreciate very much you all being here and sharing with us your experiences and the leadership that you are providing in communities across our country.

I listened to Mr. Millar talk about the advantage that accrues some of the operators of mass transit outside of this country and how they use real estate. I used to be on the Amtrak Board, and we found ways within Amtrak to use our right-of-way as an asset that we could sell or lease, for example, for fiberoptic. And I always thought it made sense to try to wield electricity, especially in the Northeast corridor between Washington and Boston, there is major real estate development up at 30th Street Station in Philadelphia, a beautiful building. And we are about to undertake a major redevelopment of the Wilmington train station, which is right in the middle of our riverfront in Wilmington, Delaware. And it used to be sort of like the crown jewel of the riverfront, and today it is a little shoddy compared to everything else that has gone on there in the last 10 years. But they are some things that—some ways to use even the assets that the railroads especially—and that includes Amtrak—already enjoy.

Maybe a question to start off with Mr. Puentes and Mr. Darrell. I think maybe it was Mr. Parker from Charlotte, North Carolina—Mr. Parker mentioned in his testimony that his transit agency has ordered hybrid buses with funding from the Congestion Mitigation and Air Quality program. In the past, some States have chosen—I am told some States have chosen not to use their CMAQ funding, while at the same time we are seeing that there is a need for more funding for transit and for roads.

Let me just say, as we consider funding and providing additional funding for transit and for roads, are you aware of some States that may not be using all of their CMAQ funds. And, again, this would be for Mr. Puentes and Mr. Darrell. Are they leaving some money on the table from their CMAQ money?

Mr. DARRELL. I do not have figures with me today to share with you on that. I have heard anecdotally, as you have, that there are some cases that I know about, particularly examples from here or there. I also understand that sometimes the capital spending decision at the local front does not always match up in time and the right cycle with the availability of the Federal funds.

You know, I think the—I would be happy to look into that and see if we can provide you with the specific.

Senator CARPER. Would you please?

Mr. Puentes.

Mr. PUENTES. Thank you, Senator. Indeed, there are some States that have not spent down CMAQ funds. I think as the budget crises get tighter, we may see some movement there. But the interesting thing to consider when we think about CMAQ funding and some other programs is that there are certain States that take those CMAQ dollars and sub-allocate them directly down the metropolitan level. I think that many of us who believe that CMAQ is a program that has its roots really on the metropolitan level, and investments like you just talked about really are things that probably are best administered on the metropolitan level, on the local level.

So those places where we see those funds being sub-allocated to the metropolitan level, particularly in California, we see a much greater result in spending those dollars and spending it far greater on transit than other kinds of investments. So the interesting thing to look at is not just which States are or are not spending, but what the States do with those funds and how they are spent on the metropolitan level. I think we see some interesting diversion trends.

Senator CARPER. All right. Thank you.

Again, Mr. Darrell, I appreciate your willingness to respond additionally for the record. If you could do that, I would be grateful.

A second question I think for Mr. Kilmer, for Mr. Parker, and for Ms. Dugger. I am told the AARP recently found that more people are trying to walk and to use transit. About half the people who might want to walk or to use transit have no sidewalks or really a safe way to walk to transit stops. How does this impact your operations? Are your agencies including this in discussions that go on with respect to, say, street design? Does your DOT consider the impact on transit access of roads that are built without consideration for pedestrians?

Mr. PARKER. I can start, if that is OK.

Senator CARPER. Sure.

Mr. PARKER. Along with the city of Charlotte's big commitment to public transportation, we also saw the need to buildup the infrastructure around the train stations and around many of our bus stops. And so the short answer to your question is, yes, we have made that commitment because we recognize if people cannot walk to the bus station or the train station, there is really—that sort of defeats the purpose in trying to attract them as customers.

The other thing we have tried to do is make some smart choices in regards to some of the technology we use. We are purchasing almost all low-floor buses now, buses with a kneeling feature, so people who have difficulty walking, particularly seniors and others, can have easier access to the vehicles. On the light rail line, for example, that is also a low-floor car, which allows the customer, without having to walk up any steps, easy access onto the platforms and easy access onto the vehicles themselves.

So we are trying to do the small things to attract the new customer base. Traditionally, seniors do not ride transit in very high numbers. It has been one of the market areas over the last 5 years that in Charlotte we have been able to increase dramatically. And we think we have done that through increased marketing, for one, but also by making those, what seem to be relatively simple but real improvements to make the service easier to navigate and to access.

Senator CARPER. Before your two colleagues respond to the same question, just a real quick question. The hybrid buses that you all have been buying and the low-platform vehicles, are those made in America?

Mr. PARKER. Well, we are required that all buses need to meet "buy America" requirements, so yes.

Senator CARPER. All right. Thank you.

Ms. Dugger or Mr. Kilmer.

Ms. DUGGER. Yes, thank you very much, Senator. One of the places where we can have one of the most direct impacts on the issue of pedestrian walkability of access to our stations is in transit-oriented development projects where we are partnering with others and developing land that we actually control. And certainly pedestrian, bike access in that planning activity is an important consideration, and we, in fact, have established a hierarchy of access as we look at our station area planning activities with pedestrian and walking being at the top of that tiering.

In our area, our MPO has also been an active advocate and has provided particularly some of the flexible funding that we were just discussing to the counties and cities who are developing pretty comprehensive pedestrian and bike plans that are being knit together on a regional level. And they in some respects are in the better position in terms of control of the decisionmaking and funding activities.

So in terms of our priorities, we look first where we are an active partner, an owner of property, and, second, where we can be a partner in advocacy working with the communities that we serve.

Senator CARPER. All right. Thank you.

And maybe just very, very briefly, Mr. Kilmer. My time has expired.

Mr. KILMER. Sure. In Lancaster, it is very rural. In fact, we have one bus route that is 28 miles in one direction and probably 20 of that is a rural road with no sidewalks whatsoever. So as we try to place bus shelters and other amenities at some of those more heavily used stops, we try to incorporate sidewalks and other things so that people feel safe when they are waiting for a bus along a rural road. And we work very closely with our county MPO and with the townships locally to try to impress upon them the need for sidewalks for new developments.

Senator CARPER. Good. Thanks. Again, our thanks. This was a great hearing.

Mr. Chairman, thank you.

Senator CASEY. Thank you, Senator Carper.

Senator Menendez.

Senator MENENDEZ. Thank you, Mr. Chairman.

I would like to ask any one of you listening to the Secretary of Transportation's call to the Majority Leader for urgently filling $8 billion to the Highway Trust Fund, does anyone on the panel believe that the appropriate way to do that is to take the money from the Mass Transit account?

Mr. MILLAR. No, sir, we do not believe it should come from the Mass Transit account.

Senator MENENDEZ. The silence of the rest I will take as that you agree with Mr. Millar.

Mr. DARRELL. We certainly do.

Ms. DUGGER. Completely.

Senator MENENDEZ. All right. Thank you. Then here is our challenge. I say that a lot less in jest than in saying some of the challenges of what we have here. We have heard an excellent panel, excellent presentations. I am foursquare with all of you collectively in what you have said. And the difficulty is that we just have some of our colleagues who do not fully understand the dimensions of how beneficial this is.

So I would like to go to the next step, which is say let us say we can get over that hurdle for argument's sake. Mr. Millar, there are different views as to how we pursue investments in mass transit. You have Senator Clinton's legislation, which is obviously a direct investment. You have some who are suggesting that maybe competitive grants that deal with making more mass transit more energy efficient is a more appropriate way. If you had the ability to prioritize, how would you prioritize it?

Mr. MILLAR. Let me share some information, and perhaps it goes to the Chairman's question earlier as well. In the survey we just conducted, when we asked our members what was the immediate need, 56 percent said it was to purchase fuel, that they were really having difficulty, diesel fuel prices up 166 percent for them. Another 20 percent, as the panelists indicated to you, said also the immediate need was for new transit vehicles, and then the rest of it was split different ways.

The reason I said in my testimony that I think we need to take the best of Senator Clinton's approach and the work that had been done by Majority Leader Reid in the Reid substitute this summer was that both things are necessary. If we buy capital equipment and do not have money to operate the equipment, well, we really have not helped anyone very much. If we simply get money for fuel, but we cannot put additional equipment out there, again, you can see the catch-22.

So that is why we believe that a joint approach—but the key is we need the money quickly. Transit systems are in the process now of raising the fares. They are in the process now of cutting the service. Americans need these choices now, and so we would certainly encourage the Senate to act as quickly as possible.

Senator MENENDEZ. And just to take a further step in that, if you got that type of assistance now, isn't it true that you would capitalize on the increased ridership in maintaining it as a more permanent ridership so that an investment now goes beyond meeting the emergency of the moment, but actually hopefully creates transit systems that are efficient, effective, and at the same time cost-effective for the rider and, therefore, captures this new universe who have moved to the mass transit system in a way, because of gas prices, it now makes them a more permanent ridership?

Mr. MILLAR. Absolutely. They may have come to public transit to beat the high cost of fuel, but they are going to stay if it is convenient and meets their needs. So absolutely, sir, you are correct.

Senator MENENDEZ. And in that respect, to my good friend Senator Corker, who always asks questions that I find very relevant to the issue we are discussing and often hits it on the head in terms of what some may not mention but is the underlying issue, the question of how we evaluate or whether we subsidize or whether we can expect such systems to be totally self-sufficient and even make a profit. And I think you described some of that, as well as Mr. Puentes.

Let me ask you, Mr. Puentes, I think you mentioned in your opening statement about valuation, how we value this process and how we look at it. It seems to me that we do a pretty poor job in ascribing the benefits of a mass transit system and adding those as part of an equation. For example, creating ratable bases where there were none along the Hudson River waterfront, where we had abandoned railroad yards and now have not only great residences but great places of business where people get to work and have economic opportunity. That is a ratable base. It is an economic opportunity base. It has an environmental base to it in terms of air quality, global warming. What we spend in a State, just to take mine, for example, where we have such a high incidence of cancer and many respiratory illnesses, what do we spend on the public health side in dealing with that; how we look at issues of taking land management and creating transit villages where there is already the nexus of bringing people to a location and taking the air rights over those properties and creating developments that make a lot of sense in multiple ways.

Shouldn't we be looking at the valuation aspects of this in that wider range?

Mr. PUENTES. Thank you, Senator. I could not have said it better myself. I think that the scrutiny that we place on the Federal level to transit proposals now is generally the right idea. We need to make sure that we are spending Federal dollars on the best kind of projects. It is hyper-competitive now. The demand for transit, as we have heard, is very, very high. Communities all across the country are looking for transit investments, particularly in the South, West, fast growing parts of the country.

So we need to prioritize those investments. I think the problem that we have now, particularly as it relates to the New Starts Program, is that we are not measuring the right things. It is not enough to just have a measurement process. If we are measuring the wrong things, we are not going to get the best kind of projects.

So I think what it does now is just too limited. We measure things, lost cost savings and there is cost effect and there are some small measures in there right now. But we don't capture the things that you just talked about which I think, as we've said this morning, are critically important to how we evaluate transit projects. Energy benefits, environmental benefits, we have a housing crisis in this country, housing should be a part of it, public health, all of the things you mentioned.

I think that the Federal Government has a very clear and very profound role to play in laying out what that vision should be, and then the construction of those formulas to meet that vision. Right now, without that big, bold, Federal vision, we have these formulas and these processes which clearly, I think as you mentioned, are very lacking.

Senator MENENDEZ. And if we did that, then what we might—what those who would call a subsidy—the numbers might be dramatically different.

Mr. PUENTES. I do not think there is any question. As you hinted at earlier, if there is a fiscal crisis that we are facing, if you are trying to convince your colleagues and other members that we are spending American taxpayer dollars in the most effective and efficient manner possible, we are going to have to do a better job in measuring how we are doing that.

Senator MENENDEZ. Thank you, Mr. Chairman. I thank the panel.

Senator CASEY. Thank you very much. I just have a couple of concluding questions and if there are comments before we wrap up, that is certainly appropriate. I wanted to go back to the Bay Area for a second.

Ms. Dugger, I have to apologize to you. I think I mispronounced your name before. I was saying Dugger instead of Dugger, and I am sorry about that.

Ms. DUGGER. That is fine. Thank you.

Senator CASEY. I wanted to ask you, you had mentioned—and I just want to have a better understanding of it—about retrofitting rail cars to provide more energy savings. Can you tell me a little more about that, how that works and whether there is application to other systems or other situations around the country?

Ms. DUGGER. Yes, we have just completed, as I mentioned, some work with our local utility provider to look at energy efficiency retrofit opportunities and have identified a potential universe of about eight, ranging from lighting retrofits to redirecting cooler air into the HVAC systems, et cetera.

The one that I focused on this morning and that, frankly, has the biggest single conservation opportunity is associated with regenerative braking features on the BART system that is a new ultra capacitor storage capability that we could locate potentially—we have some further testing of the concept to apply it to our specific system—but located on the vehicle itself that would allow for longer storage of that regenerated energy for use in propelling the car itself. So there would be less draw from our third rail power, that would be supplemented by the draw from this stored capacity in the car itself.

This is a technology that has been applied and is in revenue service, I believe, in a light rail application in Germany. We are unaware of any application currently in place in the United States. There are a couple of other properties around the country who are looking at the same concept but located on the wayside rather than on the vehicle itself.

Senator CASEY. I just want to make sure I understand what you mean by that. You are storing what?

Ms. DUGGER. It is kinetic energy that is created by the velocity of the rail vehicle. And when the brakes are applied—I am going to fast get out of my electrical engineering capabilities here, Senator—but to take that kinetic energy, currently the design of the BART system transforms that into energy that is fed back into the third rail, our major source of power. If there happens to be a passing train within proximity, space, and time, that passing train can draw some of that power that was created by the movement and braking of the vehicle, as opposed to from an energy-supplied power source.

BART was one of the first systems where that design was put in place in the United States. It has been fairly common in most systems built since ours in the late 1960s.

What we are talking about today, the new opportunity, is a better battery, a better storage device that could be located on the cars that could hold that same power that is created through the movement of the vehicle and the braking, hold it longer, store it longer for use for a longer period of time and reducing the draw from our externally supplied electricity.

Senator CASEY. But when you talk about retrofitting in terms of the cost, how much of that—or can you absorb all of that? Is that another area where you need help?

Ms. DUGGER. We do not have a budget for that application. We have provided funding out of our own operating revenues this year to conduct the demonstration and further testing of the installation. But the total cost of retrofitting our entire fleet of 669 vehicles, about $94 million, we do not have an identified funding source for that.

In the Bay Area today, we are consuming not only all of the Federal Formula Fund and Flexible Fund—and our region flexes a lot of dollars over to transit—as well as a strong self-help funding commitment by our local citizens through local sales tax and are not meeting the basic needs to maintain our existing systems, much less do these kinds of good, cost-effective investments that will pay back over the long term. But we do not have an identified source of capital, no.

Senator CASEY. But you think you could save as much as almost 45 percent by implementing all of the changes you are talking about?

Ms. DUGGER. That comes with a larger price tag, about $130 million. But yes, those are the numbers that we have calculated based on our modeling and experience of our utility company.

Senator CASEY. Well, it is at times like this that we wish the Federal Government had a capital budget to help on a lot of things, including transit.

I did want to, before we conclude, I wanted to ask about Mr. Millar's testimony. You mentioned the APTA study showing public transit saves America 4.2 billion gallons of gasoline each year. I was going to ask Mr. Darrell, just from an environmental standpoint, we hear numbers all the time and they are big numbers. Some people understand them, some people do not. Some people pretend they understand them, some are most honest about it.

But what is the significance of that in terms of our environment? I know it is kind of a broad question, but is there any way to kind of put that kind of a number into context in terms of our environmental concerns?

Mr. DARRELL. Sure. We would be happy to run some numbers to show you what 4.2 billion gallons would translate into in terms of air pollution, greenhouse gas emissions. I think that one of the opportunities here is to look at a transportation investment and ask the basic efficiency question, if we are going to try to move a certain number of people from point A to point B, or a certain number of goods from point A to point B, what is the most efficient way to do that? What is the right mix of roads and transit that gets us there with the fewest emissions with the most convenience.

At a time when the transportation sector's emissions are the fastest growing set of greenhouse gas emissions in the country right now, to about 30 percent of the greenhouse gas impact, and in many cities about 70 percent of the local air cancer risk, asking that question in the planning process and testing our transportation networks across agencies, the highway agencies, the transit agencies, asking them to come together and say look, let us design a system for performance on the environment and on efficiency. That is a fundamentally important step that is not always taken.

And I think as we look toward a reauthorization of the Federal transportation bill or action on a climate bill, to reward communities and States that are taking that step, to plan essentially the roads and the transit together as one system, it is asking the question how do we perform the best in terms of the environment? How do we perform the best in terms of the economics and the efficiency of the system?

There is no question that in order to deal—I think in California right now, the State of California passed the first cap on greenhouse gas emissions of any American State, an economy-wide cap. And the State agencies now are trying to figure out how to meet that cap.

And one thing that they have realized from the transportation sector is that we are not going to get there through increases in efficiency of automobiles alone.

In other words, there is an enormous amount—I cannot remember off the top of my head what the number is, maybe you can help me if you do. But essentially, in order to meet the cap that California has set for itself, we have to go well beyond automobile and truck efficiency. We have to get into the realm of more transit and cleaner freight infrastructure. And there is a certain target that they have set, that they have identified as a necessary reduction in greenhouse gas emissions from non-pure efficiency gains, but actual transit investments, transit-oriented development, that kind of thing.

That conversation that is playing itself out in California, I believe will play itself out nationally as the country tries to figure out how do we deal with our own climate policy? What is the best approach here?

So to help the communities now that are finding ways to get those tons of carbon dioxide out of the air right now by investing in transit, that is the fundamental and essential first step, to plan those two things together.

And I will be happy to get you the specific numbers on that 4.2 billion.

Senator CASEY. I appreciate that.

Mr. MILLAR. Senator, may I comment on that, as well?

Senator CASEY. Sure.

Mr. MILLAR. Let me give you a big number and then let me give you a number that I think answers your question. The big number is that it is about 37 million metric tons less carbon in the air because people use transit. What does that mean in sort of every day terms?

If you had a typical American household, two commuters, both driving separately to work, and just one of those commuters starts using public transit, you find that gets you about a 10 percent savings in that household carbon footprint.

Well, what is that? You know, we are all told we should change to compact flourescent lights and that is a good thing to do. We are all told we should winterize our homes. That is a good thing to do. We are all told to get rid of our old refrigerator, get an Energy Star appliance. All good things to do.

When you have done all of those things in your household, you have not saved as much as the 10 percent you would have saved if just one person in the household started taking transit. That is the significance of transit investments.

We hear some people say how to reduce carbon footprint is going to have an enormous disruption in American life. It will not. If you took that same household, they started using public transit, found it worked, they sold their second car. They kept their first, they sold their second car. Now you are saving 30 percent of your household carbon footprint. That is more than if your household could do without electricity all together.

So I think when we take these huge numbers, and I apologize that sometimes we present those kinds, and bring them down to this kind of thinking, Americans—by making simple choices—can do a lot for the environment without sacrificing mobility, without sacrificing the way they live.

But they have to have options available and only about 54 percent of all American households have any form of public transit at all. So that is why we need to invest in more public transit. Americans can make the choices that then will just naturally reduce the carbon and we will be a long way down the road to solving our problems.

Senator CASEY. I would say thank you for that closing statement. Thank you.

Mr. DARRELL. Just a quick statistic. If every American drove 10 fewer miles per week, we would save enough energy to power about 8 million homes across the country. So that is the scale of the opportunity that we are taking about.

Senator CASEY. Anyone else before we conclude? I know it has been a little more than 2 hours so I know people are ready to wrap up.

Thank you very much for your time and for the expertise, we are grateful. Again, Ms. Dugger, I will pronounce it better at the end of the record than I did at the beginning of the record.

Ms. DUGGER. Thank you very much. Not to worry.

Senator CASEY. Thank you very much.

[Whereupon, at 12:16 p.m., the hearing was concluded.]

[Prepared statements and responses to written questions supplied for the record follow:]

**TESTIMONY OF**

**WILLIAM W. MILLAR, PRESIDENT**

**AMERICAN PUBLIC TRANSPORTATION ASSOCIATION**

**BEFORE THE**

**SENATE COMMITTEE ON BANKING, HOUSING, AND URBAN AFFAIRS**

**ON**

**STRENGTHEING THE ABILITY OF PUBLIC TRANSPORTATION TO HELP AMERICANS ESCAPE HIGH FUEL COSTS**

*******

**September 9, 2008**

**SUBMITTED BY**

**American Public Transportation Association**
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**Washington, DC 20006**
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**APTA is a nonprofit association of more than 1,500 public and private member organizations including transit systems and commuter rail operators; planning, design, construction and finance firms; product and service providers; academic institutions; transit associations and state departments of transportation. APTA members serve the public interest by providing safe, efficient and economical transit services and products. More than ninety percent of persons using public transportation in the United States and Canada are served by APTA members.**

**Introduction**

Chairman Dodd, Ranking Member Shelby and distinguished members of the Committee, on behalf of the American Public Transportation Association (APTA) I thank you for the opportunity to testify today. We have witnessed sweeping changes in American travel patterns in 2008 in response to rising fuel prices, and public transportation is playing a key role in helping individuals escape the heavy burden of $4 a gallon gasoline while preserving the mobility we have all come to expect. In the second quarter of 2008 as the price of gasoline rose steadily, Americans took more than 2.8 billion trips on public transportation vehicles. This is almost 140 million more trips than last year for the same time period or 1.5 million more each day.

Americans are changing their travel behavior because they realize that taking transit, using a bicycle or walking can dramatically reduce their commuting costs. On average, a transit user saves more than $9,596 per year by taking public transportation instead of driving based on today's gas prices. These savings are important not only for individuals and families, they are important when we consider the urgent need for the United States to attain energy independence. By reducing travel and congestion on roadways and supporting more efficient land use patterns, transit saves the U.S. 4.2 billion gallons of gasoline each year, the equivalent of more than 11 million gallons per day. That amount of savings is equivalent to oil refined from 102 supertankers, or more than three times the amount of oil we import from Kuwait each year.

It should be noted that transit ridership has been growing robustly in recent years. Last year, 10.3 billion trips were taken on U.S. public transportation – the highest number of trips taken in fifty years. Public transportation use is up 32 percent since 1995, a figure that is more than double the growth rate of the population (13 percent) and up substantially over the growth rate for the vehicle miles traveled (VMT) on our nation's highways (24 percent) for that same period. In fact, in recent months growth in transit ridership has accelerated while use of our highways has fallen. Transit ridership grew by more than 5.2 percent in the second quarter of 2008, while the Federal Highway Administration (FHWA) has reported that the vehicle miles traveled on our nation's roads declined by 3.3 percent.

While discussing declining highway travel, I want to note that APTA strongly supports the legislation to provide a short-term fix to the funding shortfall facing the Federal Highway Trust Fund. While that legislation does not address the larger issue of underinvestment in our nation's transportation system, particularly underinvestment in public transportation, it will give the Congress more time to address the long term funding need without drastically reducing current surface transportation investment levels.

Turning back to the role of transit, increasing access to public transportation is key to sustaining ridership growth and expanding the fuel savings attributed to transit use. Households within close proximity of public transportation drive an average of 4,400 fewer miles annually than those with no access to public transportation, but Americans can't use what they don't have. According to U.S. Census data, only 54 percent of American households have access to any public transportation services.

**Barriers to Expanding Public Transportation Ridership**

APTA's member transit systems are working hard to meet the increased demand for their services, but they face many difficulties. As ridership has increased, transit facilities across the country are often operating at capacity during peak travel times. Transit providers are struggling to maintain the quality of their physical infrastructure and the reliability of their service. Transit systems are under pressure to raise passenger fares, cut service or find other means to pay for the higher operating costs produced by increased ridership and their own rising fuel costs. Unfortunately, higher fares and reduced service will only undermine the increased transit ridership that advances so many national goals.

We recently conducted a survey of U.S. transit systems to determine how increased ridership and rising fuel prices have impacted transit operations. We found that six out of ten (63 percent) of transit systems that participated in the survey are experiencing capacity problems in the peak period, and almost four out of ten (39 percent) report they are now turning away passengers. Overall, 85 percent of the systems that responded to the survey have capacity constraints on portions of their systems.

U.S. transit systems simply do not have the resources to expand service as needed. In the past year more than half of U.S. transit systems reported dealing or stable local and state financial assistance over the last year. Just as revenues that support the Federal Highway Trust Fund are declining as a result of reduced driving, many states are experiencing similar declines in revenue from their motor fuel taxes. Meanwhile, the slowdown in the economy is shrinking other state and local resources as sales taxes and real-estate based revenues decline. Also, despite the growth of the federal transit program, which this Committee has championed, federal funding has not kept up with the growing needs or inflation. According to the Associated General Contractors of America (AGC), the price of construction materials for transportation infrastructure has increased by 77 percent in the past 5 years, a much faster rate of growth than the consumer price index (CPI) which increased 19 percent.

It is a tragedy that public transportation systems cannot expand their services enough to help more Americans leave their cars at home and save fuel and money, but transit providers are currently facing an even grimmer prospect: many of APTA's member transit systems are being forced to choose between raising passenger fares or cutting service to make up for the increased cost of the diesel fuel used by most transit vehicles. The price of diesel fuel paid by transit systems has increased by more than 166 percent in just 4 years, and for every penny added to the cost of diesel and gasoline, the public transportation industry faces an increased cost of more than $7.6 million dollars. The burden of increased transit fuel costs is so great that 35 percent of public transportation providers responding to our survey have been forced to cut or plan to cut the level of passenger service they provide in spite of the growing demand. Transit needs to be part of the solution to – not the victim of – high petroleum prices.

**APTA Recommendations**

To provide the level of public transportation service that continues the growth in ridership and allows more Americans to avoid the burden of high gas prices, APTA urges Congress to provide immediate new investment in public transportation infrastructure and service. Without new federal resources, transit providers will struggle to maintain current levels of service, be required to raise fares, or worse, be forced to reduce service. Better transit service is one of the few policy options the federal government can pursue quickly that can offer Americans immediate relief from high gas prices, and your support can help make that option a reality.

To meet these pressing challenges, APTA offers the following recommendations:

➢ **Provide immediate federal investment through energy or stimulus legislation to help transit systems meet the rapid growth in demand for public transportation services resulting from high gas prices.**

As Congress considers proposals to address energy prices and to foster economic activity, federal investment in public transportation clearly addresses both needs. The record ridership numbers on U.S. transit systems this year demonstrate that Americans want increased transportation choices to help them escape the high price of gasoline.

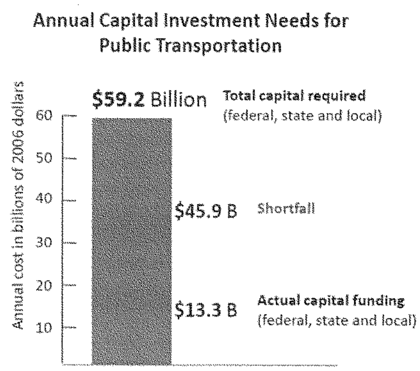
Earlier this year APTA identified and shared with this Committee more than $3.6 billion of capital transit projects that could begin within 90 days of federal funding being made available. Federal investment could be targeted to provide transit systems with the means to quickly expand current services and meet the increased demand for transit services. Examples of potential projects include:

- purchase of rolling stock (buses, locomotives and rail cars, etc.) under existing contracts,
- acceleration of construction projects that add capacity, including fixed guideway projects under the News Starts and Small Starts programs (49 U.S.C. 5309), and
- acceleration of activities that yield improvements in transit operations, including deferred maintenance projects and general procurement.

All three categories would help transit systems increase the availability and capacity of their services.

By choosing to invest in public transportation that gives Americans more transportation choices, Congress can help the economy. For every $1 billion invested by the federal government in transportation infrastructure, the U.S. Department of Transportation estimates that approximately 35,000 jobs are created. If Congress chooses to provide immediate new investment in transit, several high priority areas of capital investment could be targeted to ensure that federal funding is quickly utilized, resulting in new economic activity that can also help give consumers more transit options, easing the burden of high gas prices.

While immediate investment would be extremely beneficial, Congress in the longer term must begin to address the annual capital funding shortfall for public transportation. U.S. transit systems need approximately $60 billion a year in capital investment to improve and maintain transit infrastructure at a rate that would allow ridership to double in 20 years. The federal government traditionally provided approximately 50 percent of the capital investment in transit, but that share has shrunk. In 2006, the most recent year reported, the federal government provided 43.6 percent. As we move ahead, the federal government needs to invest upwards of $30 billion a year to support vibrant transit service across the nation.




Source: Cambridge Systematics, "State and National Public Transportation Needs Analysis," 2008.

➢ **Help public transportation agencies avoid fare increases or service cuts necessitated by increased fuel and operating costs.**

In addition to taking advantage of the benefits of capital investment in public transportation, Congress should consider the operating needs of transit providers. Transit systems across the country are currently under pressure to raise passenger fares or find other means to offset higher operating costs produced by rising fuel and electricity costs. As mentioned earlier, the average price paid by transit systems for diesel increased 166 percent in just four years, from $1.25 to $3.32 per gallon. That price continues to rise as long-term fuel contracts, which are utilized by many agencies, expire and transit systems are forced to purchase fuel at current market prices, which currently are above $4 a gallon.

Transit agency budgets generally set aside funds to deal with normal fluctuations in the price of fuels, but recent increases in the price of diesel have far exceeded the financial reserves that publicly funded agencies commonly maintain. Just like households, business and other organizations, transit systems are struggling to cope with high fuel prices, but only transit providers are being asked to expand services and thus increase their fuel consumption in order to increase service and provide more transportation options for their communities.

Transit systems have already taken steps to improve fuel efficiency in response to rising diesel prices. Such steps include route changes, driver training to minimize fuel consumption, and vehicle maintenance, but these actions have only a modest effect on total fuel costs. To avoid further harm, Congress must act quickly to help transit systems cope with rising fuel prices by offering federal assistance to mitigate transit fuel prices.

| **Impact of Rising Fuel Costs on Transit Services**<br>APTA Survey Results – August 2008 | |
|---|---|
| Action under consideration by transit systems to address increased fuel costs | Percent responding "Yes" |
| **Fare increases** | 61% |
| **Service cuts** | 35% |
| **Delay or cancellation of operating improvements** | 33% |
| **Delay or cancellation of planned service increases** | 31% |
| **Transferred funds from capital use to operations** | 25% |

➢ **Promote energy efficient technology in public transportation systems to increase the already substantial fuel savings from transit and improve operational efficiency.**

Congress should encourage new investment in energy efficient technology that could increase the annual fuel savings from current public transportation services. Transit agencies, often using local funding, have already begun to invest in new vehicle technology, such as hybrid buses, and new energy efficient facilities. New federal support for such investment would speed the deployment of advanced technologies, increasing fuel savings and simultaneously reducing the cost of transit operations, thereby freeing up resources to support expanded service.

Several categories of federal investment could yield important improvements to the efficiency of transit operations:

- **Purchase of clean and alternative fuel rolling stock.** The purchase of new bus and rail rolling stock makes transit fleets more energy efficient. For example, the fuel economy of hybrid buses in operation today is between 10 to 40 percent better than conventional diesel buses. Transit systems have also made innovative investments in vehicle fleets that utilize compressed natural gas (CNG) and liquid natural gas (LNG), a clean, often domestically supplied fuel sources. Unfortunately, many transit agencies are unable to purchase clean and alternative fuel fleets because of the higher upfront capital costs. Additional federal investment, without the local match requirement, would encourage and accelerate the acquisition and deployment of such new vehicle technology and help agencies reduce the cost of operations in the long term. It would also put more Americans to work in new "green collar" jobs because all transit vehicles purchased with federal resources are manufactured domestically.

- **Grants for improvements that reduce energy consumption at transit facilities.** Many transit systems have begun to invest in efforts to reduce energy consumption at stations and other facilities. New standards such as U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) standards are informing and guiding transit systems as they construct new facilities and retrofit existing infrastructure, but transit systems often lack the resources to undertake the additional planning and higher upfront construction costs that can be associated with new energy efficient building practices. New federal investment would accelerate the implementation of "green" building practices and help agencies reduce their energy costs.

**Conclusions**

APTA notes that several legislative efforts have already begun to address these issues. We urge the U.S. Senate to approve language such as the transit provisions of the Reid substitute to the energy bill, S. 3268, that was considered by the Senate in late July 2008 or the House-passed "Saving Energy Through Public Transportation Act of 2008" (S. 3380, as introduced by Senator Hillary Clinton). Both proposals would authorize more than $1.7 billion of much needed new capital investment, and the Reid substitute would make funding immediately available to transit systems. Meanwhile, the "Saving Energy Through Public Transportation Act of 2008" would help transit systems cope with increased fuel costs. These proposals should be combined and passed by the Senate at the earliest opportunity. Better transit service provides immediate relief to the high cost of gasoline, and federal action is essential to meeting this need.

Expanding public transportation in the U.S. is a national priority that should be specifically targeted as Congress works to secure energy independence. We all have a stake in expanding public transportation use. Mr. Chairman and members of the Committee, on behalf of APTA's more than 1,500 member organizations, I thank you for this opportunity to express our views.

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ENVIRONMENTAL DEFENSE FUND

finding the ways that work

Testimony of Andrew H. Darrell

Vice President

Environmental Defense Fund

Before the

**U.S. Senate Committee on Banking Housing and Urban Affairs**

**At the Oversight Hearing, "Strengthening the Ability of Public Transportation to Reduce Our Dependence on Foreign Oil"**

**September 9, 2008**

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Good morning Chairman Dodd, Ranking Member Shelby and members of the committee. Thank you for inviting me to testify today. My name is Andrew Darrell. I am Vice President for Living Cities at Environmental Defense Fund*.

It's no secret that over the past year, Americans have felt a powerful financial wallop from rising gas prices. At a time of economic uncertainty, high gas prices have raised the cost of driving to work, of the family vacation, of the simple act of driving to the grocery store. According to U.S. Public Interest Research Group, the average American family is now spending close to one hundred dollars a week on gasoline. Transportation is the second-largest household expense for the average American household, second only to shelter (and ahead of food).

As a result of high gas prices, Americans are driving less. According to the Federal Highway Administration's data, which has been gathered since 1942, the past year has brought the steepest decline in vehicle miles traveled ever recorded.[1] That's a steeper drop than even during the gas crisis of the 1970s. This is true across the country: rural interstate highways saw some of the biggest change; the Midwest, West and the South have seen sharper declines than the Northeast, and in June, driving was down nearly 8 percent in Alabama from a year ago.

Some of this shift undoubtedly means less travel. But Americans are also turning to transit like never before – especially for essential trips like going to work. To this

* Environmental Defense Fund, a leading national nonprofit organization, represents more than 500,000 members. Since 1967, Environmental Defense Fund has linked science, economics, law and innovative private-sector partnerships to create breakthrough solutions to the most serious environmental problems. For more information, visit www.edf.org.

testimony, I am attaching a map that EDF produced using data from the National Transit Database that shows the many places across the country where transit ridership has jumped along with gas prices. This is a challenge for the whole country.

In the first quarter of 2008, public transit ridership rose by 88 million trips compared to 2007[2]. The following remarkable statistics have been reported in the media:

- A 42% rise in commuter rail use for South Florida in June 2008 versus 2007 [3]
- Charlotte saw a 34% jump in transit ridership this February compared to last February [4] Some express bus routes are seeing gains as high as 70%[5]
- In Denver, ridership up 8% from last year, despite a fare increase and a slowing economy[6]
- In Austin, express bus service jumped 69% in July over last year[7]
- In Nashville, ridership is up 11% - a million more trips a year[8]
- In Minneapolis, June ridership was up 20% over last year and is the highest it's been in 25 years.[9]
- Ridership is up even in more rural Western states: For example, new records on Casper Wyoming's bus system this summer[10] up 23% from last year[11] 40% growth in Boise City's ValleyRide commuter buses[12]; and an 8% increase in Omaha's Metro Area Transit ridership over last year.[13]
- Express commuter bus in Denton County, a suburb of Dallas, saw a 53% increase in ridership this June versus last June – despite the fact that ridership is usually lower in the summer since the bus is typically used by students.[14]

- In my own hometown of New York City, there are over 300,000 more subway trips a day.[15]
- 9 out of the 10 most sprawling regions (according to Smart Growth America's sprawl index), including Atlanta, Dallas, and Southern California, have seen transit ridership growth since last year.[16]

These trends reveal a basic truth: Americans are looking for an affordable and sustainable ride to work. The question is: is government prepared to meet that demand? Americans are making the sustainable choice: but are our transit networks ready? Without federal help, they cannot be.

The answer so far is that transit networks are struggling. Yes, an increase in ridership can mean more revenue from the fare box. But that revenue can barely keep up with increased operating costs. After all, bus networks feel the pinch from increased diesel prices too.

Transit systems are clearly struggling with significant budget gap:
Minneapolis: $15 million[17], Nashville: $3 million[18], Charlotte: $4 million[19], South Florida: $18 million[20], Denver: $19 million[21], Seattle: $70 million[22].

And those increased revenues are certainly not enough to allow for capital investment in expansion. When Americans turn to their transit networks, they should be able to find enough buses, enough light rail cars, enough subway cars to meet the demand.

From the point of view of public health, air quality and the environment, this turn to transit is a good thing. The transportation sector accounts for 30% of the nation's greenhouse gas emissions, and in many large metropolitan areas, over 70% of the added air cancer risk comes from traffic. The worse the traffic, the more severe the problem: a car in stop-and-go traffic can emit three times the pollution of one moving freely. More than 30 peer-reviewed scientific studies confirm that exposure to traffic pollution is linked to a wide range of disease, from asthma attacks to heart disease, stunted childhood lung development, cancer – even lowered IQ in children. [23] Less driving means less traffic pollution, and less exposure to traffic pollution is essential to health and the environment.

Expanding transit is essential to reducing dependence on foreign oil. Two-thirds of oil in the United States goes to transportation, with the largest share consumed by cars and trucks.[24] Overall, the typical public transit rider consumes on average one half of the oil consumed by an automobile rider[25], mainly because they can integrate transit use into their daily routine. Nationwide, public transportation saves our country over four billion gallons of fuel each year, which translates into billions of dollars in avoided gasoline costs.[26]

Expanding transit is also a wise economic investment. It brings jobs, from construction to installation, equipment manufacturing and operation. And it relieves congestion on the streets, making for a better business climate. Congestion, for example, costs New York City about $13 billion a year in lost productivity, wasted time, and wasted fuel.[27] The

Metropolitan Planning Council in Chicago estimates that congestion annually costs that City over $7 billion. According to their recently released report, for every hour a driver sits in stop and go rush hour traffic, he or she loses about $15. Expanding transit can ease the gridlock on our streets.

Transit agencies are trying to innovate to create networks that fit the many different communities in our country. For example:

- In Charlotte, NC, a new light rail system opened last November with projected weekday ridership of 9,100. By April ridership reached 18,600 – surpassing its 2025 projections and already accounting for 20% of total system-wide trips.[28]
- In Kansas City, Missouri their new MAX BRT bus service cut trip times by 25% and now helps connect an estimated 150,000 jobs to the city[29]. The system is now being expanded to additional corridors, while ridership is on the rise, up 12% from last year. [30]
- In communities like Maplewood, New Jersey and Hialeah, Florida, van networks pick up suburban commuters on their local streets, dropping them off at the train station so that commuters traveling to job centers can save fuel by leaving their cars at home.[31]
- In Alabama, the city of Montgomery piloted 3 new bus routes in 2000. Today that system has expanded to 16 routes and services almost 400% more trips.[32] But demand continues to rise as driving plummets, with 8% fewer miles driven in June compared to last year.[33]

- In Chattanooga, Tennessee ridership is up 14% this year[34] as citizens choose from a variety of transit options: commuter bus routes complete with Wi-Fi and park-and-ride lots, free downtown shuttle buses with emissions-free electric engines, and on-demand vanpool servicing rural parts of Hamilton County.[35]
- In New York City, new Select Bus Service on crowded routes has shaved 20% off of travel times by using dedicated lanes, clean-fuel articulated buses and signal prioritization technology.[36]

Innovations like these make transit a practical alternative to high gas prices. After all, what better economic stimulus can there be than to offer Americans an affordable and sustainable ride to work?

This is why EDF is here today to ask for immediate federal help for our country's transit systems. When Americans turn to transit, we believe it is essential to meet them at the subway station, at the bus stop, at the light rail stop with good and expanded service. Across the country, transit systems are trying hard to do just that – but they need financial help to meet growing demand.

We urge immediate federal action to:

- **Provide emergency grants** to expand transit service to meet rising demand, for example by bringing new buses and rolling stock into the system quickly;
- **Support transit innovation** , for example through highly-efficient technologies, like light rail and bus-rapid-transit, that can deliver transit results in communities that do not have good access now;

- **Get the most out of existing networks,** by providing financial support to ease the backlog of maintenance needs and upgrading signalization and other technologies that allow transit systems to work more efficiently;
- **Expand access to transit**, for example by making transit easier to access from residential areas through local van pools or encouraging residential development near transit hubs; and
- **Invest in energy efficiency** of transit networks. A hybrid-electric transit bus, for example, uses far less fuel than a traditional diesel bus.

We ask you to act quickly to provide an infusion into transit networks this year. That will help Americans weather the surge in gas prices now.

America also needs a long term strategy. The upcoming reauthorization of the federal transportation bill provides a remarkable opportunity to provide one. In that reauthorization, we urge you to dramatically expand the resources available to cities and states ready to deliver clean transportation choices. Transit innovation, clean freight infrastructure and the best and most efficient technologies are essential not only for the environment, but also for America's future economic competitiveness.

Expanding transit now is just the right tonic to help get through tough economic times. It is also a key solution to tackle climate change, reduce dependence on foreign oil, and boost the economic competitiveness of our population centers.

Thank you for the opportunity to testify today.

[1] National Transit Database, TS2 - Operating Expenses, Service Supplied and Consumed, 2008, http://www.ntdprogram.gov/ntdprogram/data.htm
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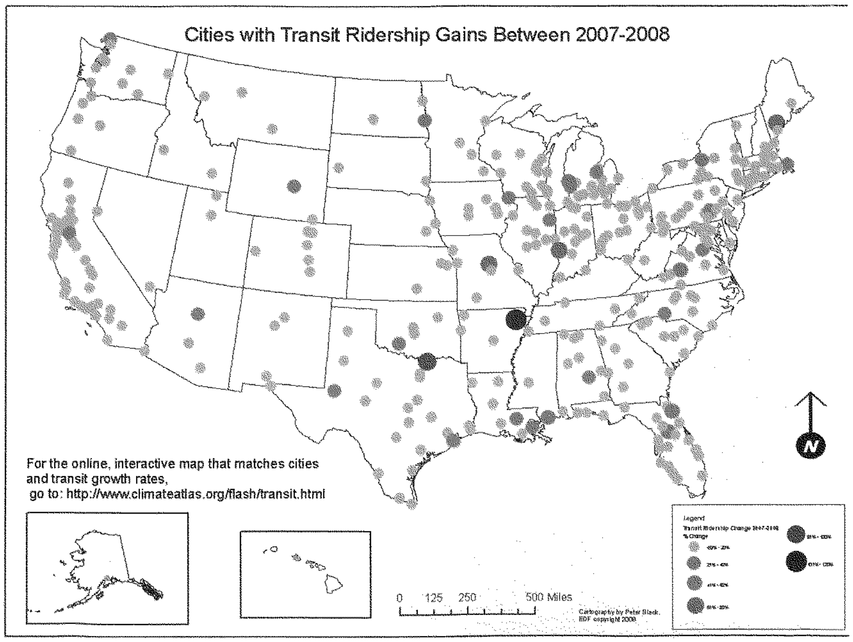
Cities with Transit Ridership Gains Between 2007-2008
For the online, interactive map that matches cities
and transit growth rates,
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**Dorothy W. Dugger**
**General Manager**
**San Francisco Bay Area Rapid Transit District (BART)**
**Senate Banking, Housing and Urban Affairs full committee**
*Strengthening the Ability of Public Transportation to Reduce Our Dependence on Foreign Oil*
**September 9, 2008**

Chairman Dodd, Ranking Member Shelby and Members of the Committee, thank you for the opportunity to testify on this timely topic this morning.

While California is no stranger to the vulnerability of energy markets and rising energy prices, this past year has pushed the state with the nation's highest gas prices to new heights.

Since service began 36 years ago, BART has played a unique and important role in reducing the Bay Area's congestion and connecting a diverse region.

Increasingly, our service is becoming an even more attractive transportation option for people trying to combat rising gas prices.

BART, which serves four counties in the San Francisco Bay Area, carries over 360,000 people each weekday or more than 104 million passengers a year.

Our ridership has increased over five and a half percent this year--which is more than double our normal growth rate.

Last month, ridership was up 7% over the month of July a year ago. And we have seen a 9% growth in people using our system during non-peak times.

In fact, our service to and from the San Francisco International Airport grew by 37%.

Clearly, more people are choosing to ride transit and not just to get to work.

During this same period, we have also seen our power costs increase by 16%.

BART is a 100% electric with two-thirds of our power provided by renewable, hydro-electric power.

BART uses approximately 400 million kilowatt hours annually to power our trains and stations.

Seventy-five percent of this is used for train operations, which is the equivalent of the electricity needed to power about 11,000 homes for a year.

In order to reduce our own energy costs, BART is partnering with Pacific Gas and Electric to identify and hopefully implement energy efficiency strategies to reduce our monthly bill and demand on the grid.

PG&E and BART have identified eight strategies to reduce energy consumption by retrofitting our rail car fleet.

I would like to highlight one of these technologies this morning and ask that the full report be submitted for the record.

The BART fleet is equipped with regenerative brakes, which already have higher energy savings than systems with vehicles that are unable to redirect the electricity generated from braking, back into the third rail.

The new technology we analyzed would install an ultra capacitor storage device on-board each vehicle, which would be able to store the electricity generated from breaking and use it for propulsion.

If these ultra-capacitors were installed on all of our 669 vehicle fleet, we estimate that we'd reduce our traction power demands by 26%.

This translates into a savings of about eight million dollars a year and almost 83 million kilowatt hours reduced from the grid.

Retrofitting our entire fleet is estimated to cost about 94 million dollars, which would be paid for through energy savings over eleven years.

The resulting energy and emissions benefits would be immediate.

If we were able to fund all of the vehicle efficiency retrofits in this report, we would save almost 130 million kilowatt hours of electricity each year or 43% of the power necessary to run our vehicles.

These reductions would not only benefit our customers, but reduce demand on the grid and allow PG&E a bit more flexibility in managing the power demands of Northern California.

BART is also looking at ways to generate some of our own power. We have a solar demonstration project underway at two of our maintenance facilities and at one of our stations.

We are installing energy efficient lighting at these same locations to demonstrate that more efficient lighting can be powered by smaller solar panels--making these investments, when combined with the federal tax credit, a bit more cost-effective.

These energy efficiency technologies are scalable, in terms of cost, and have quantifiable benefits in terms of reducing our energy-use.

These technologies are not unique to BART and could be applied on a national level in a relatively short time frame, but this will require a strong federal partner to make it possible.

The largest contribution that BART, and other transit operators around the country, can make to reduce our dependence on foreign oil is to provide enough service--

that is safe, reliable, and convenient to continue to give travelers an attractive alternative to driving.

When polled, eighty percent of our customers tell us they have another means to get where they are going, but chose to ride BART. Most tell us that other mode is a car.

The BART system is 104 miles, connecting suburban and urban centers on both sides of the San Francisco Bay and beyond.

With an average trip length of almost 14 miles and a 96% on-time performance rating, we ***are*** providing an attractive alternative to driving.

In fact, during rush-hour, our customers are traveling at the equivalent of 249 Miles per Gallon.

According to a study released in March of this year by U.S. PIRG, entitled, "A Better Way to Go," riders on our system saved about $522 million in fuel costs by riding BART and avoided consuming almost 200 million gallons of gas.

This data was from 2006, so those savings are certainly higher today.

As you have heard from Mr. Millar, transit agencies across the country are facing record ridership increases as people are forced to drive less due to high gas prices.

This trend is expected to continue and coupled with an aging and growing population, BART and other large rail operators will soon be facing a capacity crisis.

We are seeing this today during our peak commute hours and in fact are removing some seats as a temporary way to expand our capacity.

If transit is to continue to be a viable alternative to driving and meet our country's growing mobility demands, we ***must*** address our core capacity needs.

At BART and in the Bay Area, we have seen several successful Transit Oriented Development projects take root.

Data shows that households living in these developments drive half as many miles as people living in traditional suburban neighborhoods.

The future success of this model will depend on transit agencies being able to serve these developments with robust, reliable service.

For BART, and many operators serving metropolitan areas, this will require additional capacity in our existing core systems.

To achieve this, we will need a new and sustained federal investment.

I look forward to working with this Committee, APTA and our industry partners to advance this concept and achieve needed funding levels to support this initiative in the next authorization bill.

Like the energy efficiency technologies, the return on investment for expanding our ridership is significant and quantifiable.

The question of whether people will get out of their cars and ride transit has been answered.

The new question is - will we be able to meet this growing demand?

That is our challenge and one that requires a strong federal partnership to achieve.

Thank you and I am happy to answer your questions.

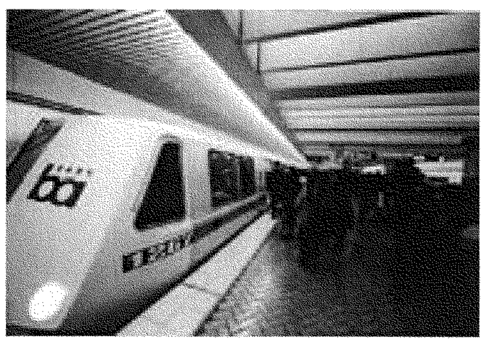
Pacific Gas and Electric Company.
WE DELIVER ENERGY.
CUSTOMER ENERGY EFFICIENCY PROGRAM

## ENERGY EFFICIENCY ASSESSMENT

OF

# Bay Area Rapid Transit (BART) Train Cars

**San Francisco Bay Area**



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## CONTENTS

# 1. INTRODUCTION

The work presented in this report is a service of the **Pacific Gas & Electric Company** (PG&E) to its large commercial and industrial customers under its Customer Energy Efficiency Program, which has been contracted to BASE Energy, Inc. This work has been supported by the Integrated Energy Audit and Non-Residential New Construction Programs as PG&E's continuing commitment to provide energy efficiency, energy cost reduction services and technical solutions to its customers. The Integrated Energy Audit is intended to identify, analyze, and serve as a "roadmap" for defining and implementing cost effective energy efficiency and modernization measures, demand response opportunities, as well as any potential for self-generation (including renewables and cogeneration) for PG&E's customers. Implementing the Integrated Energy Audit recommendations will result in avoided energy, maintenance and capital costs that will assist in financing the cost of the energy efficiency improvements. Data are gathered through site visits, measurements and collection of information from customers, and energy conservation and efficiency as well as demand response opportunities are identified. When a measure is attractive and involves engineering design and capital investment, and engineering services are not available in-house, it is recommended that a consulting engineering firm be engaged to do the detailed engineering design and cost estimation for implementing the measures.

The scope of the work in this energy assessment includes:

1 - Field survey of energy consuming equipment
2 - Evaluation of as built plans and other energy related documentation
3 - Identification of energy conservation and efficiency opportunities and modernization needs
4 - Analysis of existing conditions and alternative energy efficiency, modernization and demand response opportunities
5 - Implementation analysis of major energy efficiency, modernization and demand response opportunities

The assumptions used to arrive at the energy consumption and cost savings for the recommended measures are provided in the report. These assumptions are intended to be conservative and are often arrived at in consultation with Customer (audited facility) personnel.

Three important factors that affect energy consumption and savings are operating hours, utility factor of the equipment (actual hours of operation of a device divided by the hours of operation of the department), and load factor (actual energy draw divided by the nominal draw). The numbers used in this report are based on the information provided by the customer and should be taken as average. Cost estimates have been done based on common cost estimation manuals, contacts with equipment manufacturers and contractors to the extent possible. We **recommend** that the customer consult various suppliers for competitive bids for implementation of measures whenever deemed appropriate.

We have not evaluated these measures for other factors that could impact the ultimate implementation of each measure, such as future expansion capability, regulatory compliance and permitting, ease and cost of maintenance, etc.

The assessment team would like to thank PG&E Customer Energy Efficiency managers and staff, Genrick Gofman, Michael Juniphant, and Charlie Middleton in particular, for supporting and encouraging this work. Also our sincere thanks go to Henry Kolesar of BART for his diligent attention and help in the course of developing this study.

Please feel free to contact BASE Energy, Inc. at (415) 543-1600, Rod Lee, PG&E Account Manager at (415) 973-4830, Charlie Middleton, PG&E Senior Chemical Engineer at (415) 973-4008 or Michael Juniphant at (415) 973-2983 if there are any questions or comments related to this report.

## 2. EXECUTIVE SUMMARY

This report includes the results of a limited energy efficiency evaluation of the train cars of Bay Area Rapid Transit (BART) of San Francisco Bay Area, California.

BART service territory covers the San Francisco Bay Area – from Millbrae to Pittsburg and Richmond to Fremont. Due to the vast distance covered by the transit system, there are several electric substations throughout the Bay Area that supply electricity to BART cars and facilities. However, this study focuses exclusively on energy efficiency improvements of BART cars, thus it was determined that the annual electrical consumption from billing data would not be appropriate to establish a baseline for the cars' electrical energy consumption. Instead, it was proposed that test results from the *Energy Consumption Test on Test Track* (for both C and A/B cars) be used as a baseline. Results are presented as the electrical consumption of one car per mile (kWh/car-mi). Once the yearly distance covered by each car type is determined, it is possible to determine the annual electrical energy consumption in the more conventional kilo-watt-hour per year (kWh/yr). Since not all cars operate continuously, it has been estimated that during BART's peak period, a total of 500 cars would be operating (50 trains, 10 cars per train). It is assumed that the 500 cars will be composed of: 112 C1 cars, 60 C2 cars, 44 A cars and 284 B cars. These numbers are derived from a proportional relationship between the total number of cars of a specific type to the total number of cars and the estimated 500 cars that would be operating during BART's peak period. The table below summarizes the baseline energy consumption, demand and electric costs for operating the BART cars.

| ANNUAL CAR OPERATION AND ENERGY SUMMARY | | | | | | |
|---|---|---|---|---|---|---|
| **Car Type** | **Number of Cars** | **Mileage** (mi/car-yr) | **Car Energy Consumption** (kWh/car-mi) | **Maximum Demand** (MW) | **Total Energy Consumption** (kWh/yr) | **Energy Cost** |
| C1 | 150 | 116,435 | 3.6170 | 16.8 | 63,171,946 | 6,633,054 |
| C2 | 80 | 127,020 | 3.6122 | 8.9 | 36,705,269 | 3,854,053 |
| A | 59 | 122,275 | 3.3708 | 6.1 | 24,317,710 | 2,553,360 |
| B | 380 | 137,605 | 3.3708 | 39.7 | 176,258,795 | 18,507,173 |
| **Totals** | **669** | | | **71.6** | **300,453,720** | **31,547,641** |
| | | | | Average Unit Costs | | $0.105/kWh |

Application of energy efficient technologies to the current BART fleet (considered as retrofit) and to new cars (considered non-residential new construction, NRNC) has been evaluated in this report.

**Retrofit**

The energy efficiency opportunities (EEMs) included in this report could save an estimated 129,629,488 kWh of electrical energy each year, or 43.1% of the BART cars' total electrical energy usage. This estimated electrical energy savings would translate into a cost savings of $13,632,650 per year. Total estimated implementation cost is $156,891,233 giving an average simple payback of 11.5 years. A summary for the savings and costs for these EEMs are listed in Table ES-1A. Detailed information on these recommendations and calculations of savings are in Section 5.1, Energy Efficiency Opportunities (EEMs).

**TABLE ES-1A SUMMARY OF SAVINGS AND COSTS FOR RETROFITTED BART CARS (RETROFIT)**

| EEM No. Description | Potential Energy Conserved | Maximum Demand Savings* (kW) | Potential Savings ($/yr) | Savings per car type per mile (kWh/car-mi) | Installed Project Cost ($) | Simple Payback (yr) |
|---|---|---|---|---|---|---|
| **Investment Grade Measures** | | | | | | |
| 1. High Efficiency Lighting for C1 Cars and New Cars | 156,872 kWh/yr | 42 | 37,891 | 0.009 (C1) | Included in EEM No. 4 | Included in EEM No. 4 |
| 2. Direct Cooler Air to the Inlet of HVAC Condensers | 1,717,819 kWh/yr | 409 | 180,370 | 0.019 (C1, C2) / 0.020 (A, B) | 200,000 | 1.1 |
| 3. Install Higher Efficiency HVAC Units on C Cars and New Cars | 413,021 kWh/yr | 107 | 43,367 | 0.015 (C1, C2) | 690,000** | 15.9 |
| 4. Optimize Outside Air Intake into Cars | 1,444,334 kWh/yr | 0 | 151,791 | 0.016 (C1, C2) / 0.017 (A, B) | 1,050,000 | 6.9 |
| 5. Install Daylight Controls on the Fluorescent Lamps | 837,433 kWh/yr | 0 | 87,930 | 0.011 (C1, C2) / 0.009 (A, B) | 2,869,985 | 32.6 |
| 6. Install Variable Frequency Drives on HVAC Supply Fans | 3,206,292 kWh/yr | 0 | 336,661 | 0.047 (C1, C2) / 0.032 (A, B) | 2,950,000 | 8.8 |
| 7. Use Permanent Magnet (PM) Motors for Car Propulsion | 38,905,029 kWh/yr | 9,424 | 4,085,028 | 0.663 (C1, C2) / 0.346 (A, B) | 54,456,600 | 13.3 |
| 8. Use Ultracapacitors for Regenerative Braking Energy Storage | 82,948,688 kWh/yr | 19,733 | 8,709,612 | 0.952 (All Cars) | 94,674,648 | 10.9 |
| **Total Electrical Energy Savings** | **129,629,488 kWh/yr** | | | | | |
| **Total Demand Savings** | | **29,715** | | | | |
| **Total Cost Savings** | | | **13,632,650** | | | |
| **Total Installed Project Cost** | | | | | **156,891,233** | |
| **Simple Payback** | | | | | | **11.5** |

* The demand savings considers that at most 500 cars will be operating during BART's peak period. Additionally the demand savings does not consider the interaction between the regenerated energy and the electric grid.

** The implementation cost for these measures consider the cost premium for installing the proposed system as older systems come to their end-of-life (i.e on a replacement basis).

PG&E offers incentives for energy efficiency and/or demand response opportunities under the Non-Residential Retrofit – Demand Response (NRR-DR) program. The incentives for energy efficiency projects are subject to the following limitations:

- A measure's incentive cannot exceed 50% of the measure's cost, and
- The total incentives for all measures cannot exceed the project site cap of $3,600,000.

The total implementation cost of the EEMs recommended in this project is estimated to be $156,891,233. The total potential incentives and rebates for these measures (in using both incentive/rebate programs) are estimated to be $3,600,000 shown in Table ES-2. The total cost savings of $13,632,650 per year will pay for the adjusted total implementation cost (including incentives) of $153,291,233 in approximately 11 years.

**TABLE ES-2A SUMMARY OF ENERGY EFFICIENCY OPPORTUNITY INCENTIVES FOR EXISTING CARS (RETROFIT)**

| EEM No. Description | Energy Savings | Incentive or Rebate Program and Amount | Potential Incentive ($) | Installed Project Cost with Incentive ($) | Simple Payback Period w/ Incentive (yrs) |
|---|---|---|---|---|---|
| 1. High Efficiency Lighting for C1 Cars and New Cars | 156,872 kWh/yr | NRR-DR *$0.05/kWh* | Included in EEM 5 | Included in EEM 5 | Included in EEM 5 |
| 2. Direct Cooler Air to the Inlet of HVAC Condensers | 1,717,819 kWh/yr | NRR-DR *$0.14/kWh* | 240,495 | 100,000* | 0.6 |
| 3. Install Higher Efficiency HVAC Units on C Cars and New Cars | 413,021 kWh/yr | NRR-DR *$0.14/kWh* | 57,823 | 632,177 | 14.6 |
| 4. Optimize Outside Air Intake into Cars | 1,444,334 kWh/yr | NRR-DR *$0.14/kWh* | 202,207 | 847,793 | 5.6 |
| 5. Install Daylight Controls on the Fluorescent Lamps | 837,433 kWh/yr | NRR-DR *$0.05/kWh* | 49,715 | 2,820,270 | 22.4 |
| 6. Install Variable Frequency Drives on HVAC Supply Fans | 3,206,292 kWh/yr | NRR-DR *$0.14/kWh* | 448,881 | 1,475,000* | 4.4 |
| 7. Use Permanent Magnet (PM) Motors for Car Propulsion | 38,905,029 kWh/yr | NRR-DR *$0.08/kWh* | 3,112,402 | 51,344,198 | 12.6 |
| 8. Use Ultracapacitors for Regenerative Braking Energy Storage | 82,948,688 kWh/yr | NRR-DR *$0.08/kWh* | 6,635,895 | 88,038,753 | 10.1 |
| **Total Energy Savings** | **129,629,488 kWh/yr** | | | | |
| **Total Potential Incentives and Rebates** | | | **$3,600,000**** | | |
| **Total Installed Project Costs with Incentives** | | | | **$153,291,233**** | |
| **Simple Payback Period** | | | | | **11 years** |

* Incentive limited to 50% of measure's implementation cost.
** $3,600,000 is the maximum amount of incentive that PG&E can provide under this program.

**Non Residential New Construction (NRNC)**

The energy efficient measures (EEMs) included in this report that could be implemented in BART's new cars may save an estimated 179,038 kWh/car-yr of electrical energy each year. This estimated electrical energy savings would translate into a cost savings of $18,799 per year. Total estimated implementation cost is $220,913 giving an average simple payback of 11.8 years. A summary for the savings and costs for these EEMs are listed in Table ES-1B. Detailed information on these recommendations and calculations of savings are in Section 5.1, Energy Efficiency Opportunities (EEMs).

**TABLE ES-1B SUMMARY OF SAVINGS AND COSTS FOR NEW BART CARS (NRNC)**

| **EEM No. Description** | **Savings per car per mile** (kWh/car-mi) | **Potential Energy Conserved** (kWh/car-yr) | **Potential Savings** ($/yr) | **Installed Project Cost** ($) |
|---|---|---|---|---|
| **Investment Grade Measures** | | | | |
| 1. High Efficiency Lighting for C1 Cars and New Cars | 0.007793 | 1,170 | 123 | Included in EEO No. 5 |
| 2. Direct Cooler Air to the Inlet of HVAC Condensers | N / A | N / A | N / A | N / A |
| 3. Install Higher Efficiency HVAC Units on C Cars and New Cars | 0.009534 | 1,242 | 130 | 1,031 |
| 4. Optimize Outside Air Intake into Cars | 0.01677 | 2,184 | 229 | 1,570 |
| 5. Install Daylight Controls on the Fluorescent Lamps | 0.009171 | 1,194 | 125 | 4,066 |
| 6. Install Variable Frequency Drives on HVAC Supply Fans | 0.03222 | 4,196 | 441 | 4,410 |
| 7. Use Permanent Magnet (PM) Motors for Car Propulsion | 0.346 | 45,063 | 4,732 | 81,400 |
| 8. Use Ultracapacitors for Regenerative Braking Energy Storage | 0.952 | 123,989 | 13,019 | 128,436 |
| **Total Electrical Energy Savings** | | **179,038** | | |
| **Total Cost Savings** | | | **18,799** | |
| **Simple Payback Period** | | | | **220,913** |

The total implementation cost of the EEMs recommended in this project is estimated to be $220,913/car. The total potential incentives for these measures are estimated to be $14,709/car shown in Table ES-2. The total cost savings of $18,799/car per year will pay for the adjusted total implementation cost (including incentives) of $206,204 in approximately 11 years.

| TABLE ES-2B SUMMARY OF ENERGY EFFICIENCY OPPORTUNITY INCENTIVES FOR NEW CARS (NRNC) | | | | | |
|---|---|---|---|---|---|
| **EEM No. Description** | **Energy Savings** | **Incentive Amount** | **Potential Incentive ($)** | **Installed Project Cost with Incentive ($)** | **Simple Payback Period w/ Incentive (yrs)** |
| 1. High Efficiency Lighting for C1 Cars and New Cars | 1,170 kWh/car-y | *$0.05/kWh* | Included in EEM 5 | Included in EEM 5 | Included in EEM 5 |
| 2. Direct Cooler Air to the Inlet of HVAC Condensers | N / A | N / A | N / A | N / A | N / A |
| 3. Install Higher Efficiency HVAC Units on C Cars and New Cars | 1,242 kWh/car-y | *$0.14/kWh* | 174 | 857 | 6.6 |
| 4. Optimize Outside Air Intake into Cars | 2,184 kWh/car-y | *$0.14/kWh* | 306 | 1,264 | 5.5 |
| 5. Install Daylight Controls on the Fluorescent Lamps | 1,194 kWh/car-y | *$0.05/kWh* | 118 | 3,948 | 15.9 |
| 6. Install Variable Frequency Drives on HVAC Supply Fans | 4,196 kWh/car-y | *$0.14/kWh* | 587 | 3,823 | 8.7 |
| 7. Use Permanent Magnet (PM) Motors for Car Propulsion | 45,063 kWh/car-y | *$0.08/kWh* | 3,605 | 77,795 | 16.4 |
| 8. Use Ultracapacitors for Regenerative Braking Energy Storage | 123,989 kWh/car-y | *$0.08/kWh* | 9,919 | 118,517 | 9.1 |
| **Total Energy Savings** | **179,038 kWh/car-yr** | | | | |
| **Total Potential Incentives and Rebates** | | | **$14,709** | | |
| **Total Installed Project Costs with Incentives** | | | | **$206,204** | |
| **Simple Payback Period** | | | | | **11 years** |

* Incentive limited to 50% of the total implementation cost.
$500,000/car is the maximum amount of incentive that PG&E can provide under this program.

This study did not involve analysis of demand response opportunities for the BART system. However the following are some ideas for demand reduction during PG&E demand response events. Detailed studies of these measures are strongly recommended:

- Using more A and B cars instead of C cars.
- Reduce the acceleration rate.
- Resetting the temperature in the cars to a higher value.
- Dimming lights inside cars and stations.

**Note:**

1. Some energy efficiency and demand response projects qualify for incentives through the PG&E Customer Energy Efficiency and Demand Response Programs. The PG&E link http://www.pge.com/biz/rebates/ has complete PG&E Program information. Section 9 has an overview of these programs and incentives.

2. Please note that the final financial incentive amount will depend on the final installed project cost

**Further Steps for Implementation of the Measures**

Further steps to successfully implement the energy efficiency measures identified in this report may include the following:

1. Perform further detailed engineering evaluation of the measures that are economically and technically attractive to BART.
2. Decide whether BART would like to choose the retrofit and/or new construction path for implementation of the measures.
3. Apply for PG&E Incentives.
4. Test the measures in a prototype car or station for providing further practical insight into the implementation of the measures.
5. After trial tests, plan for further implementation on the BART system.

# 3. GENERAL BACKGROUND

## 3.1 System Description

BART has four different car types in service: C1, C2, A and B cars. The C1 cars were the first generation cars that entered service.

The propulsion systems in C1 and C2 cars consist of four direct current (DC) motors per car. There are two HVAC systems, one supplying the front and one supplying the rear of the car. C2 cars are essentially the same as C1 cars, except the interior lighting of the cars was retrofitted from T12 fluorescent lamps to T8 fluorescent lamps.

A and B cars are the first major rehabilitation project done to the BART cars. The main propulsion system was changed from DC motors to induction motors (IM). Also a higher efficiency HVAC system was used, the two larger units were replaced with six smaller units, half of them serving the front and half serving the rear of the car. The lighting system remained the same as the one used in the C2 cars, which use high efficiency T8 lamps. The main difference between A and B cars is the external shell; one has a "nose" used at the ends of the train and the other does not (thus can be used in the middle of the train).

Power is fed to the cars through a 1,000 Vdc (nominal) third rail, which runs parallel to the rail tracks. There are three main voltage busses used in a car: there is a 1,000 Vdc bus used mainly by the propulsion system; a 208 Vac bus used by the HVAC system, air compressor, hydraulic pump, propulsion blower and scavenger blower; and finally a 36.5 Vdc bus which is maintained by on-board batteries to supply critical systems like interior lighting, communications, etc. A simplified single line diagram of the electrical distribution system and loads inside a typical C car is shown in Figure 1 on the following page.

The propulsion system has the capability of recovering some of the car's kinetic energy through regenerative braking. The system is set up to redirect the regenerated energy to the third rail, where it can be used by nearby trains. If there are no nearby trains that can use the regenerated energy it is dissipated by on-board resistors.

Based on average daily operating hours provided by BART personnel, the table below summarizes the average yearly operating hours for each BART car type.

| YEARLY OPERATING HOURS BY CAR TYPE | | | |
|---|---|---|---|
| **Car Type** | **Daily Hours** (hr/day) | **Days per Year** (day/yr) | **Operating Hours** (hr/yr) |
| A | 8.1 | 365 | 2,957 |
| B | 9.1 | 365 | 3,322 |
| C1 | 7.7 | 365 | 2,811 |
| C2 | 8.4 | 365 | 3,066 |

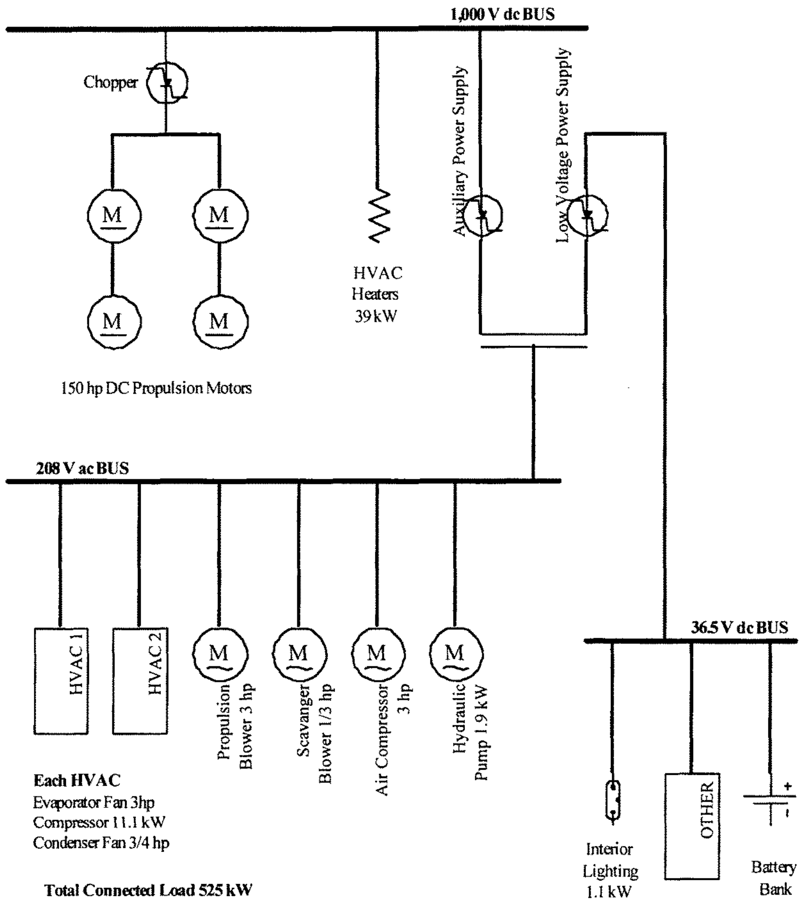



**Figure 1** Typical BART Car (C car) Electrical Distribution System and Loads

### 3.2 Major Energy Consuming Equipment Used by BART Cars

Major energy consuming devices used in the cars are shown in the following table. The power ratings listed are as read from the nameplates, or the measured power draw.

| ENERGY CONSUMING EQUIPMENT | | |
|---|---|---|
| **Energy Application** | **Quantity** | **Nominal Power** |
| **C Cars** | | |
| HVAC Indoor Fans | 2 | 2.7 kW |
| HVAC Compressors | 2 | 14.62 kW |
| HVAC Outdoor Fans | 2 | 0.6 kW |
| HVAC Heaters | 2 | 19.5 kW |
| Air Compressor | 1 | 3 hp |
| Propulsion Blower | 1 | 3 hp |
| Scavenger Blower | 1 | 0.33 hp |
| Hydraulic Pump | 1 | 1.9 kW |
| Other Equipment (e.g. communications, etc.) | 1 | 1.3 kW |
| Propulsion Motors | 4 | 150 hp |
| **A and B Cars** | | |
| HVAC Indoor Fans | 6 | 0.65 kW |
| HVAC Compressors | 6 | 5.46 kW |
| HVAC Outdoor Fans | 6 | 0.15 kW |
| HVAC Heaters* | 2 | 19.5 kW |
| Air Compressor* | 1 | 3 hp |
| Propulsion Blower* | 1 | 3 hp |
| Scavenger Blower* | 1 | 0.33 hp |
| Hydraulic Pump* | 1 | 1.9 kW |
| Other Equipment (e.g. communications, etc.)* | 1 | 1.3 kW |
| Propulsion Motors | 4 | 150 hp |

* No detail data was available for the auxiliary equipment used by the A and B cars. However it is expected that these systems will be similar to those used on the C cars.

### 3.3 Summary of Interior Lighting

The interior lighting for each car type is summarized in the following table.

Prefixes Used In Tables:

F20 = 20-Watt T12 fluorescent (with magnetic ballast), one lamp per fixture
T8-17 = 17-Watt T8 fluorescent (with electronic ballast), one lamp per fixture

| FACILITY LIGHTING SCHEDULE | | | | |
|---|---|---|---|---|
| **Car Type** | **Lamp Type** | **Number of Fixtures** | **Wattage/ Fixture** | **Total Wattage (kW)** |
| C1 Cars | F20 | 55 | 28.70 | 1.58 |
| C2 Cars | T8-17 | 55 | 20.44 | 1.12 |
| A Cars | T8-17 | 48 | 20.44 | 0.98 |
| B Cars | T8-17 | 48 | 20.44 | 0.98 |

* Each lighting fixture has only one lamp.

# 4. HISTORICAL ENERGY SUMMARY

## 4.1 Car Energy Consumption and Demand Summary

To establish a baseline for the electrical energy consumption of each BART car, we have used the following documents:

- *Qualification Test Report, Energy Consumption on Test Track, Rev C, 05/14/89.* This document presented the energy consumption of the C cars on a test track. From this document we also extracted the operational profile (how the cars were accelerated, maximum speeds as well as total distance covered).
- The result of the Energy Consumption on Test Track for the A/B cars (which were provided in an Excel spread sheet).

Based on the operational profile presented in *Qualification Test Report, Energy Consumption on Test Track, Rev C, 05/14/89* it is estimated that on average, a car will take approximately 0.024167 hours (approximately 1.45 minutes) to cover one mile. This conversion constant will be used throughout the report unless otherwise noted. The speed profile considered accelerating the train to approximately 80 mph in 45 seconds, maintaining a speed of 80 mph for 35 seconds and decelerating to a full stop in 60 seconds. A more detailed plot of the profile, which was used to derive the above constant, is included in the Appendix section at the end of the report.

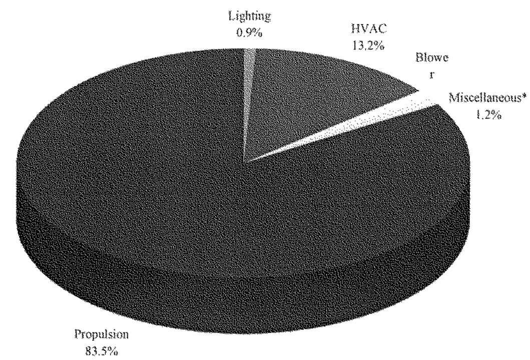
From the above documents and the average daily operating hours of the cars* it is possible to estimate the annual electrical energy consumption and demand of each car type as well as the total annual electrical energy consumption of all BART cars. The results are presented in the following table.

| ANNUAL ELECTRICAL ENERGY CONSUMPTION BY CAR TYPE | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Car Type** | **N** | **H** (hr/day) | **D** (mi/yr) | **EEC** (kWh/car-mi) | **AEEC** (kWh/car-yr) | **CD** (kW) | **AEE** (kWh/yr) |
| C1 | 150 | 7.7 | 116,435 | 3.6170 | 421,146 | 150 | 63,171,946 |
| C2 | 80 | 8.4 | 127,020 | 3.6122 | 458,816 | 150 | 36,705,269 |
| A | 59 | 8.1 | 122,275 | 3.3708 | 412,165 | 140 | 24,317,710 |
| B | 380 | 9.1 | 137,605 | 3.3708 | 463,839 | 140 | 176,258,795 |
| **Totals** | **669** | | | | | | **300,453,720** |

N = number of cars, H = average daily operating hours per car (provided by BART personnel), D = distance covered by each car in one year, EEC = electrical energy consumption per car per mile, AEEC = annual electrical energy consumption per car, CD = average created electrical demand per car and AEE = annual electrical consumption for all cars.

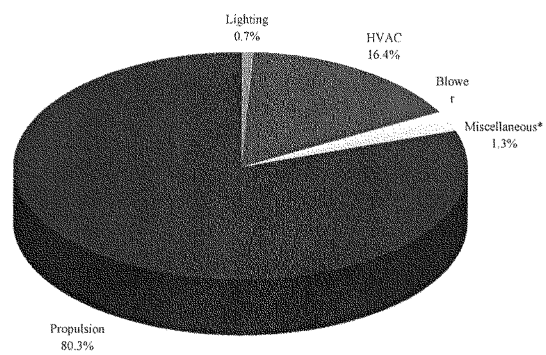
A pie chart illustrating the percentage of electrical energy usage for various functions is shown for C and A/B cars in Figures 2 and 3 respectively.

* Information provided by BART personnel through an Excel spread sheet.




* Unaccounted for, which also includes equipment not covered by the shown categories.

**Figure 2** – C Cars Electricity Consumption by Function




* Unaccounted for, which also includes equipment not covered by the shown categories.

**Figure 3** – A/B Cars Electricity Consumption by Function

# 5. DESCRIPTION OF ENERGY CONSERVATION AND EFFICIENCY MEASURES

This section summarizes the opportunities for energy efficiency for BART cars. The recommendations suggest methods of implementing energy efficiency measures. Implementation cost estimates are compared with energy cost savings to obtain simple payback periods. Detailed analysis for each proposed measure is presented in Section 6 – Detailed Analysis of the Measures.

Please note that the analyses presented here are preliminary and very limited in scope, which can serve as a guideline for further detailed analysis and engineering work. The assessment team has strived to utilize as much measured data, from present and past projects, as possible. Wherever assumptions were made, they have been clearly stated.

Tables ES-2A and ES-2B summarize the energy efficiency measures as elaborated in this section, in the respective categories of no-cost, low-cost, and investment grade.

**TABLE ES-2A SUMMARY OF ENERGY EFFICIENCY OPPORTUNITY INCENTIVES FOR EXISTING CARS (RETROFIT)**

| EEM No. Description | Energy Savings | Incentive or Rebate Program and Amount | Potential Incentive ($) | Installed Project Cost with Incentive ($) | Simple Payback Period w/ Incentive (yrs) |
|---|---|---|---|---|---|
| 1. High Efficiency Lighting for C1 Cars and New Cars | 156,872 kWh/yr | NRR-DR *$0.05/kWh* | Included in EEM 5 | Included in EEM 5 | Included in EEM 5 |
| 2. Direct Cooler Air to the Inlet of HVAC Condensers | 1,717,819 kWh/yr | NRR-DR *$0.14/kWh* | 240,495 | 100,000* | 0.6 |
| 3. Install Higher Efficiency HVAC Units on C Cars and New Cars | 413,021 kWh/yr | NRR-DR *$0.14/kWh* | 57,823 | 632,177 | 14.6 |
| 4. Optimize Outside Air Intake into Cars | 1,444,334 kWh/yr | NRR-DR *$0.14/kWh* | 202,207 | 847,793 | 5.6 |
| 5. Install Daylight Controls on the Fluorescent Lamps | 837,433 kWh/yr | NRR-DR *$0.05/kWh* | 49,715 | 2,820,270 | 22.4 |
| 6. Install Variable Frequency Drives on HVAC Supply Fans | 3,206,292 kWh/yr | NRR-DR *$0.14/kWh* | 448,881 | 1,475,000* | 4.4 |
| 7. Use Permanent Magnet (PM) Motors for Car Propulsion | 38,905,029 kWh/yr | NRR-DR *$0.08/kWh* | 3,112,402 | 51,344,198 | 12.6 |
| 8. Use Ultracapacitors for Regenerative Braking Energy Storage | 82,948,688 kWh/yr | NRR-DR *$0.08/kWh* | 6,635,895 | 88,038,753 | 10.1 |

* Incentive limited to 50% of measure's implementation cost.

**TABLE ES-2B SUMMARY OF ENERGY EFFICIENCY OPPORTUNITY INCENTIVES FOR NEW CARS (NRNC)**

| EEM No. Description | Energy Savings | Incentive Amount | Potential Incentive ($) | Installed Project Cost with Incentive ($) | Simple Payback Period w/ Incentive (yrs) |
|---|---|---|---|---|---|
| 1. High Efficiency Lighting for C1 Cars and New Cars | 1,170 kWh/car-y | *$0.05/kWh* | Included in EEM 5 | Included in EEM 5 | Included in EEM 5 |
| 2. Direct Cooler Air to the Inlet of HVAC Condensers | N / A | N / A | N / A | N / A | N / A |
| 3. Install Higher Efficiency HVAC Units on C Cars and New Cars | 1,242 kWh/car-y | *$0.14/kWh* | 174 | 857 | 6.6 |
| 4. Optimize Outside Air Intake into Cars | 2,184 kWh/car-y | *$0.14/kWh* | 306 | 1,264 | 5.5 |
| 5. Install Daylight Controls on the Fluorescent Lamps | 1,194 kWh/car-y | *$0.05/kWh* | 118 | 3,948 | 15.9 |
| 6. Install Variable Frequency Drives on HVAC Supply Fans | 4,196 kWh/car-y | *$0.14/kWh* | 587 | 3,823 | 8.7 |
| 7. Use Permanent Magnet (PM) Motors for Car Propulsion | 45,063 kWh/car-y | *$0.08/kWh* | 3,605 | 77,795 | 16.4 |
| 8. Use Ultracapacitors for Regenerative Braking Energy Storage | 123,989 kWh/car-y | *$0.08/kWh* | 9,919 | 118,517 | 9.1 |

**EEM No. 1 - High Efficiency Lighting for C1 Cars and New Cars**

In summary for this measure:

| | | |
|---|---|---|
| Retrofit | | |
| **Savings per car** | | |
| Electrical Energy Savings for C1 Cars | = | 0.008982 kWh/car-mi |
| | | 1,046† kWh/car-yr |
| **Savings for whole BART fleet** | | |
| Electrical Energy Savings | = | 156,872 kWh/yr |
| Demand Reduction | = | 42 kW |
| Electrical Cost Savings | = | $16,472/yr |
| Maintenance Cost Savings | = | $21,419/yr |
| Total Cost Savings | = | $37,891/yr |
| Implementation Cost | = | Included in EEO No. 4 |
| Simple Payback Period | = | Included in EEO No. 4 |
| New Construction | | |
| **Savings per car** | | |
| Electrical Energy Savings per Car | = | 0.007793 kWh/car-mi |
| | | 1,170‡ kWh/car-yr |
| Demand Reduction | = | 0.32 kW |
| Electrical Cost Savings | = | $123/yr |
| Implementation Cost | = | Included in EEO No. 4 |
| Simple Payback | = | Included in EEO No. 4 |

**Retrofit**

Currently only C1 cars use old 20-Watt T12 fluorescent lighting with magnetic ballasts. The retrofitted C cars (C2) as well as the A and B cars use the more energy efficient 17-Watt T8 fluorescent lighting with electronic ballast, which has an equivalent light output to the 20-Watt fluorescent lamp. In addition to lighting energy savings, retrofitting the T12 fluorescent lamps with T8 fluorescent lamps will result in HVAC energy savings since heat generated by lighting must be removed by the HVAC system. Based on the test profile presented in the *Energy Consumption Test On Test Track*, the difference in input wattage (including lamp and ballast power) and the energy efficiency ratio (EER) of the HVAC system, it is estimated that replacing the existing T12 fluorescent lamps with T8 fluorescent lamps will save approximately 0.013209 kWh/car-mi (or 230,695 kWh/yr) resulting in a demand reduction of 62 kW. These electrical savings will result in an avoided cost of approximately $24,223/yr.

† Based on average miles per year for C1 Cars.
‡ Based on average miles per year for all cars.

Please note that if EEO No. 4 *"Install Daylight Controls on the Fluorescent Lamps"* is implemented, the potential electrical savings will slightly decrease due to the lower operating wattage of the lamps. It is estimated that the savings would be reduced by 32%. The new electrical savings would be:

EES = 0.008982 kWh/car-mi
AEES = 156,872 kWh/yr
DS = 42 kW
EECS = $16,472/yr

To avoid overlap of savings this reduced electrical savings will be used unless otherwise noted.

This recommendation will also reduce annual maintenance cost of lighting due to longer life of T8 fluorescents lamps. It is estimated that this recommendation will reduce the annual maintenance cost by $21,419. The total cost savings will be the sum of the annual electrical energy cost savings and the maintenance cost savings, which is estimated to be $37,891 per year.

The implementation cost for this recommendation is included in EEO No. 4 - *Install Daylight Controls on the Fluorescent Lamps.*

**NRNC**

*The IESNA Lighting Handbook Reference and Application* recommends that seating areas in transit systems be illuminated at 30 footcandles (fc). However, the logged light level data inside a BART car shows that the minimum light level in the train car is approximately 50 fc. Based on the train car square footage, fixture efficiency, number of light fixtures in each car and a light level depreciation factor, it is estimated that to maintain 50 fc inside a train car will require that each fluorescent lamp output 948 lumens. The T12 and T8 fluorescent lamps that can output this light level are 20- and 17-Watt lamps, respectively.

Since there are no lighting energy efficiency standards for transportation vehicles it is proposed that the present light level of 50 fc be considered as baseline.

- Based on the number of fixtures inside each train car (55 fixtures), train car square footage (735 $ft^2$) and the input power rating of a standard efficiency 20-Watt fluorescent lamp (28.7 Watts), the baseline lighting power density ($LPD_B$) for high efficiency lighting should be 2.1 $W/ft^2$.

The annual electrical energy savings (for one car) for using high efficiency T8 lighting would be 1,170 kWh/yr.

**EEM No. 2 - Direct Cooler Air to the Inlet of HVAC Condensers**

Directing cooler air to the inlet of the HVAC condensers will reduce the energy consumption of the HVAC system. In summary for this measure:

Retrofit
**Savings per car**

| | | |
|---|---|---|
| Electrical Energy Savings for A/B Cars | = | 0.01995 kWh/car-mi<br>2,704 kWh/car-yr |
| Electrical Energy Savings for C Cars | = | 0.01921 kWh/car-mi<br>2,307 kWh/car-yr |

**Savings for whole BART fleet**

| | | |
|---|---|---|
| Electrical Energy Savings | = | 1,717,819 kWh/yr |
| Peak Demand Reduction | = | 409.29 kW |
| Electrical Cost Savings | = | $180,370/yr |
| Implementation Cost | = | $200,000 |
| Simple Payback Period | = | 1.1 years |

New Construction
**Savings per car**

| | | |
|---|---|---|
| Electrical Energy Savings per Car | = | N / A |

**Retrofit**

Table 2-1 summarizes the HVAC system for various BART cars as well the nominal rating of the various HVAC system components. The HVAC units are controlled based on the return air temperature.

**TABLE 2-1 SUMMARY OF BART CAR HVAC SYSTEM**

| HVAC Component | Number of Units per Car | Nominal Rating per Unit* (kW/unit) |
|---|---|---|
| **A & B Cars** | | |
| HVAC Compressor | 6 | 5.46 |
| Evaporator (Supply) Blower | 6 | 0.65 |
| Condenser Fan | 6 | 0.15 |
| **C1 & C2 Cars** | | |
| HVAC Compressor | 2 | 14.62 |
| Evaporator (Supply) Blower | 2 | 2.7 |
| Condenser Fan | 2 | 0.6 |

Currently the heat generated by the resistor banks due to regenerative braking affects the temperature of the inlet to the condensers. Generally, the higher the temperature at the inlet of the condensers, the more energy the HVAC system will consume to cool the air.

To evaluate how the heat absorbed from the regenerative braking by the resistor bank affects the temperature of the inlet to the condensers, the audit team requested for temperature measurements of the inlet to the condenser heat exchanger and the outside ambient temperature to be performed. The audit team borrowed two temperature probes and a datalogger from the Pacific Energy Center's Tool Lending Library and sent this equipment to BART personnel to install on a BART car. The measurement was first performed on BART's test track to ensure that the equipment was set-up properly and the datalogger was recording the desired measurements. Since the regenerative braking system does not work on the test track, the inlet temperature to the condensers was found to be close to ambient conditions. BART personnel were able to schedule the measurements to be performed on a live track run, where passengers were not allowed on the car in which the equipment was installed. Figure 2-1 shows where the temperature probes were placed on the C cars to measure the temperature of the inlet to the condensers and the outside ambient temperature.

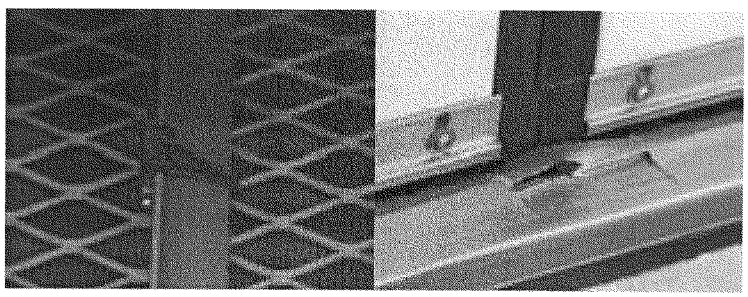


**Figure 2-1** (*Left*) Temperature Probe Mounted on Inlet to Condenser Heat exchanger. (*Right*) Temperature Probe Mounted on Car Door to Measure Outdoor Ambient Temperature

Figure 2-2 below shows the results of the live track run for a roundtrip run from Hayward to Richmond. The measurements show that the temperature of the inlet to the condenser was (for most cases) significantly higher than ambient outdoor conditions.

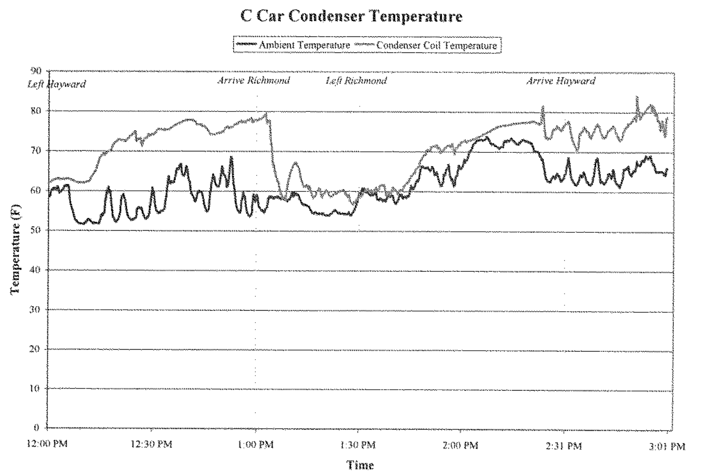



**Figure 2-2** C Car Condenser and Ambient Temperature Measurements from Live Track Run

It is recommended that cooler outside air be directed to the inlet of the condenser heat exchanger, thereby reducing the amount of work required by the compressors to cool the air. The details of the methodology and analysis of this measure is included in the Section 6 of this report. Table 2-2 summarizes the potential electrical energy, demand and cost savings that may be realized by directing cooler air to the inlet of the condenser.

| Car Type | Number of Cars | Savings per car per mile (kWh/car-mi) | Annual Distance Covered (mi/yr) | Energy Savings (kWh/yr) | Peak Demand Savings (kW) | Total Cost Savings ($/yr) |
|---|---|---|---|---|---|---|
| A | 59 | 0.01995 | 122,275 | 143,924 | 36.50 | 15,112 |
| B | 380 | 0.01995 | 137,605 | 1,043,184 | 235.52 | 109,534 |
| C1 | 150 | 0.01921 | 116,435 | 335,507 | 89.52 | 35,228 |
| C2 | 80 | 0.01921 | 127,020 | 195,204 | 47.75 | 20,496 |
| **Totals** | **669** | | | **1,717,819** | **409.29** | **180,370** |

Table title: TABLE 2-2 SUMMARY OF ELECTRICAL AND COST SAVINGS

From Table 2-2, directing cooler air to the intake of the condenser heat exchanger will reduce the electrical energy consumption of the HVAC compressors by approximately 1,717,819 kWh/yr resulting in a peak demand reduction of 409.29 kW. These electrical savings will result in an avoided electrical cost of approximately $180,370 per year.

Implementing this recommendation will require installing pathways to bring outside air from the sides of the cars to the inlet of the condenser heat exchanger. It has been estimated that installing pathways to direct outside air to the inlet of the condenser heat exchanger will result in an implementation cost of roughly $200,000.

Please note that the implementation cost includes only the typical installed cost of pathways. This cost does not include the engineering costs associated with the design of such a system. The total cost savings of $180,370 will pay back for the implementation cost of $200,000 in approximately 1.1 years.

**Note:** Detailed engineering will be needed to implement this measure, which is beyond the scope of this project.

**NRNC**

Since this recommendation deals with directly modifying an existing system (with no newer energy efficient equipment), this recommendation does not apply to new construction.

**EEM No. 3 - Install Higher Efficiency HVAC Units on C Cars and New Cars**

Replace the existing packaged air conditioning units on the C cars with higher efficiency units.

| | | |
|---|---|---|
| Retrofit | | |
| **Savings per car** | | |
| Electrical Energy Savings for C Cars | = | 0.01495 kWh/car-mi<br>1,796 kWh/car-yr |
| **Savings for whole BART fleet** | | |
| Electrical Energy Savings | = | 413,021 kWh/yr |
| Peak Demand Reduction | = | 106.83 kW |
| Electrical Cost Savings | = | $43,367/yr |
| Implementation Cost Premium | = | $690,000 |
| Simple Payback Period | = | 16 years |
| New Construction | | |
| **Savings per car** | | |
| Electrical Energy Savings per Car | = | 0.009534 kWh/car-mi<br>1,242 kWh/car-yr |
| Demand Reduction | = | 0.39 kW |
| Electrical Cost Savings | = | $130/yr |
| Implementation Cost Premium | = | $1,031 |
| Simple Payback | = | 7.9 years |

**Retrofit**

The C cars (C1 and C2 cars) utilize two HVAC units per car to provide heating and cooling. Each HVAC unit is equipped with a 14.6 (nominal rating) kW reciprocating R-22 compressor, 2.7 kW evaporator blower and a 0.6 kW condenser fan. The HVAC units are controlled based on the return air temperature.

The HVAC systems for the C cars have been installed in the 1980s. More efficient technologies are currently available that are more efficient than the existing HVAC units. According to the "*Qualification Test Report: Performance of HVAC System (Energy Consumption) Installed on BART C Car*" provided to the audit team by BART, the energy efficiency ratio (EER) of the existing HVAC units while in cooling mode is approximately 8.4. EER is a measure of an air conditioning unit's cooling capacity (in Btu/hr) per electrical energy input (power draw in watts). The higher a HVAC unit's EER, the less electricity the unit uses to provide the same amount of cooling. Based on data provided by StoneAir, a manufacturer of HVAC units for the transit industry, higher efficiency HVAC units currently available have an EER of about 9.1.

Another benefit with the higher efficiency HVAC units is that the new HVAC system utilizes scroll-type compressors instead of the existing reciprocating compressors. Scroll compressors are lighter, more reliable and less maintenance intensive compared to reciprocating compressors. Other benefits of the higher efficiency HVAC units as presented by StoneAir is included in the appendix of this report.

The details of the methodology and analysis of this measure is included in the Section 6 of this report. Table 3-1 on the following page summarizes the potential electrical energy, demand and cost savings that may be realized by replacing the existing HVAC units with higher efficiency units.

**TABLE 3-1 SUMMARY OF ELECTRICAL AND COST SAVINGS**

| Car Type | Number of Cars | Savings per car per mile (kWh/car-mi) | Annual Distance Covered (mi/yr) | Energy Savings (kWh/yr) | Peak Demand Savings (kW) | Total Cost Savings ($/yr) |
|---|---|---|---|---|---|---|
| C1 | 150 | 0.01495 | 116,435 | 261,105 | 69.67 | 27,416 |
| C2 | 80 | 0.01495 | 127,020 | 151,916 | 37.16 | 15,951 |
| **Totals** | **230** | | | **413,021** | **106.83** | **43,367** |

From Table 6-1, replacing the existing HVAC units with higher efficiency units will reduce the electrical energy consumption by approximately 413,021 kWh/yr resulting in a peak demand reduction of 106.83 kW. These electrical savings will result in an avoided electrical cost of approximately $43,367 per year.

The implementation cost premium for this measure is taken to be the cost differential between a high efficiency HVAC unit and a standard efficiency HVAC unit. The costs of the existing HVAC units and the proposed higher efficiency units were not available to BASE, thus we have taken the cost differential between a typical standard 7-ton HVAC unit and a high efficiency 7-ton HVAC unit to be the implementation cost premium for this case. The total implementation cost premium for this measure has been roughly estimated to be $690,000. The estimated total cost savings of $43,369 per year would pay for the estimated implementation cost premium of $690,000 in about 16 years.

**Notes:**

1. It should be noted when purchasing higher efficiency HVAC units, they should be specified to be equipped with the capabilities as recommended in EEOs No. 2, 4, and 6. This will increase the initial cost of the new HVAC system, however this may be less costly than retrofitting the existing units if plans are eventually made for replacing the entire HVAC system with more efficient units.
2. This recommendation only considers the HVAC system for the C cars because these were the cars that BART personnel were more focused in upgrading the HVAC system. C cars are much older than the A and B cars. As mentioned previously, the EER for the C car HVAC system was estimated to be approximately 8.4. The A and B cars are estimated to have an EER of 8.7. Since BART personnel were concerned mainly with the C cars' HVAC system, we have based our analyses on these cars in this project.

**NRNC**

For new cars, the baseline considered for a high efficiency HVAC system is the existing HVAC system in the newer A/B cars. This includes six 5.46 kW HVAC compressors (motor efficiency of 0.918) and an energy efficiency ratio (EER) value of 8.7 Btu/W-h. Using the A/B car HVAC system as baseline, and comparing the energy consumption of the proposed, more energy efficient, HVAC system (with an EER value of 9.1 Btu/W-h), the potential energy savings would be 0.009534 kWh/car-mi, resulting in an annual electrical energy savings of approximately 1,242 kWh/car-yr.

**EEM No. 4 - Optimize Outside Air Intake into Cars**

Optimize the amount of outside air intake into the cars based on the outside air temperature. In summary for this measure:

| | | |
|---|---|---|
| Retrofit | | |
| **Savings per car** | | |
| Electrical Energy Savings for A/B Cars | = | 0.01677 kWh/car-mi |
| | | 2,273 kWh/car-yr |
| Electrical Energy Savings for C Cars | = | 0.01616 kWh/car-mi |
| | | 1,941 kWh/car-yr |
| **Savings for whole BART fleet** | | |
| Electrical Energy Savings | = | 1,444,334 kWh/yr |
| Peak Demand Reduction | = | 344.16 kW |
| Electrical Cost Savings | = | $151,791/yr |
| Implementation Cost | = | $1,050,000 |
| Simple Payback Period | = | 6.9 years |
| New Construction | | |
| **Savings per car** | | |
| Electrical Energy Savings per Car | = | 0.01677 kWh/car-mi |
| | = | 2,184 kWh/car-yr |
| Demand Reduction | = | 0.69 kW |
| Electrical Cost Savings | = | $229/yr |
| Implementation Cost | = | $1,570 |
| Simple Payback | = | 6.8 years |

**Retrofit**

Fresh outside air should to be used directly for space cooling whenever outdoor temperature and humidity levels are favorable. By using cool **outside** air whenever possible, the energy usage by the cars' HVAC compressors can be reduced. Table 4-1 summarizes the HVAC system for various BART cars as well the nominal rating of the various HVAC system components. The HVAC units are controlled based on the return air temperature.

| TABLE 4-1 SUMMARY OF BART CAR HVAC SYSTEM | | |
|---|---|---|
| **HVAC Component** | **Number of Units per Car** | **Nominal Rating per Unit*** (kW/unit) |
| | **A & B Cars** | |
| HVAC Compressor | 6 | 5.46 |
| Evaporator (Supply) Blower | 6 | 0.65 |
| Condenser Fan | 6 | 0.15 |
| | **C1 & C2 Cars** | |
| HVAC Compressor | 2 | 14.62 |
| Evaporator (Supply) Blower | 2 | 2.7 |
| Condenser Fan | 2 | 0.6 |

Based on documents provided and conversations with BART personnel regarding the operation of the HVAC units, outside air is drawn into the cars through 'grilles in the sides on feature line'. The air then passes through ducts to inlet mixing plenums upstream of the air treatment units where it is mixed with recirculated air. The amount of outside air drawn into the cars does not vary, regardless of outdoor temperature conditions. Optimizing the usage of outside air will reduce the electrical energy consumption of the HVAC compressor motor. The air distribution fan in each unit must still be used.

The details of the methodology and analysis of this measure is included in the Section 6 of this report. The results for potential electrical energy, demand and cost savings are summarized on Table 4-2 on the following page.

| TABLE 4-2 SUMMARY OF ELECTRICAL AND COST SAVINGS | | | | | | |
|---|---|---|---|---|---|---|
| **Car Type** | **Number of Cars** | **Savings per car per mile** (kWh/car-mi) | **Annual Distance Covered** (mi/yr) | **Energy Savings** (kWh/yr) | **Peak Demand Savings** (kW) | **Total Cost Savings** ($/yr) |
| A | 59 | 0.01677 | 122,275 | 120,983 | 30.69 | 12,839 |
| B | 380 | 0.01677 | 137,605 | 876,902 | 197.98 | 92,075 |
| C1 | 150 | 0.01616 | 116,435 | 282,238 | 75.32 | 29,635 |
| C2 | 80 | 0.01616 | 127,020 | 164,211 | 40.17 | 17,242 |
| **Totals** | **669** | | | **1,444,334** | **344.16** | **151,791** |

From Table 4-2, bringing in outside air when outdoor temperature and humidity levels are favorable will reduce the electrical energy consumption by the HVAC compressors by approximately 1,444,334 kWh/yr, resulting in a peak demand reduction of 344.16 kW. These electrical savings will result in an avoided electrical cost of approximately $151,791 per year.

Implementing this recommendation will require installing motorized dampers onto the existing HVAC units that will bring in outside air when outdoor ambient conditions are favorable and temperature sensors to measure the ambient conditions. It has been estimated that the total implementation cost of this measure is roughly $1,050,000.

Please note that the implementation cost includes only the typical installed cost of the motorized damper and outdoor temperature sensor. This cost does not include the cost to interface the damper and sensor to the HVAC control system, nor the engineering costs associated with the design of such a system. The total cost savings of $151,791 will pay back for the implementation cost of $1,050,000 in approximately 6.9 years.

**Notes:**

1. It must be noted that the HVAC run hours and the temperature ranges used in this EEO was estimated from an annual average weather condition database taken from the Oakland area, and is subject to change depending on the location of the BART car. Moreover, the EEO does not account for possible changes in the relative humidity.
2. This measure may require increasing the size of the outside air duct, which will be determined from the detailed engineering of this measure.
3. Detailed engineering will be needed to implement this measure, which is beyond the scope of this project.

**NRNC**

For new cars, the baseline considered for a high efficiency HVAC system is the existing HVAC system in the newer A/B cars. The potential energy savings would be 0.01677 kWh/car-mi, resulting in an annual electrical energy savings of approximately 2,184 kWh/car-yr.

**EEM No. 5 - Install Daylight Controls on the Fluorescent Lamps**

In summary for this measure:

| | | |
|---|---|---|
| Retrofit | | |
| **Savings per car** | | |
| Electrical Energy Savings for A/B Cars | = | 0.009171 kWh/car-mi<br>1,243 kWh/car-yr |
| Electrical Energy Savings for C Cars | = | 0.010560 kWh/car-mi<br>1,268 kWh/car-yr |
| **Savings for whole BART fleet** | | |
| Electrical Energy Savings | = | 837,433 kWh/yr |
| Demand Reduction | = | 0 kW |
| Electrical Cost Savings | = | $87,930/yr |
| Implementation Cost | = | $2,720,330 |
| Simple Payback Period | = | 31 years |
| New Construction | | |
| **Savings per car** | | |
| Electrical Energy Savings per Car | = | 0.009171 kWh/car-mi<br>1,194§ kWh/car-yr |
| Demand Reduction | = | 0.0 kW |
| Electrical Cost Savings | = | $125/yr |
| Implementation Cost | = | $4,066 |
| Simple Payback | = | 16.4** years |

**Retrofit**

Currently C1 cars use 20-Watt T12 fluorescent lighting with magnetic ballasts, while A/B and C2 cars use high efficiency 17-Watt T8 fluorescent lighting with electronic ballasts. These lamps remain fully on, although 64% of BART tracks are above ground. Figure 5-1 below shows the light level inside a BART car starting on the Daly City Station and ending on the Pittsburg/Bay Point Station as measured by light sensors installed by the assessment team.

Figure 5-1, in the following page, shows the following interesting trends:

- The minimum light level required inside a BART car is about 50 fc.
- Approximately 62% of the track covered by the Daly City – Pittsburg/North Point line is on the surface. This is very close to the fraction of tracks that are on the surface for all BART lines, which is 64%.

§ This is with the assumption that new train cars will use high efficiency lighting.
** Considers the electrical cost savings from EEM No. 1 - High Efficiency Lighting

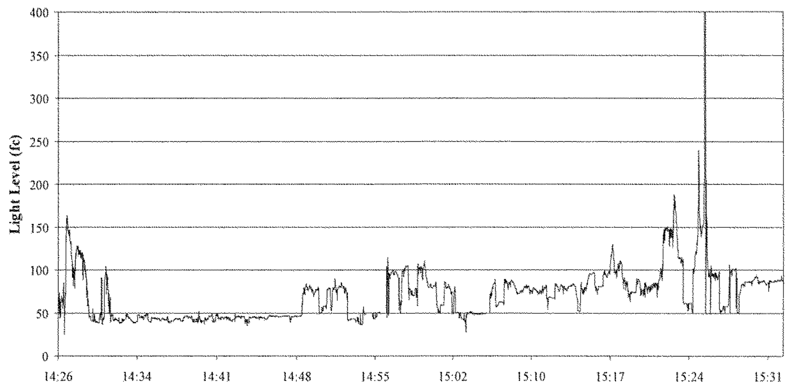



**Figure 5-1 Light Level inside a BART Car during June 9 2006 (Daly City – Pittsburg/Bay Point)**

Based on the logged light level data, the fraction of surface track of all BART lines, and a computer simulation of the light levels from sunrise to sun set for each month of the year, it is estimated that on average, the fluorescent lamps could be dimmed to 55% of its nominal light output during daytime (with the added restriction that the lamps output should never go below 25%, even when there is enough daylight available from windows).

Table 5-1 summarizes the potential electrical energy and cost savings for the A/B and C cars.

**TABLE 5-1 SUMMARY OF ELECTRICAL ENERGY AND COST SAVINGS**

| Car Type | Number of Cars | Number of Fixtures | IW (W) | EES (kWh/C-mi) | AEES (kWh/yr) | CS ($/yr) |
|---|---|---|---|---|---|---|
| A | 59 | 48 | 20.44 | 0.009171 | 66,160 | 6,947 |
| B | 380 | 48 | 20.44 | 0.009171 | 479,540 | 50,352 |
| C1 | 150 | 55 | 20.44* | 0.010560 | 184,428 | 19,365 |
| C2 | 80 | 55 | 20.44 | 0.010560 | 107,304 | 11,267 |
| **Totals** | **669** | | | | **837,433** | **87,930** |

* C1 cars currently use standard efficiency T12 lamp. However it is assumed that these lamps will be replaced with the more energy efficient T8 lamps. Thus saving estimates are based on the more energy efficient T8 lamp.
IW = lamp input wattage, EES = electrical energy savings, AEES = annual electrical energy savings and CS = cost savings.

From Table 5-1, dimming the fluorescent lamps could save approximately 837,433 kWh/yr. Since the lights would have to come to full brightness when the train goes underground, it is expected that this recommendation will not result in demand savings. The total avoided electrical cost would be approximately $87,930.

Implementing this recommendation will require installing 277 V dimmable fluorescent ballasts (2-lamp ballasts), a daylight sensor, a daylight controller, a power pack and a 1.8 kW inverter to transform DC voltage (from the battery system) to AC voltage. Based on a manufacturer's quote and RS Means Electrical Cost Data 2006, the implementation cost can be itemized as follows:

| | |
|---|---|
| (16,976) 2-lamp dimmable ballasts | $ 1,188,320 |
| (669) Daylight sensors | $ 73,590 |
| (669) Daylight controllers | $ 267,600 |
| (669) Power Packs | $ 120,420 |
| (669) 1.8 kW inverters | $ 869,700 |
| Installation Costs | $ 200,700 |
| **Total Cost** | **$ 2,720,330** |

Therefore the total cost savings of $87,930 will pay back for the implementation cost of $2,720,330 in approximately 31 years.

**NRNC**

Installing daylight controls on new BART car lighting fixtures will result in electrical energy savings. The proposed baseline for estimating the electrical savings of daylight controls on new train cars is the lighting system in the A/B cars without daylight controls. From the above, the potential electrical energy savings per car mile for installing daylight controls in the A/B cars will be 0.009171 kWh/car-mi resulting in an annual electrical energy savings of 1,194 kWh/car-yr ( at an average distance covered by one car in one year of 130,241 mi/yr).

**EEM No. 6 - Install Variable Frequency Drives on HVAC Supply Fans**

Install variable frequency drives (VFD, the same as adjustable speed drive) on the HVAC supply fan motors in all car units. A VFD will reduce the power consumption of the supply fans depending on the cars' return air temperature.

| | | |
|---|---|---|
| Retrofit | | |
| **Savings per car** | | |
| Electrical Energy Savings for A/B Cars | = | 0.03222 kWh/car-mi |
| | | 4,367 kWh/car-yr |
| Electrical Energy Savings for C Cars | = | 0.04666 kWh/car-mi |
| | | 5,604 kWh/car-yr |
| **Savings for whole BART fleet** | | |
| Electrical Energy Savings | = | 3,206,292 kWh/yr |
| Peak Demand Reduction | = | 0.0 kW |
| Electrical Cost Savings | = | $336,661/yr |
| Implementation Cost | = | $2,950,000 |
| Simple Payback Period | = | 8.8 years |
| New Construction | | |
| **Savings per car** | | |
| Electrical Energy Savings per Car | = | 0.03222 kWh/car-mi |
| | = | 4,196 kWh/car-yr |
| Demand Reduction | = | 0.0 kW |
| Electrical Cost Savings | = | $441/yr |
| Implementation Cost | = | $4,410 |
| Simple Payback | = | $10.0 years |

**Retrofit**

Table 6-1 summarizes the HVAC system for various BART cars as well the nominal rating of the various HVAC system components. The HVAC units are controlled based on the return air temperature.

| TABLE 6-1 SUMMARY OF BART CAR HVAC SYSTEM | | |
|---|---|---|
| **HVAC Component** | **Number of Units per Car** | **Nominal Rating per Unit*** (kW/unit) |
| **A & B Cars** | | |
| HVAC Compressor | 6 | 5.46 |
| Evaporator (Supply) Blower | 6 | 0.65 |
| Condenser Fan | 6 | 0.15 |
| **C1 & C2 Cars** | | |
| HVAC Compressor | 2 | 14.62 |
| Evaporator (Supply) Blower | 2 | 2.7 |
| Condenser Fan | 2 | 0.6 |

Based on conversations with BART personnel regarding the operation of the HVAC system, the operation of the HVAC compressors are controlled based on the return air temperature, however the air supplied to the cars are constant with only damper control. It is recommended that variable frequency drives (VFDs) be installed on the evaporator (supply) blowers to replace damper control. A VFD will control the airflow provided to the cars based on the cars' return air temperature, which varies based on the occupancy level of the cars. The hourly passenger loading variation for the BART system was not available to BASE. Thus, we have taken a typical transit passenger loading profile shown in Figure 6-1 on the following page, extracted from Vuchic (2005).

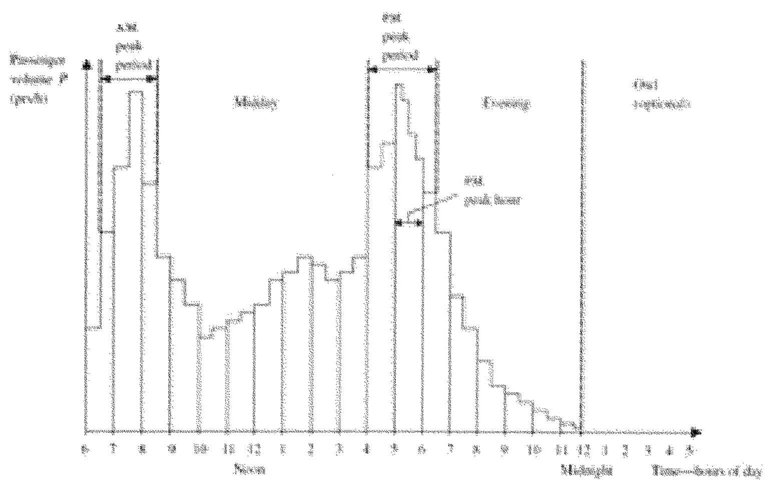


**Figure 6-1** Hourly Variation of Passenger Volume for a Typical Transit Line

By installing a VFD on each HVAC supply fan, energy savings can be obtained due to the fact that the fan motors will no longer be consuming 100% of its rated power during a majority of the cars' running hours.

The details of the methodology and analysis of this measure is included in Section 6 of this report. The results for potential electrical energy, demand and cost savings are summarized on Table 6-2 below.

**TABLE 6-2 SUMMARY OF ELECTRICAL AND COST SAVINGS**

| Car Type | Number of Cars | Savings per car per mile (kWh/car-mi) | Annual Distance Covered (mi/yr) | Energy Savings (kWh/yr) | Total Cost Savings ($/yr) |
|---|---|---|---|---|---|
| A | 59 | 0.03222 | 122,275 | 232,442 | 24,406 |
| B | 380 | 0.03222 | 137,605 | 1,684,781 | 176,902 |
| C1 | 150 | 0.04666 | 116,435 | 814,929 | 85,568 |
| C2 | 80 | 0.04666 | 127,020 | 474,140 | 49,785 |
| **Totals** | **669** | | | **3,206,292** | **336,661** |

From Table 6-2 installing VFDs on the HVAC supply fans will reduce the electrical energy consumption by 3,206,292 kWh/yr. There is not expected to be any demand savings due to implementation of this measure since the fans are expected to operate at or near full load during peak hours. The electrical energy savings will result in an avoided electrical cost of approximately $336,661 per year.

Implementing this recommendation will require installing VFD control units onto the existing supply fans and removing the existing dampers. The VFD will be controlled based on the car units' return air temperature. It has been estimated that installing VFD control units on all of the BART car HVAC supply fans will result in an implementation cost of roughly $2,950,000.

Please note that the implementation cost includes only the typical installed cost of the VFD control units. This cost does not include the cost to interface the VFDs to the HVAC control system, nor the engineering costs associated with the design of such a system. The total cost savings of $336,661 will pay back for the implementation cost of $2,950,000 in approximately 8.8 years.

**Note:** Detailed engineering will be needed to implement this measure, which is beyond the scope of this project.

**NRNC**

For new cars, the baseline considered for HVAC fan control is the existing HVAC fan control in the newer A/B cars. For installing VFD control on HVAC fans in new train cars, the potential energy savings would be 0.03222 kWh/car-mi, resulting in an annual electrical energy savings of approximately 4,367 kWh/car-yr.

**EEM No. 7 - Use Permanent Magnet (PM) Motors for Car Propulsion**

In summary for this measure:

| | | |
|---|---|---|
| Retrofit | | |
| **Savings per car** | | |
| Electrical Energy Savings for A/B Cars | = | 0.346 kWh/car-mi |
| | | 46,898 kWh/car-yr |
| Electrical Energy Savings for C Cars | = | 0.663 kWh/car-mi |
| | | 79,637 kWh/car-yr |
| **Savings for whole BART fleet** | | |
| Electrical Energy Savings | = | 38,905,029 kWh/yr |
| Demand Reduction | = | 9,424 kW |
| Electrical Cost Savings | = | $4,085,028/yr |
| Implementation Cost Premium | = | $54,456,600 |
| Simple Payback | = | 13.3 years |
| New Construction | | |
| **Savings per car** | | |
| Electrical Energy Savings per Car | = | 0.346 kWh/car-mi |
| | | 45,063 kWh/car-yr |
| Demand Reduction | = | 14.32 kW |
| Electrical Cost Savings | = | $4,732/yr |
| Implementation Cost Premium | = | $81,400 |
| Simple Payback | = | 17.2 years |

**Retrofit**

Currently the C1 and C2 cars use direct current motors (DC) while the A and B cars use induction motors (IM) for propulsion. Replacing these motors with permanent magnet (PM) motors could result in significant electrical energy and maintenance cost savings. Based on test data provided by BART personnel and with the help of *DRS ELECTRIC POWER TECHNOLOGIES, INC.* (a PM motor manufacturer) a computer model was developed to compare the electrical energy consumption as well as potential electrical energy regeneration capability of an IM and a PM propulsion system. The results of the computer model for the IM and PM motors were then scaled to the results of the Qualification Test Report: Energy Consumption Test on Test Track performed for the A/B cars. For the C cars, which use DC motors, the results were obtained based on the comparison of actual test track data of C cars and the scaled data for the PM motors.

The details of the methodology and analysis of the computer model is included in the Appendix of the report. The results from this study are summarized on Table 7-1 below.

| TABLE 7-1 SUMMARY OF ELECTRICAL AND COST SAVINGS | | | | | | |
|---|---|---|---|---|---|---|
| **Car Type** | **Number of Cars** | **Savings per car per mile** (kWh/car-mi) | **Distance Covered** (mi/yr) | **Energy Savings** (kWh/yr) | **Demand Savings** (kW) | **Total Cost Savings** ($/yr) |
| A | 59 | 0.346 | 122,275 | 2,496,122 | 631 | 262,093 |
| B | 380 | 0.346 | 137,605 | 18,092,305 | 4,071 | 1,899,692 |
| C1 | 150 | 0.663 | 116,435 | 11,579,461 | 3,079 | 1,215,843 |
| C2 | 80 | 0.663 | 127,020 | 6,737,141 | 1,642 | 707,400 |
| **Totals** | **669** | | | **38,905,029** | **9,424** | **4,085,028** |

From Table 7-1, replacing the existing induction motors and DC motors with permanent magnet motors will reduce the electrical energy consumption by 38,905,029 kWh/yr resulting in a demand reduction of 9,424 kW. These electrical savings will result in an avoided electrical cost of approximately $4,085,028 per year.

Besides the overall increase in energy efficiency, PM motors will result in significant annual maintenance cost savings. The non-energy efficiency benefits that PM motors could provide to BART are:

1. The possibility of completely eliminating gear boxes since PM motors can provide the required torque throughout its rpm range.
2. Since PM motors are synchronous machines, each motor will have to be powered from independent motor drives to prevent damage to the machine from uneven ware of the steel wheels; however this can be used to an advantage by preventive maintenance personnel since it will be possible to track defects and worn out steel wheels electronically.

Implementing this recommendation will require a major retrofit to the existing BART cars. The essential required components will be four permanent magnet motors and new electronic drives for each motor. Based on a **very preliminary quotation** by the PM motor manufacturer, the implementation cost could be itemized as follows[††]:

(2,676) 175 hp PM motor plus cooling pack........................................$ 66,900,000
(2,676) 450 hp water cooled electronic drives......................................$ 133,800,000
Non-refundable engineering costs........................................................$ 8,697,000
**Total Cost...............................................................................................$ 209,397,000**

If it is opted to install the permanent magnet motors as the existing AC (or DC) systems come to their end-of life, then the implementation cost will be the cost premium for choosing a PM drive system instead of an AC or DC drive system. Based on RS Means Electrical Cost Data 2007, the cost for purchasing the 150 hp AC motors and 400 hp variable frequency drives can be estimated as follows:

[††] These are off-the-shelf product prices.

| | |
|---|---|
| (2,676) 150 hp AC TEFC motor | $ 30,238,800 |
| (2,676) 400 hp variable frequency drives | $ 124,701,600 |
| **Total Cost** | **$ 154,940,400** |

The cost premium will be the cost difference between replacing the existing units with PM units instead of replacing them with new AC (or DC) systems. Therefore, the total cost savings of $4,085,028 would pay for the cost premium of $54,456,600 in approximately 13 years.

Notes:

1. This cost estimate does not consider installation costs.
2. For calculation of cost premium, it is assumed that the cost of DC motors and choppers is similar to the cost of the AC motors and variable frequency drives.

**NRNC**

Installing permanent magnet motors on new BART cars will result in electrical energy savings. The proposed baseline for estimating the electrical savings of permanent magnet motors on new train cars is the existing AC motor system in the A/B cars. From the above, the potential electrical energy savings per car mile for installing permanent magnet motors in the A/B cars will be 0.346 kWh/car-mi resulting in an annual electrical energy savings of 45,063 kWh/car-yr ( at an average distance covered by one car in one year of 130,241 mi/car-yr).

**EEM No. 8 - Use Ultracapacitors for Regenerative Braking**

In summary for this measure:

| | | |
|---|---|---|
| Retrofit | | |
| **Saving per car** | | |
| Electrical Energy Savings per car mile | = | 0.952 kWh/car-mi<br>123,989 kWh/car-year |
| **Savings for whole BART fleet** | | |
| Electrical Energy Savings | = | 82,948,688 kWh/yr |
| Demand Reduction | = | 19,733 kW |
| Electrical Cost Savings | = | $8,709,612/yr |
| Implementation Cost | = | $94,674,648 |
| Simple Payback Period | = | 10.9 years |
| New Construction | | |
| **Saving per car** | | |
| Electrical Energy Savings per Car | = | 0.952 kWh/car-mi<br>123,989 kWh/car-year |
| Demand Reduction | = | 39.39 kW |
| Electrical Cost Savings | = | $13,019/yr |
| Implementation Cost | = | $128,439 |
| Simple Payback | = | 9.9 years |

**Note: Please refer to Appendix B – Ultracapacitor Implementation Addendum for details on reference and application of this technology**

**Retrofit**

The ultracapacitor is a new electrical energy storage device. Its working principle is a combination of traditional batteries and capacitors. A typical double layer ultracapacitor uses a very porous material (like carbon), which is immersed in an electrolyte solution. When an electric field is applied across the ultracapacitor terminals, the electrodes and electrolyte polarize forming a double layer of ions. These ions (electrical energy) are stored in the pores of the electrodes.‡‡ Due to the electrochemical properties of the electrodes, no electrons are transferred between the electrode and electrolyte.

Because of the large effective surface area of the porous electrodes (500 – 2,000 $m^2/g$) and the and small pore diameter (in the range of nanometers), ultracappacitors are able to store a large amount of energy (e.i. a very high capacitance relative to traditional capacitors). Additionally,

‡‡ Bruke, Andrew, "Ultracapacitors: Why, How, and Where is the Technology," Institute of Transportation Studies (University of California, Davis), http://repositories.cdlib.org/itsdavis/UCD-ITS-REP-00-17.

since energy is stored as a separation of charge (electric energy storage), ultracapacitors are capable of releasing the stored energy very quickly (i.e. high output power).

The ultracapacitor energy density (Wh/kg) is about ten times smaller than that of conventional chemical batteries, however its power density (W/kg) is similar to the conventional capacitor, which is one thousand times larger than conventional batteries[§§]. Destraz et.al. (2004) compare the energy storage performance of ultracapacitors and conventional batteries; the following table is taken form Destraz et.al. (2004) paper.

| COMPARISON OF ACCUMULATOR AND ULTRACAPACITOR PERFORMANCE | | |
|---|---|---|
| **Performance Parameter** | **Accumulator (Batteries)** | **Ultracapacitors** |
| Specific Energy (Wh/kg) | 10 – 100 | 1 – 10 |
| Number of Cycles | 1,000 | > 500,000 |
| Specific Power (W/kg) | < 1,000 | < 10,000 |

Currently BART cars regenerate electrical energy while braking. Regenerated energy is transferred to the third rail, where nearby trains can utilize the regenerated electricity while accelerating out of a station. If the regenerated energy cannot be used by nearby trains, it is dissipated through on-board resistors. Installing ultracapacitors to store the regenerated energy instead of transferring it to the third rail will ensure that electrical energy is regenerated, stored and used to the extent possible.

With help from BART personnel, the voltage across one of the two energy dissipation resistors (both resistors are in parallel and have the same resistance) in a C car was monitored for a round trip between the South Hayward and Richmond Stations[***]. The monitoring was done during a weekday between noon and 3:00 p.m. The round trip should have taken about 2 hours, however the train was stuck at the Oakland Y for some time. From the data recorded by BART, it is estimated that during the trip from South Hayward Station to Richmond the resistors dissipated approximately 34.8 kWh. For the trip from Richmond to South Hayward, the resistors dissipated approximately 32.3 kWh. The average dissipation between both trips was approximately 333.5 kWh.

If the dissipated energy of on-board resistors is utilized, significant energy and cost savings could be realized. We have made the following assumptions in this analysis:

- The same dissipation resistors are used in all car types (A, B and C cars).
- All cars have a similar energy regeneration capability.
- All BART tracks have approximately similar line receptivity.
- Enough capacitance will be installed in each car to store all the dissipated energy.
- The added weight of the capacitors will not greatly affect the performance of the cars.

[§§] Destraz, B., Barrade, P., Rufer, A., Power Assistance for Diesel – Electric Locomotives with Supercapacitive Energy Storage," 2004 35th Annual IEEE Power Electronics Specialists Conference.

[***] BASE Energy engineers were granted access only to detail design schematics of C cars. For the purpose of analysis, it has been assumed that the dissipation resistors used by the A and B cars are the same as those used in the C cars.

- Losses due to interfacing electronics between ultracapacitors and BART electrical system have not been considered.

The details of the methodology and analysis of this measure is included in the appendix of the report. The results for potential energy, demand and cost savings are summarized on Table 8-1 below.

**TABLE 8-1 SUMMARY OF ELECTRICAL AND COST SAVINGS**

| Car Type | Number of Cars | Savings per car per mile (kWh/car-mi) | Distance Covered (mi/yr) | Energy Savings (kWh/yr) | Demand Savings (kW) | Total Cost Savings ($/yr) |
|---|---|---|---|---|---|---|
| A | 59 | 0.9520 | 122,275 | 6,867,942 | 1,736 | 721,134 |
| B | 380 | 0.9520 | 137,605 | 49,779,985 | 11,208 | 5,226,898 |
| C1 | 150 | 0.9520 | 116,435 | 16,626,918 | 4,420 | 1,745,826 |
| C2 | 80 | 0.9520 | 127,020 | 9,673,843 | 2,368 | 1,015,754 |
| **Totals** | **669** | | | **82,948,688** | **19,733** | **8,709,612** |

From Table 8-1, installing ultracapacitors (on-board electrical energy storage devices) will reduce the electrical energy consumption by 82,948,688 kWh/yr resulting in a demand reduction of 19,733 kW. These electrical savings will result in an avoided electrical cost of approximately $8,709,612 per year.

*On-Board Implementation*
Implementing this recommendation will require retrofitting the braking system with ultracapacitors. This may be accomplished by incorporating an ultracapacitor interface within the electric drive system. The essential required component is the ultracapacitor modules for storing the energy currently dissipated by the resistor. Based on the data collected by BART personnel and conversation with Maxwell Technologies (an ultracapacitor manufacturer) it is estimated that it will require 28 modules (28 Farad total) to store all the energy dissipated by the resistors. From a **very preliminary quotation** by the ultracapacitor manufacturer, the implementation cost could be itemized as follows:

(18,732) Ultracapacitor power modules ........................................ $53,948,160
(669) DC/DC Boost Converters ........................................ $7,425,900
Installation Costs ........................................ $24,549,624
**Total Cost ........................................ $85,923,684**

*Rail-Side Implementation*
An alternative to installing the ultracapacitors on-board is to install them close to the rail tracks at strategic locations throughout BART lines. A more detailed analysis of the implementation strategy is described in Appendix B - Ultracapacitor Implementation Addendum.

Under the assumption that at most two 10-car trains arrive at a station at any given time, then 24,080 modules and 86 DC/DC boost converters will be required, reducing the implementation cost and simple payback to $94,674,648 and 14.2 years respectively.

**NRNC**

Installing ultracapacitor modules for energy storage on new BART cars will result in electrical energy savings. The proposed baseline for estimating the electrical savings of on board ultracapacitor modules on new train cars is the existing regenerative braking system (without energy storage). From the above, the potential electrical energy savings per car mile for installing ultracapacitor modules in the train cars will be 0.952 kWh/car-mi resulting in an annual electrical energy savings of 123,989 kWh/car-yr ( at an average distance covered by one car in one year of 130,241 mi/car-yr).

**Notes:**

1. A more detailed cost savings estimate will require measurement of the energy dissipation on each line in a 24-hour period during weekdays and weekends.
2. Detailed engineering will be needed to implement this measure, which is far beyond the scope of this work.
3. The approximate total volume and mass required by 28 ultracapacitor modules is 1.8 $m^3$ and 1,400 kg (3,080 lb). Each module has a volume and mass of 0.063 $m^3$ and 50 kg.

# 6. DETAILED ANALYSIS OF THE MEASURES

## EEM No. 1 - High Efficiency Lighting for C1 Cars and New Cars

### Retrofit

The electrical energy savings due to replacing the T12 fluorescent lighting with T8 fluorescent lighting, EES, per car-mile can be estimated as follows:

$$EES = N \times (IW_C - IW_P) \times H \times [1 + C_1 \times LF / EER] / C_2$$

Where,

| | | |
|---|---|---|
| $N$ | = | number of lamps in one car, 55 no units |
| $IW_C$ | = | current lamp input wattage, 28.70 W |
| $IW_P$ | = | proposed lamp input wattage, 20.44 W |
| $H$ | = | average number of hours covered in one mile, 0.024167 hr |
| $C_1$ | = | conversion constant, 3.4122 Btu/W-h |
| $LF$ | = | fraction of heat generated by lighting that must be removed by HVAC system, 0.5 no units |
| $EER$ | = | HVAC energy efficiency ratio, 8.4 Btu/W-h |
| $C_2$ | = | conversion constant, 1000 W/kW |

Therefore the electrical energy savings, EES, per car-mile can be estimated as,

$$EES = (55)(28.70 - 20.44)(0.024167)[1 + (3.4122)(0.5)/(8.4)]/(1{,}000)$$
$$EES = 0.013209 \text{ kWh/car-mi}$$

The annual electrical energy savings, AEES, for replacing the T12 fluorescents with T8 fluorescents can be estimated as follows:

$$AEES = NC \times EES \times mi$$

Where,

| | | |
|---|---|---|
| $NC$ | = | number of C1 cars. 150 no units |
| $mi$ | = | is the average total distance traveled by one car during one year, 116,435 miles |

Therefore the annual electrical energy savings, AEES, for C1 cars can be estimated as,

$$AEES = (150)(0.013209)(116{,}435)$$
$$AEES = 230{,}695 \text{ kWh/yr}$$

The demand savings, DS, can be estimated as follows:

$$DS = AEES \times CF / H_{total}$$

Where all variables are the same as in the electrical energy savings, except:

CF = coincidence factor, fraction of total number of C1 cars that will run during BART's peak period, 0.75 no units
$H_{total}$ = the total number of hours per car type that will operate in one year, hr/yr

Therefore the demand savings for replacing the T12 lamps with T8 lamps will be:

$$DS = (230{,}695)(0.75)/(2{,}811 \text{ hr/yr})$$
$$DS = 61 \text{ kW}$$

The electrical energy cost savings, EECS, can be calculated as follows:

$$EECS = AEES \times (\text{average unit cost of electricity})$$
$$EECS = (230{,}695 \text{ kWh/yr})(\$0.105/\text{kWh})$$
$$EECS = \$24{,}223/\text{yr}$$

The maintenance cost savings can be estimated as follows,

$$MCS = NC \times N \times H \times mi \times [(LC_C + LC) / LL_C - (LC_P + LC) / LL_P]$$

Where all the variables are the same as in the electrical energy and demand savings except,

NC = number of C1 cars, no units
$LL_C$ = current lamp cost, $
LC = labor cost for replacing one lamp, $
$LL_C$ = current lamp life, hr
$LC_P$ = proposed lamp cost, $
$LL_P$ = proposed lamps life, h

Therefore the annual maintenance cost savings can be estimated as follows,

$$MCS = (150)(55)(0.024167)(116{,}435)[(8.64 + 6.81)/(9{,}000) - (9.07 + 6.81)/20{,}000)]$$
$$MCS = \$21{,}419/\text{yr}$$

The total cost savings is the sum of the electrical energy cost savings and the maintenance cost savings, which is estimated to be $45,642/yr.

**NRNC**

The annual electrical energy savings per car, $AEES_{NRNC}$, for installing T8 fluorescents instead of T12 fluorescents in new cars can be estimated as follows:

$$AEES_{NRNC} = (1 - RF) \times EES_{NRNC} \times mi_A$$

Where,

| | | |
|---|---|---|
| RF | = | reduction factor from day lighting EEM, 0.32 no units |
| $EES_{NRNC}$ | = | electrical energy savings per car mile, 0.011461[†††] kWh/car-mi, calculated through the same formulation as in the retrofit section |
| $mi_A$ | = | average annual distance covered by one train car, 130,241 mi/yr |

Therefore the expected electrical energy savings can be calculated as follows:

$$AEES_{NRNC} = (1 - 0.32)(0.011461)(130{,}241)$$
$$AEES_{NRNC} = 1{,}015 \text{ kWh/car-yr}$$

[†††] The electrical energy savings per car mile considers the A/B cars as baseline: 48 lighting fixtures per car and a higher efficiency HVAC system with an EER value of 8.7.

**EEM No. 2 - Direct Cooler Air to the Inlet of HVAC Condensers**

**Retrofit**

**Set-Up of Measurements**

Figure 2-1 shows where the temperature probes were placed on the C cars to measure the temperature of the inlet to the condensers and to measure the outside ambient temperature.

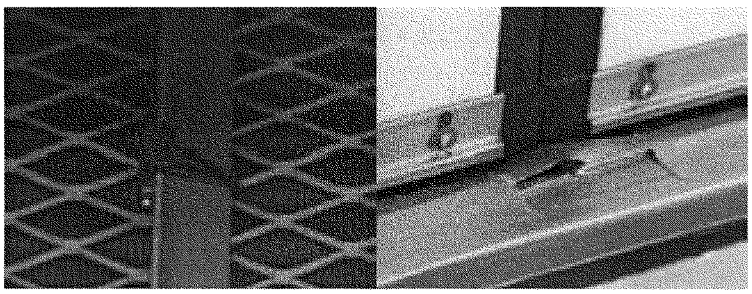


**Figure 2-1** (*Left*) Temperature Probe Mounted on Inlet to Condenser Heat Exchanger (*Right*) Temperature Probe Mounted on Car Door to Measure Outdoor Ambient Temperature

**Results from Live Track Run**

The measurements were performed on a live track run from Hayward to Richmond and returning back to Hayward on Wednesday December 20, 2006 from noon to 3 p.m. The temperatures at the inlet of the condenser heat exchanger and the ambient outdoor temperature were recorded and the results are presented in Figure 2-2 on the following page.

Based on the temperature measurements from the test run, the temperature differential between the temperature at the inlet of the heat exchanger and the ambient temperature ranged from 0°F to 24°F. This wide range is due to the fact that the regenerative braking system does not always produce heat in the resistors. When it does work, the heat absorbed from the regenerative braking by the resistor banks significantly increases the temperature of the inlet to the condensers. When the regenerative braking system is not producing heat in the resistors, hot air is still trapped underneath the cars, but will cool to near ambient temperature conditions. On average, the temperature at the inlet of the condenser heat exchanger was (on average) approximately 10°F higher than the ambient outdoor temperature. Thus, we have taken a temperature differential of 10°F between the inlet to the condenser heat exchanger and ambient conditions in all relevant calculations.

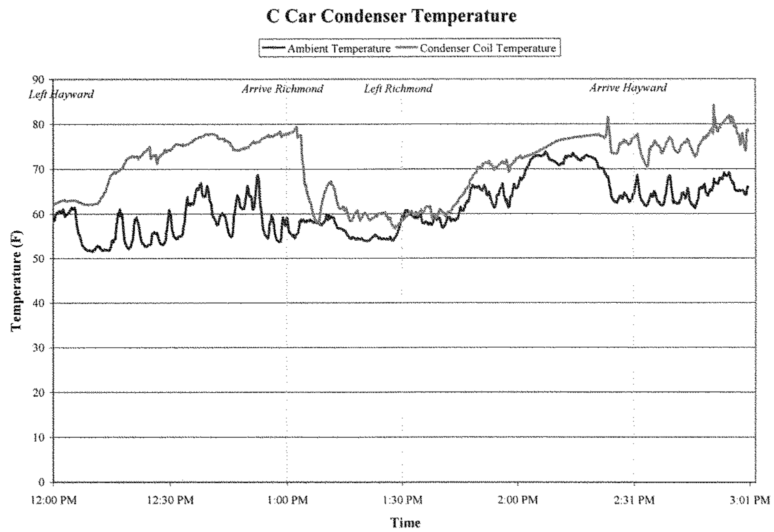



**Figure 2-2** C Car Condenser and Ambient Temperature Measurements from Live Track Run

**Electrical Energy Savings**

By directing cooler air to the intake of the condenser heat exchanger, less energy will be required by the HVAC compressors to condition the air. Based on the "*Qualification Test Report: Performance of HVAC System (Energy Consumption) Installed on BART C Car*" provided to the audit team by BART, the performance curve for the HVAC compressor shows that a 10°F drop in condensing temperature will result in a 9.7% drop in the energy consumed by the HVAC compressor. Conservatively, we have assumed that directing cooler air to the intake of the condenser heat exchanger will result in a HVAC compressor electrical energy savings of 9%.

The electrical energy savings due to directing cooler air to the intake of the condenser heat exchanger, EES, can be calculated using the following equation. It has been assumed that EEM No. 2 "*Optimize Outside Air Intake into Cars*" will be implemented simultaneously with this measure to avoid any overlapping in energy savings.

$$EES = \{[N \times (IW/Eff) \times LF \times H \times UF] - EES_{OA}\} \times FCS$$

Where,

N = total number of compressor motors per car, no units
IW = nominal input wattage of compressor motor, kW

| | | |
|---|---|---|
| Eff | = | efficiency of compressor motor, no units |
| LF | = | load factor of compressor motor (*estimated from Test Track data*), no units |
| H | = | average number of hours covered in one mile, 0.024167 hr |
| UF | = | utilization factor of compressor motor (estimated), 0.50 |
| $EES_{OA}$ | = | electrical energy savings due to implementation of EEM No. 2 "*Optimize Outside Air Intake into Cars*", kWh/car-mile |
| FCS | = | fraction of compressor energy savings due to directing cooler outside air to inlet of condenser heat exchanger, no units |

The electrical energy savings for the directing cooler air to the inlet of the C1 cars' condenser heat exchanger, $EES_1$, is estimated as:

$$EES_1 = \{(2)[(14.62)/(0.900)](0.585)(0.024167)(0.5) - 0.01616\}(0.09)$$
$$EES_1 = 0.01921 \text{ kWh/car-mi}$$

The annual electrical energy savings, AEES, due to directing cooler air to the inlet of the condenser heat exchanger can be calculated as follows:

$$AEES = NC \times EES \times mi$$

Where,

| | | |
|---|---|---|
| NC | = | number of A, B or C cars, no units |
| EES | = | total electrical energy savings for optimizing outside air usage, kWh/car-mi |
| mi | = | distance covered by each car type per year, mi/yr |

Using the same example as before, the annual electrical energy savings due to directing cooler air to the inlet of the C1 cars' condenser heat exchanger, $AEES_1$, is:

$$AEES_1 = (150 \text{ cars})(0.01921 \text{ kWh/car-mile})(116{,}435 \text{ miles/yr})$$
$$AEES_1 = 335{,}507 \text{ kWh/yr}$$

The average peak demand savings, DS, due to directing cooler air to the inlet of the condenser heat exchanger can be estimated as follows:

$$DS = AEES_i \times CF_i / H_{total}$$

Where,

| | | |
|---|---|---|
| $AEES_i$ | = | annual electrical energy savings for optimizing outside air usage for each car type (A, B or C cars), kWh/car-mi |
| $CF_i$ | = | coincidence factor, fraction of total number of cars (A, B or C cars) that will run during BART's peak period, no units |
| $H_{total}$ | = | total number of hours per car type (A, B or C cars) that will operate in one year, hr/yr |

Using the same example as in the annual electrical energy savings, the average demand savings due to directing cooler air to the inlet of the C1 cars' condenser heat exchanger, $DS_1$, is estimated to be:

$DS_1$ = (335,507 kWh/yr)(0.75) / (2,811 hr/yr)
$DS_1$ = 89.53 kW

The associated annual electrical energy cost savings, AECS, can be estimated as follows:

AECS = AEES × (average unit cost of electricity, \$0.105/kWh)
$AECS_1$ = (335,507 kWh/yr)(\$0.105/kWh)
$AECS_1$ = \$35,228/yr

Continuing the electrical energy and demand savings for the remaining BART cars yields the results shown in Table 2-2 below.

| TABLE 2-2 SUMMARY OF ELECTRICAL AND COST SAVINGS | | | | | | |
|---|---|---|---|---|---|---|
| **Car Type** | **Number of Cars** | **Savings per car per mile** (kWh/car-mi) | **Annual Distance Covered** (mi/yr) | **Energy Savings** (kWh/yr) | **Peak Demand Savings** (kW) | **Total Cost Savings** (\$/yr) |
| A | 59 | 0.01995 | 122,275 | 143,924 | 36.50 | 15,112 |
| B | 380 | 0.01995 | 137,605 | 1,043,184 | 235.52 | 109,534 |
| C1 | 150 | 0.01921 | 116,435 | 335,507 | 89.52 | 35,228 |
| C2 | 80 | 0.01921 | 127,020 | 195,204 | 47.75 | 20,496 |
| **Totals** | **669** | | | **1,717,819** | **409.29** | **180,370** |

**EEM No. 3 - Install Higher Efficiency HVAC Units on C Cars and New Cars**

**Retrofit**

| | | |
|---|---|---|
| Existing C Car HVAC Units (2 HVAC units/car) | | |
| 7-ton HVAC Unit: | Reciprocating Compressor: | 14.62 kW |
| | Evaporator Fan: | 2.7 kW |
| | Condenser Fan: | 0.6 kW |
| Overall EER: | 8.4 Btu/W-hr | |

| | |
|---|---|
| Existing C Car HVAC Units (2 HVAC units/car) | |
| 7-ton HVAC Unit: | Scroll Compressor |
| Overall EER: | 9.1 Btu/W-hr |

**Electrical Energy Savings**

The electrical energy savings from using higher efficiency HVAC units in the C cars, EES, can be estimated as follows:

$$EES = \{[N \times (IW/Eff) \times LF \times H \times UF] - (EES_{OA} + EES_{Cond})\} \times [1 - (EER_C/EER_P)]$$

Where,

- $N$ = total number of compressor motors per car, no units
- $IW$ = nominal input wattage of compressor motor, kW
- $Eff$ = efficiency of compressor motor, no units
- $LF$ = load factor of compressor motor (*estimated from Test Track data*), no units
- $H$ = average number of hours covered in one mile, 0.024167 hr
- $UF$ = utilization factor of compressor motor (estimated), 0.50
- $EES_{OA}$ = electrical energy savings due to implementation of EEM No. 3 "*Optimize Outside Air Intake into Cars*", kWh/car-mile
- $EES_{Cond}$ = electrical energy savings due to implementation of EEM No. 2 "*Direct Cooler Air to the Inlet of HVAC Condensers*", kWh/car-mile
- $EER_C$ = energy efficiency ratio of the current HVAC units, 8.4 Btu/W-hr
- $EER_P$ = energy efficiency ratio of the proposed HVAC units, 9.1 Btu/W-hr

The electrical energy savings due to replacing the existing HVAC units on the C cars with more efficient HVAC units, EES, is estimated to be:

$$EES = \{(2)[(14.62)/(0.900)](0.585)(0.024167)(0.5) - (0.01616 + 0.01921)\} \times [1 - (8.4)/(9.1)]$$

$$EES = 0.01495 \text{ kWh/car-mi}$$

The annual electrical energy savings, AEES, due to replacing the existing HVAC units with higher efficiency units can be calculated as follows:

$$AEES = NC \times EES \times mi$$

Where,

| | | |
|---|---|---|
| NC | = | number of C1 or C2 cars, no units |
| EES | = | total electrical energy savings for installing higher efficiency HVAC units, kWh/car-mi |
| mi | = | distance covered by each car type per year, mi/yr |

As an example, the annual electrical energy savings due to replacing the existing HVAC units in the C1 cars, $AEES_1$, is:

$$AEES_1 = (150 \text{ cars})(0.01495 \text{ kWh/car-mile})(116{,}435 \text{ miles/yr})$$
$$AEES_1 = 261{,}105 \text{ kWh/yr}$$

The average peak demand savings, DS, due to replacing the existing HVAC units with higher efficiency units can be estimated as follows:

$$DS_i = AEES_i \times CF_i / H_{total}$$

Where,

| | | |
|---|---|---|
| $AEES_i$ | = | annual electrical energy savings for optimizing outside air usage for each car type (C1 or C2 cars), kWh/car-mi |
| $CF_i$ | = | coincidence factor, fraction of total number of cars (C1 or C2 cars) that will run during BART's peak period, no units |
| $H_{total}$ | = | total number of hours per car type (C1 or C2 cars) that will operate in one year, hr/yr |

Using the same example as in the annual electrical energy savings, the average peak demand savings due to installing higher efficiency HVAC units on the C1 cars, $DS_1$, is estimated to be:

$$DS_1 = (261{,}105 \text{ kWh/yr})(0.75) / (2{,}811 \text{ hr/yr})$$
$$DS_1 = 69.67 \text{ kW}$$

The associated annual electrical energy cost savings for the C1 cars, $AECS_1$, can be estimated as follows:

$$AECS = AEES_1 \times (\text{average unit cost of electricity, \$0.105/kWh})$$
$$AECS_1 = (261{,}105 \text{ kWh/yr})(\$0.105/\text{kWh})$$
$$AECS_1 = \$27{,}416/\text{yr}$$

Continuing the electrical energy and demand savings for the C2 cars yields the results shown in Table 3-1 below.

**TABLE 3-1 SUMMARY OF ELECTRICAL AND COST SAVINGS**

| Car Type | Number of Cars | Savings per car per mile (kWh/car-mi) | Annual Distance Covered (mi/yr) | Energy Savings (kWh/yr) | Peak Demand Savings (kW) | Total Cost Savings ($/yr) |
|---|---|---|---|---|---|---|
| C1 | 150 | 0.01495 | 116,435 | 261,105 | 69.67 | 27,416 |
| C2 | 80 | 0.01495 | 127,020 | 151,916 | 37.16 | 15,951 |
| **Totals** | **230** | | | **413,021** | **106.83** | **43,367** |

### NRNC

The annual electrical energy savings, $AEES_{NRNC}$, for installing high efficiency HVAC units in new cars can be estimated as follows:

$$AEES_{NRNC} = EES_{NRNC} \times mi_A$$

Where,

$EES_{NRNC}$ = electrical energy savings per car mile for installing high efficiency HVAC units in new cars instead of the HVAC units in A/B cars, 0.009534[‡‡‡] kWh/car-mi, same formulation as in retrofit section

$mi_A$ = average distance covered by one car in one year, mi

Therefore the expected electrical energy savings can be calculated as follows:

$$AEES_{NRNC} = (0.009534)(130,241)$$
$$AEES_{NRNC} = 1,242 \text{ kWh/car-yr}$$

[‡‡‡] The energy savings per car mile considers the HVAC system used in A/B cars as baseline, which includes: six 5.46 kW HVAC compressors and an EER value of 8.7 Btu/W-h.

**EEM No. 4 - Optimize Outside Air Intake into Cars**

**Retrofit**

Optimize the amount of outside air intake into the BART cars based on the outside air temperature. The proposed recommendation will generate savings based upon the reduced usage of the compressor motor. The air distribution fan in each unit must still be used.

**Electrical Energy Savings**

The electrical energy savings, EES, which can be realized by optimizing the outside air intake based on outside air temperature, may be estimated as follows:

$$EES = N \times (IW/Eff) \times LF \times FR \times H \times FH \times UF$$

Where,

| | | |
|---|---|---|
| N | = | total number of compressor motors per car, no units |
| IW | = | nominal input wattage of compressor motor, kW |
| Eff | = | efficiency of compressor motor, no units |
| LF | = | load factor of compressor motor (*estimated from Test Track data*), no units |
| FR | = | fraction that each unit is loaded depending on temperature (*refer to Table 3-3*), no units |
| H | = | average number of hours covered in one mile, 0.024167 hr |
| FH | = | fraction of time that each unit could be shut off for a particular temperature range, no units |
| UF | = | utilization factor of compressor motor (estimated), 1.0 |

According to the BART document (BARVE4G02571) provided to the audit team, the HVAC equipment must be able to operate without damage at a temperature as high as 120°F. Thus, the fraction that each air conditioning unit is loaded, FR, is calculated assuming that at 120°F the units are fully loaded and at 55°F, the units will shut off. A linear approximation is then used to determine the fraction of loading at temperatures between 55°F and 120° F.

The fraction of time that each unit could be shut off for a particular temperature range, FH, was estimated based on the following relationship:

$$FH = FH_i / H_{total}$$

Where,

| | | |
|---|---|---|
| $FH_i$ | = | number of hours that fall between a certain temperature range (based on weather data developed by the United States Department of Energy) for the Oakland area , hr/yr |
| $H_{total}$ | = | annual operating hours for each car type, hr/yr |

It is assumed that outdoor air can be optimized during periods of the year when the temperature range is between 55°F and 65°F (average temperature of 58°F) and at a favorable relative humidity below 50%. As an example, the fraction of time that C1 car compressors can be shut off for the temperature range of 55°F to 60°F, $FH_1$, is estimated to be:

$$FH_1 = (825 \text{ hr/yr}) / (7.7 \text{ hr/day} \times 365 \text{ day/yr})$$
$$FH_1 = 0.29$$

Using the same example, the electrical energy savings for the C1 cars' HVAC compressors at an average temperature of 58° F, $EES_1$, is estimated as:

$$EES_1 = N \times (IW/Eff) \times LF \times FR \times H \times FH \times UF$$
$$EES_1 = (2)[(14.62)/(0.900)](0.585)(0.0385)(0.024167)(0.29)(1.0)$$
$$EES_1 = 0.00512 \text{ kWh/car-mi}$$

The following table (Table 4-3) shows the fraction of loading for average temperatures for one year as well as the number of hours of operation of the C1 car HVAC units that fall within a temperature range for the A/C units. Table 4-3 also shows the electrical energy savings for the various temperature bins for the C1 cars.

**TABLE 4-3 ELECTRICAL ENERGY SAVINGS FOR C1 CARS**

| **Dry Bulb Temp. Range** (°F) | **Hours of Operation*** (hr/yr) | **A/C Fraction Loading **** (%) | **HVAC Function** | **Savings per Car per Mile** (kWh/car-mi) |
|---|---|---|---|---|
| <55 | 829 | 0 | heating | 0.00000 |
| 55-60 | 825 | 3.8 | economizer | 0.00512 |
| 60-65 | 587 | 11.5 | economizer | 0.01103 |
| > 65 | 570 | 19.2 - 100 | cooling | 0.00000 |
| **Totals** | **2,811** | | | **0.01616** |

* These hours were estimated based on data from a CD-ROM developed at the request of the United States Department of Energy. The CD-ROM contains "typical" values of dry bulb temperatures as well as average temperatures for user-defined months of the year and hours of the day. The annual operating hours were provided by BART personnel.

** The fraction that each air conditioning unit is loaded, FR, is calculated assuming that at 120 °F the units are fully loaded and at 55° F, the units will shut off.

The annual electrical energy savings, AEES, due to optimizing the amount of outside air used can be calculated as follows:

$$AEES = NC \times EES \times mi$$

Where,

NC = number of A, B or C cars, no units
EES = total electrical energy savings for optimizing outside air usage, kWh/car-mi
mi = distance covered by each car type per year, mi/yr

As an example, the annual electrical energy savings due to optimizing the amount of outside air used for the C1 cars, $AEES_1$, is:

$AEES_1 =$ (150 cars)(0.01616 kWh/car-mile)(116,435 miles/yr)
$AEES_1 =$ 282,238 kWh/yr

The average peak demand savings, DS, due to optimizing the amount of outside air used can be estimated as follows:

$$DS_i = AEES_i \times CF_i / H_{total}$$

Where,

$AEES_i =$ annual electrical energy savings for optimizing outside air usage for each car type (A, B or C cars), kWh/car-mi
$CF_i =$ coincidence factor, fraction of total number of cars (A, B or C cars) that will run during BART's peak period, no units
$H_{total} =$ total number of hours per car type (A, B or C cars) that will operate in one year, hr/yr

Using the same example as before, the total demand savings due to optimizing the amount of outside air used in the C1 cars, $DS_1$, is estimated to be:

$DS_1 =$ (282,238 kWh/yr)(0.75) / (2,811 hr/yr)
$DS_1 =$ 75.32 kW

The associated annual electrical energy cost savings, AECS, can be estimated as follows:

AECS = AEES × (average unit cost of electricity, $0.105/kWh)
$AECS_1 =$ (282,238 kWh/yr)($0.105/kWh)
$AECS_1 =$ $29,635/yr

Continuing the electrical energy and demand savings for the remaining BART cars yields the results shown in Table 4-4 below.

| TABLE 4-4 SUMMARY OF ELECTRICAL AND COST SAVINGS | | | | | | |
|---|---|---|---|---|---|---|
| **Car Type** | **Number of Cars** | **Savings per car per mile** (kWh/car-mi) | **Annual Distance Covered** (mi/yr) | **Energy Savings** (kWh/yr) | **Peak Demand Savings** (kW) | **Total Cost Savings** ($/yr) |
| A | 59 | 0.01677 | 122,275 | 120,983 | 30.69 | 12,839 |
| B | 380 | 0.01677 | 137,605 | 876,902 | 197.98 | 92,075 |
| C1 | 150 | 0.01616 | 116,435 | 282,238 | 75.32 | 29,635 |
| C2 | 80 | 0.01616 | 127,020 | 164,211 | 40.17 | 17,242 |
| **Totals** | **669** | | | **1,444,334** | **344.16** | **151,791** |

**NRNC**

The annual electrical energy savings, $AEES_{NRNC}$, for optimizing outside air intake in new cars can be estimated as follows:

$$AEES_{NRNC} = EES_{NRNC} \times mi_A$$

Where,

$EES_{NRNC}$ = electrical energy savings per car mile for optimizing outside air intake, 0.01677 kWh/car-mi

$mi_A$ = average distance covered by one car in one year, mi

Therefore the expected electrical energy savings can be calculated as follows:

$$AEES_{NRNC} = (0.01677)(130{,}241)$$

$$AEES_{NRNC} = 2{,}184 \text{ kWh/car-yr}$$

**EEM No. 5 - Install Daylight Controls on the Fluorescent Lamps**

**Retrofit**

A computer model was developed to estimate the light level inside a BART car. The model considered the following:

- A linear light level increase/decrease from sunrise to sunset, with the peak light level reached at midpoint between sunrise and sunset.
- Based on the Latitude and Longitude of San Francisco, the peak light level was estimated for a winter month (January) and a summer month (June). It is assumed that the light level will increase linearly from January until June and then decrease linearly form June to December.
- This model was then normalized to the light level data collected by the light level logger setup by the assessment team.
- Finally it was determined that the fraction of underground track for all BART lines was very close to the fraction of underground track for the Daly City – Pittsburg/Bay Point line (within 2%) from which data was collected.

From this computer model it was determined that on average the lights could be dimmed to 55% of the nominal output for approximately 72% of the time (based on weekday schedule) the lines are operational. The electrical energy savings, EES, can be estimated as follows:

$$EES = N \times IW \times H \times (1 - PR) \times FH \times (1 + C1 \times LF / EER) / C2$$

Where,

| | | |
|---|---|---|
| N | = | number of lamps in one car, no units |
| IW | = | current lamp input wattage, W |
| H | = | average number of hours covered in one mile, 0.024167 hr |
| PR | = | fraction of nominal power consumption of lamps at 55% light output, 0.55 no units |
| FH | = | fraction of time that lights can be dimmed, 0.72 no units |
| $C_1$ | = | conversion constant, 3.4122 Btu/W-h |
| LF | = | fraction of heat generated by lighting that must be removed by HVAC system, 0.5 no units |
| EER | = | HVAC energy efficiency ratio, 8.4 Btu/W-h for C cars and 8.65 Btu/W-h for A/B cars |
| $C_2$ | = | conversion constant, 1000 W/kW |

As an example, the electrical energy savings, $EES_1$, for C1 cars (which use the 20-Watt T12 fluorescent lamps) can be estimated as follows:

$$EES_1 = (55)(20.44)(0.024167)(1 - 0.55)(0.72)[1 + (3.4122)(0.5)/(8.4)]/(1{,}000)$$

$EES_1$ = 0.010560 kWh/car-mi

The annual electrical energy savings, AEES, for dimming the fluorescent lamps can be estimated as follows:

$AEES = NC \times EES \times mi$

Where,

NC = number of cars of a specific type, no units
mi = is the average total distance traveled by one car during one year, mi/yr

Using the same example as in the electrical energy savings, the annual electrical energy savings, $AEES_1$, for one C1 car can be estimated as,

$AEES_1 = (150)(0.010560)(166{,}435)$
$AEES_1 = 184{,}428$ kWh/yr

This recommendation is not expected to result in demand savings.

The electrical energy cost savings, EECS, can be calculated as follows:

EECS = AEES × (average unit cost of electricity)
EECS = (837,433 kWh/yr)($0.105/kWh)
EECS = $87,930/yr

**NRNC**

The annual electrical energy savings, $AEES_{NRNC}$, for installing daylight controls in new cars can be estimated as follows:

$AEES_{NRNC} = EES_{A/B} \times mi_A$

Where,

$EES_{A/B}$ = electrical energy savings per car mile for A/B cars, kWh/car-mi
$mi_A$ = average distance covered by one car in one year, mi

Therefore the expected electrical energy savings can be calculated as follows:

$AEES_{NRNC} = (0.009171)(130{,}241)$
$AEES_{NRNC} = 1{,}194$ kWh/car-yr

**EEM No. 6 - Install Variable Frequency Drives on HVAC Supply Fans**

**Retrofit**

Install variable frequency drives (VFD, the same as adjustable speed drive) on the HVAC evaporator (supply) fan motors in all car units.

*C1/C2 Cars* – 2 fans/car × 2.7 kW/fan
*A/B Cars* – 6 fans/car × 0.65 kW/fan

The VFDs will control the airflow provided to the car based on the car' return air temperature, which has been estimated to vary accordingly with the passenger occupancy loads of the cars.

The hourly passenger loading variation for the BART system was not available to BASE. Thus, we have taken a typical transit passenger loading profile shown in Figure 6-1 below, extracted from Vuchic (2005).

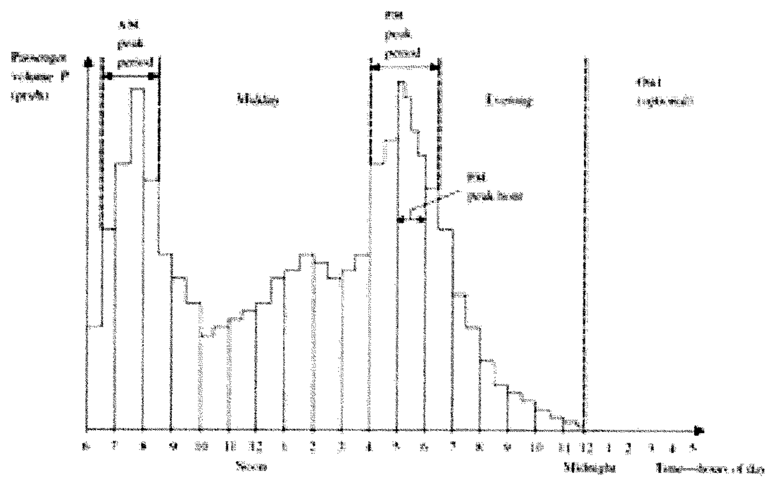


**Figure 6-1** Hourly Variation of Passenger Volume for a Typical Transit Line

Based on the above passenger volume profile, flow profiles for the various BART cars have been developed and are presented in Table 6-3 on the following page.

| TABLE 6-3 SUMMARY OF FLOW PROFILE FOR DIFFERENT BART CARS | | | | |
|---|---|---|---|---|
| **Total Flow Rate Needed** (%) | **C1 Cars Running Hours** (hr/yr) | **C2 Cars Running Hours** (hr/yr) | **A Cars Running Hours** (hr/yr) | **B Cars Running Hours** (hr/yr) |
| 100 | 234 | 256 | 246 | 277 |
| 90 | 234 | 256 | 246 | 277 |
| 80 | 351 | 383 | 370 | 415 |
| 70 | 117 | 128 | 123 | 138 |
| 60 | 351 | 383 | 370 | 415 |
| 50 | 468 | 511 | 493 | 554 |
| 40 | 351 | 383 | 370 | 415 |
| 30 | 351 | 383 | 370 | 415 |
| < 25* | 351 | 383 | 370 | 415 |
| **Totals** | **2,811** | **3,066** | **2,957** | **3,322** |

* Based on the passenger volume occupancy profile, the flow rate can be reduced further than 25%. However, conservatively it has been estimated that the fans would need to supply an airflow of 25% of maximum flow to the cars at low occupancy periods.

Table 6-4 shows the comparative energy consumption of an adjustable speed drive control and damper control. Energy consumption is presented in the table as the percentage of energy consumed relative to 100 % load with damper control. The present airflow is dependent on the pressure drop across the damper. For example, from Table 6-4, for a flow rate of 100%, an ASD controlled fan motor replacing dampers will have a power increase of 5%, while for a flow rate of 50%, a VFD controlled fan motor replacing the damper control will have a power savings of 53%.

| TABLE 6-4 RELATIVE POWER CONSUMPTION OF DIFFERENT CONTROL STRATEGIES AND SAVINGS | | | | |
|---|---|---|---|---|
| **Total Flow Rate** | **Damper Control Energy** | **Power Consumption of Motor** | | **Power Savings with Application of ASD** |
| | | **No Flow Control** | **ASD Replacing Damper Control** | |
| % | % | % | % | % |
| 100 | 100 | 100 | 105 | -5 |
| 95 | 96 | 100 | 90 | 6 |
| 90 | 94 | 100 | 78 | 16 |
| 85 | 93 | 100 | 66 | 27 |
| 80 | 89 | 100 | 57 | 32 |
| 75 | 86 | 100 | 48 | 38 |
| 70 | 83 | 100 | 41 | 42 |
| 60 | 79 | 100 | 30 | 49 |
| 50 | 74 | 100 | 21 | 53 |
| 40 | 71 | 100 | 14 | 57 |
| 30 | 70 | 100 | 8 | 62 |
| 20 | 70 | 100 | 5 | 65 |

The energy savings will be calculated by determining the energy usage of the air handler fan presently in use and subtracting the energy usage of the fan at reduced flow (load). The electrical energy savings per car-mile, EES, is estimated as:

$$EES = N \times (R/EFF) \times LF \times (AH_i / H_{total}) \times UF \times (CL_{DC} - CL_{VFD}) \times H$$

Where,

| | | |
|---|---|---|
| N | = | number of HVAC evaporator (supply) fan motors, no units |
| R | = | rated power of HVAC evaporator (supply) fan motor, hp |
| EFF | = | efficiency of the fan motor, no units |
| LF | = | fraction of rated load that fan motor operates, no units |
| $AH_i$ | = | annual operation hours of fan at a particular airflow, hr/yr |
| $H_{total}$ | = | total annual operation hours of fan (varies based on car type), hr/yr |
| UF | = | fraction of operating time that the fan is in use, no units |
| $CL_{DC}$ | = | controlled load fraction at which the motor will operate with damper control, no units |
| $CL_{VFD}$ | = | controlled load fraction at which the motor will operate with VFD control, no units |
| H | = | average number of hours covered in one mile, 0.024167 hr/car-mile |

As an example, the electrical energy savings for the C1 cars at an airflow of 50%, $EES_1$, can be estimated as follows:

$$EES_1 = (2)[(2.7)/(0.87)](0.70)[(468)/(2{,}811)](1.0)[(0.74) - (0.21)](0.024167)$$
$$EES_1 = 0.00928 \text{ kWh/car-mile}$$

Table 6-5 below summarizes the electrical energy savings for installing VFDs on the HVAC supply fans for the various BART cars at different flow rates.

**TABLE 6-5 ELECTRICAL ENERGY SAVINGS FOR BART CARS BASED ON FLOW PROFILE**

| Total Flow Rate (%) | $CL_{DC}$ | $CL_{VFD}$ | C1/C2 Cars | | | A/B Cars | | |
|---|---|---|---|---|---|---|---|---|
| | | | No. Fans | Rating of Fans (kW) | EES (kWh/yr) | No. Fans | Rating of Fans (kW) | EES (kWh/yr) |
| 100 | 1 | 1.05 | 2 | 2.7 | -0.00044 | 6 | 0.65 | -0.00030 |
| 90 | 0.94 | 0.78 | 2 | 2.7 | 0.00140 | 6 | 0.65 | 0.00097 |
| 80 | 0.89 | 0.57 | 2 | 2.7 | 0.00420 | 6 | 0.65 | 0.00290 |
| 70 | 0.83 | 0.41 | 2 | 2.7 | 0.00184 | 6 | 0.65 | 0.00127 |
| 60 | 0.79 | 0.3 | 2 | 2.7 | 0.00643 | 6 | 0.65 | 0.00444 |
| 50 | 0.74 | 0.21 | 2 | 2.7 | 0.00928 | 6 | 0.65 | 0.00640 |
| 40 | 0.71 | 0.14 | 2 | 2.7 | 0.00748 | 6 | 0.65 | 0.00517 |
| 30 | 0.7 | 0.08 | 2 | 2.7 | 0.00814 | 6 | 0.65 | 0.00562 |
| < 25 | 0.7 | 0.065 | 2 | 2.7 | 0.00833 | 6 | 0.65 | 0.00575 |
| **Totals** | | | | | **0.04666** | | | **0.03222** |

The annual electrical energy savings, AEES, due to installing VFDs on the HVAC evaporator (supply) fans can be calculated as follows:

AEES = NC × EES × mi

Where,

NC = number of A, B or C cars, no units
EES = total electrical energy savings for installing VFD on supply fans, kWh/car-mi
mi = distance covered by each car type per year, mi/yr

As an example, the annual electrical energy savings due to installing VFDs on the two supply fans for the C1 cars, $AEES_1$, is:

$AEES_1$ = (150 cars)(0.04666 kWh/car-mile)(116,435 miles/yr)
$AEES_1$ = 814,929 kWh/yr

There is not expected to be any demand savings due to implementation of this measure since the fans are expected to operate at or near full load during peak hours.

The associated annual electrical energy cost savings, AECS, can be estimated as follows:

AECS = AEES × (average unit cost of electricity, $0.105/kWh)
$AECS_1$ = (814,929 kWh/yr)($0.105/kWh)
$AECS_1$ = $85,568/yr

Continuing the electrical energy savings and cost savings for the remaining BART cars yields the results shown in Table 6-6.

TABLE 6-6 SUMMARY OF ELECTRICAL AND COST SAVINGS

| Car Type | Number of Cars | Savings per car per mile (kWh/car-mi) | Annual Distance Covered (mi/yr) | Energy Savings (kWh/yr) | Total Cost Savings ($/yr) |
|---|---|---|---|---|---|
| A | 59 | 0.03222 | 122,275 | 232,442 | 24,406 |
| B | 380 | 0.03222 | 137,605 | 1,684,781 | 176,902 |
| C1 | 150 | 0.04666 | 116,435 | 814,929 | 85,568 |
| C2 | 80 | 0.04666 | 127,020 | 474,140 | 49,785 |
| **Totals** | **669** | | | **3,206,292** | **336,661** |

**NRNC**

The annual electrical energy savings, $AEES_{NRNC}$, for optimizing the HVAC fan controls in new cars can be estimated as follows:

$$AEES_{NRNC} = EES_{NRNC} \times mi_A$$

Where,

| | | |
|---|---|---|
| $EES_{NRNC}$ | = | electrical energy savings per car mile for installing VFD on HVAC fans, 0.03222 kWh/car-mi, same as EES for A/B cars |
| $mi_A$ | = | average distance covered by one car in one year, mi |

Therefore the expected electrical energy savings can be calculated as follows:

$$AEES_{NRNC} = (0.03222)(130{,}241)$$
$$AEES_{NRNC} = 4{,}367 \text{ kWh/car-yr}$$

**EEM No. 7 - Use Permanent Magnet (PM) Motors for Car Propulsion**

**Retrofit**

A computer model was developed to estimate electrical consumption of an IM and a PM motor propulsion system. The results of the computer model were then scaled so that the IM propulsion system electrical energy consumption match the results from the *Qualification Test Report, Energy Consumption Test on Test Track* (for the A/B cars) which was supplied by BART personnel. The train/track profile used was based on the train configuration as well as the speed/time plot shown in the *Qualification Test Report, Energy Consumption Test on Test Track* (Q.09.01.4.301 Rev. C) used for the C cars. The computer model considered the following:

- **Tractive losses per car.** These were estimated for each time step in the speed/time profile based on the BART car parameters using the Davis Formula.
- **Kinetic energy change.** At each time step the kinetic energy was calculated based on $\frac{1}{2} \times M \times V^2$. The rotational energy in the axles was ignored.
- **Losses in the motor.** Speed vs. efficiency models were developed for an IM and a PM motor. The model used to derive the efficiencies assumed that speed was the only variable component for efficiency (which is true for PM motors, not so for IM). This will result in a conservative estimate of savings since IM efficiency tends to also depend on torque (e.g. efficiency goes down as the torque required by the load goes down).
- **Losses in the converter.** The converter model (electronic motor drives) used for both systems was the same. It was assumed that the nominal efficiency would be 97%. The losses were divided into two categories: Fixed losses (accounting for approximately 30% of the losses in the converter), which considers voltage drops across components, gate drives, etc. and variable losses (accounting for the remaining 70% of the losses), which account for the variation in torque (current) requirements.
- Finally the total electrical consumption for the IM and PM motor propulsion system was calculated by summing up all the above components.

The results for the computer model generated by *DRS Electric Power Technologies, Inc.* that compared the electrical energy consumption and regeneration of IM versus PM motors were:

PM Consumption = 5.330 kWh/car-mi
IM Consumption = 5.580 kWh/car-mi

PM Regeneration = 4.570 kWh/car-mi
IM Regeneration = 4.190 kWh/car-mi

The results from the computer based model where scale to the IM consumption and regeneration reported on the Test Track Data supplied by BART personnel. The scaled down PM motor electrical consumption, $PMC_S$, can be calculated as follows:

$$PMC_S = PMC \times IMC_{TT} / IMC$$

Where,

| | | |
|---|---|---|
| PMC | = | computer based model PM motor consumption, kWh/car-mi |
| $IMC_{TT}$ | = | test track IM consumption results, 4.366 kWh/car-mi |
| IMC | = | computer based model IM consumption, kWh/car-mi |

Therefore the electrical energy consumption of a PM propulsion system is estimated to be:

$PMC_S$ = (5.330)(4.366)/(5.580)
$PMC_S$ = 4.170 kWh/car-mi

Similarly, the scaled down PM electrical energy regeneration, $PMR_S$, can be calculated as follows:

$PMR_S = PMR \times IMR_{TT} / IMR$

Where,

| | | |
|---|---|---|
| PMR | = | computer based model PM motor regeneration, kWh/car-mi |
| $IMR_{TT}$ | = | test track IM regeneration results, 1.659 kWh/car-mi |
| IMR | = | computer based model IM regeneration, kWh/car-mi |

Therefore the electrical energy regeneration of a PM propulsion system is estimated to be:

$PMC_S$ = (4.570)(1.659)/(4.190)
$PMC_S$ = 1.809 kWh/car-mi

Table 7-2 below summarizes the results of the study based on the results from the computer based model and the test track data for both the IM and DC propulsion system.

**TABLE 7-2 COMPARISON OF ELECTRICAL ENERGY CONSUMPTION AND REGENERATION**

| **Propulsion Type** | **Permanent Magnet** (kWh/car-mi) | **Induction** (kWh/car-mi) | **DC** (kWh/car-mi) |
|---|---|---|---|
| Motoring | 4.170 | 4.366 | 4.048 |
| Generating | 1.809 | 1.659 | 1.024 |
| Net Consumption | 2.361 | 2.707 | 3.024 |
| **Electrical Energy Savings** | | **0.346** | **0.663** |

For a graphical description of the methodology used to analyze this measure please refer to Figure 7-1 at the end of this section.

The annual electrical energy savings, AEES, that may result for retrofitting the propulsion system with permanent magnet motors can be calculated as follows:

AEES = $N \times EES \times mi$

Where,

N = number of A, B or C cars, no units
EES = electrical energy savings for replacing induction/DC motors with PM motors, kWh/car-mi
mi = distance covered by each car type per year, mi/yr

As an example, the annual electrical energy savings for replacing the propulsion system in the C1 cars (DC motors) with PM motors can be estimated as follows:

$AEES_1 =$ (150)(0.663)(116,435)
$AEES_1 =$ 11,579,461 kWh/yr

The demand savings, DS, for replacing the induction motor propulsion system in the C1 cars with PM motors can be estimated as follows:

$DS = AEES \times CF / H_{total}$

Where all variables are the same as in the annual electrical energy savings, except:

CF = coincidence factor, fraction of cars that run during BART's peak period, 0.75 no units
$H_{total}$ = the total number of hours per each car type will operate in one year, hr/yr

Using the same example as in the annual electrical energy savings, replacing the induction motors in the C1 cars with permanent magnet motors will result in a demand savings of:

$DS_1 =$ (11,579,461 kWh/yr)(0.75)/(2,811 hr/yr)
$DS_1 =$ 3,079 kW

Table 7-3 below summarizes the electrical energy and cost savings for replacing the existing propulsion system with permanent magnet motors.

**TABLE 7-3 SUMMARY OF ELECTRICAL AND COST SAVINGS**

| Car Type | Number of Cars | Savings per car per mile (kWh/car-mi) | Distance Covered (mi/yr) | Energy Savings (kWh/yr) | Demand Savings (kW) | Total Cost Savings ($/yr) |
|---|---|---|---|---|---|---|
| A | 59 | 0.346 | 122,275 | 2,496,122 | 631 | 262,093 |
| B | 380 | 0.346 | 137,605 | 18,092,305 | 4,071 | 1,899,692 |
| C1 | 150 | 0.663 | 116,435 | 11,579,461 | 3,079 | 1,215,843 |
| C2 | 80 | 0.663 | 127,020 | 6,737,141 | 1,642 | 707,400 |
| **Totals** | **669** | | | **38,905,029** | **9,424** | **4,085,028** |

The electrical energy cost savings, EECS, can be estimated as follows:

EECS = AEES × (average unit cost of electricity)
EECS = (38,905,029 kWh/yr)($0.105/kWh)
EECS $4,085,028/yr

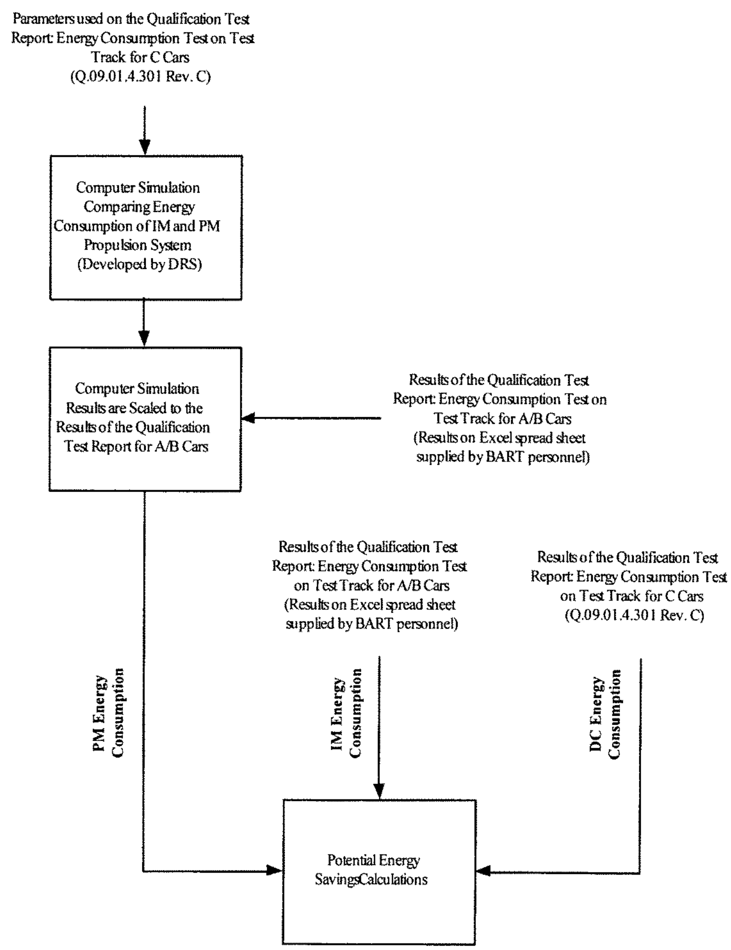



Figure 7-1 Propulsion Analysis Methodology

**NRNC**

The annual electrical energy savings, $AEES_{NRNC}$, for installing permanent magnet motors in new cars can be estimated as follows:

$$AEES_{NRNC} = EES_{A/B} \times mi_A$$

Where,

$EES_{A/B}$ = electrical energy savings per car mile for A/B cars, kWh/car-mi
$mi_A$ = average distance covered by one car in one year, mi

Therefore the expected electrical energy savings can be calculated as follows:

$$AEES_{NRNC} = (0.346)(130{,}241)$$
$$AEES_{NRNC} = 45{,}063 \text{ kWh/car-yr}$$

**EEM No. 8 - Use Ultracapacitors for Regenerative Braking**

**Retrofit**

BART helped record the following parameters with an on-board strip chart recorder:

- Capacitor Bank Voltage (third rail voltage, $V_{Rail}$)
- Dissipation Resistor Switch Duty Cycle ($D_S$)
- Dissipation Resistor Voltage Drop ($V_R$)
- Car Speed

A simplified schematic of the analyzed system along with the connections used to record the dissipated energy are shown in Figure 8-1 below.

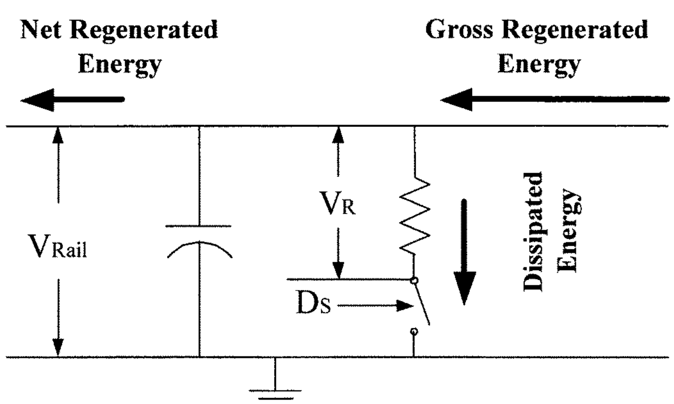



Figure 8-1 Simplified Electrical Schematic of the Regenerative Braking System

In our analysis we have used the plots for the voltage drop across one of the dissipation resistors and the car speed. Whenever there was a significant "jump" in the voltage drop across the dissipation resistor, data was considered. A total of 107 sample sets were used in our analysis (55 sample sets towards the Richmond Station and 52 sample sets coming back to the South Hayward Station). Figure 7-2 at the end of this section shows the first voltage "jump" considered in our analysis. The four plots presented are, from top to bottom: Capacitor Bank

Voltage, Switch Duty Cycle, Dissipation Resistor Voltage and Car Speed. The scales are handwritten on the left side, each horizontal division is 200 ms.

From the voltage data recorded over time and the resistance used to dissipate the excess energy we can estimate the total energy dissipated, DE, for one car on each trip:

$$DE = \sum_i \frac{V_i^2}{R} \times \Delta t \times C_1$$

Where,

| | | |
|---|---|---|
| V | = | voltage drop across the dissipation resistor during one sample, V |
| R | = | equivalent impedance for the two parallel dissipation resistors, 1.39 Ω |
| $\Delta t$ | = | sampling time interval in hours, $5.55 \times 10^{-5}$ h |
| $C_1$ | = | conversion constant, 0.001 kW/W |

Both trips had a similar amount of energy dissipated by the resistor. Table 8-3A/B at the end of this section summarizes the average voltage and dissipated energy during each braking cycle. Form Table 8-3A/B the average dissipated energy per trip was approximately 35.6 kWh. From this average dissipated energy it is possible to estimate the average energy savings, EES, per car mile that can be recovered by storing it in ultracapacitors:

EES = DE × H / HT

Where,

| | | |
|---|---|---|
| DE | = | average amount of energy dissipated by the resistors, 33.5 kWh |
| H | = | average time it takes a BART car to travel one mile, 0.024167 h/mi |
| HT | = | average time it takes to go from South Hayward to Richmond Station, 0.85 h |

Therefore the average electrical energy savings per car mile, EES, that can be realized by installing on-board electrical energy storage devices can be calculated as:

EES = (33.5)(0.024167)/(0.85)
EES = 0.952 kWh/car-mi

The annual electrical energy savings, AEES, that may result from installing on-board electrical energy storage devices can be calculated as follows:

AEES = N × EES × mi

Where,

| | | |
|---|---|---|
| N | = | number of A, B or C cars, no units |
| EES | = | electrical energy savings for installing ultracapacitors, kWh/car-mi |

mi = distance covered by each car type per year, mi/yr

As an example, the annual electrical energy savings, $AEES_1$, for installing ultracapacitors on the C1 cars to store and release all regenerated energy can be estimated as follows:

$$AEES_1 = (150)(0.952)(116{,}435)$$
$$AEES_1 = 16{,}626{,}918 \text{ kWh/yr}$$

The demand savings, DS, for installing ultracapacitors in the BART can be estimated as follows:

$$DS = N \times DE \times CF / HT$$

Where all variables are the same as in the annual electrical energy savings, except:

CF = coincidence factor, fraction of trains that run during BART's peak period, no units

Using the same example as in the annual electrical energy savings, installing ultracapacitors in the C1 cars will result in a demand savings of:

$$DS_1 = (150)(33.5 \text{ kWh})(0.746)/(0.85 \text{ h})$$
$$DS_1 = 4{,}420 \text{ kW}$$

Table 8-2 below summarizes the electrical energy and cost savings for installing on-board ultracapacitors.

**TABLE 8-2 SUMMARY OF ELECTRICAL AND COST SAVINGS**

| Car Type | Number of Cars | Savings per car per mile (kWh/car-mi) | Distance Covered (mi/yr) | Energy Savings (kWh/yr) | Demand Savings (kW) | Total Cost Savings ($/yr) |
|---|---|---|---|---|---|---|
| A | 59 | 0.9520 | 122,275 | 6,867,942 | 1,736 | 721,134 |
| B | 380 | 0.9520 | 137,605 | 49,779,985 | 11,208 | 5,226,898 |
| C1 | 150 | 0.9520 | 116,435 | 16,626,918 | 4,420 | 1,745,826 |
| C2 | 80 | 0.9520 | 127,020 | 9,673,843 | 2,368 | 1,015,754 |
| **Total** | **669** | | | **82,948,688** | **19,733** | **8,709,612** |

The electrical energy cost savings, EECS, can be estimated as follows:

$$EECS = AEES \times (\text{unit cost of electricity})$$
$$EECS = (82{,}948{,}688 \text{ kWh/yr})(\$0.105/\text{kWh})$$
$$EECS = \$8{,}709{,}612/\text{yr}$$

Based on the maximum energy that was dissipated while braking during the test runs, the following equation can be used to estimate the equivalent capacitance needed, $C_{eq}$, to store the maximum regenerated energy:

$C_{eq} = 2 \times E \times C_2 / V^2$

Where,

$E$ = maximum energy dissipated by the resistor during one braking cycle, 1.7 kWh
$C_2$ = conversion constant, $3.6 \times 10^6$ J/kWh
$V$ = maximum voltage drop allowed at the capacitor terminal to release all the stored energy, 666 V§§§

Therefore the equivalent capacitance needed to store the regenerated energy is calculated as:

$C_{eq} = (2)(1.7)(3.6 \times 10^6)/(666^2)$
$C_{eq} = 28$ Farads

Based on a conversation with Maxwell Technologies personnel (a ultracapacitor manufacturer) one of their power modules has a capacitance of 63 Farads at a nominal voltage of 125 V. The total number of modules, M, required to build a capacitor bank with 88 Farads at a nominal voltage of 1,000 V can be calculated as follows:

$M = (V_{Rail} / V_{MOD})^2 \times (C_{eq} / C_{MOD})$

Where,

$V_{Rail}$ = third rail nominal voltage, 1,000 V
$V_{MOD}$ = nominal operating voltage for one ultracapacitor module, 125 V
$C_{eq}$ = the equivalent capacitance needed to store the regenerated energy, 88 Farads
$C_{MOD}$ = the nominal capacitance of each ultracapacitor module, 63 Farads

Therefore the total number of modules required to build a capacitor bank of 156 Farads at a nominal voltage of 1,000 V is:

$M = (1{,}000/125)^2 (28/63)$
$M = 28$ modules

The total number of modules required to have an equivalent capacitance of 28 Farads at 1,000 Volts will be 28 modules.

§§§ Although we are sizing the capacitor bank to operate at 1,000 V (the nominal third rail voltage bus), as a conservative estimate we are requiring that the ultracapacitor does not drop its terminal voltage below 333 V to allow for proper boost converter operation.

**NRNC**

The annual electrical energy savings, $AEES_{NRNC}$, for installing on-board ultracapacitors in new cars can be estimated as follows:

$$AEES_{NRNC} = EES \times mi_A$$

Where,

$EES$ = electrical energy savings per car mile, kWh/car-mi
$mi_A$ = average distance covered by one car in one year, mi

Therefore the expected electrical energy savings can be calculated as follows:

$$AEES_{NRNC} = (0.952)(130{,}241)$$
$$AEES_{NRNC} = 123{,}989 \text{ kWh/car-yr}$$

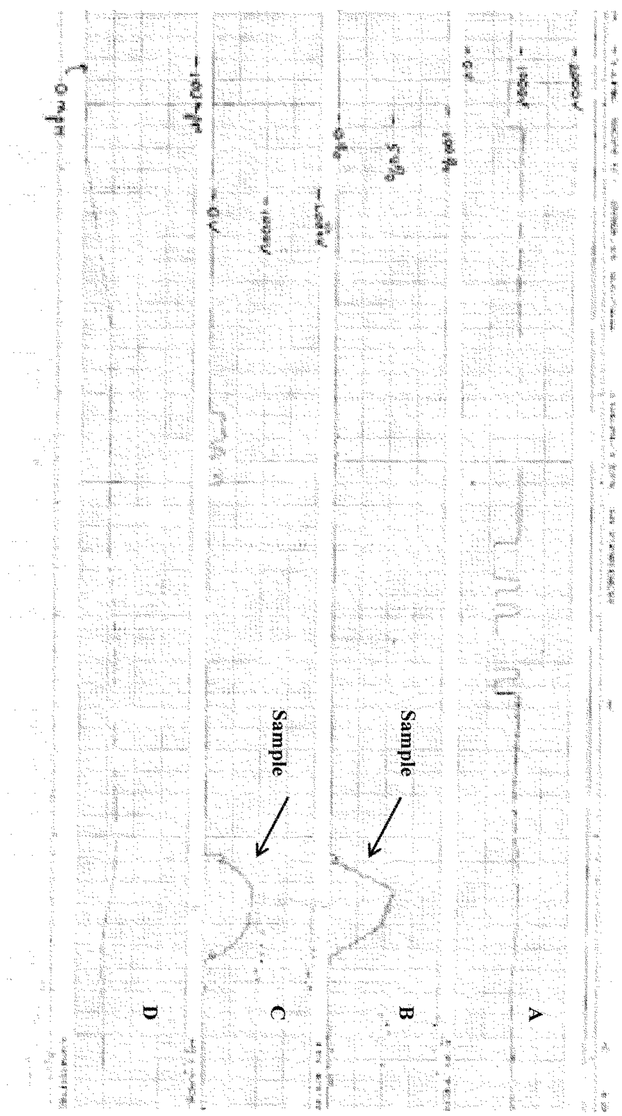



Figure 8-2 Chart Recorder Sample

(A) Capacitor Bank Voltage (third rail voltage)
(B) Dissipation Resistor Switch Duty Cycle
(C) Dissipation Resistor Voltage Drop
(D) Car Speed

| TABLE 8-3A SUMMARY RESULTS FROM ENERGY DISSIPATION TEST – SOUTH HAYWARD TO RICHMOND STATION | | | |
|---|---|---|---|
| **Sample Number** | **Sample Duration** (s) | **Average Voltage** (V) | **Dissipated Energy** (kWh) |
| 1 | 5 | 575 | 0.317146 |
| 2 | 4 | 695 | 0.366528 |
| 3 | 6 | 797 | 0.812163 |
| 4 | 4 | 333 | 0.079936 |
| 5 | 4 | 505 | 0.223839 |
| 6 | 5 | 817 | 0.639755 |
| 7 | 7 | 823 | 0.947174 |
| 8 | 3 | 673 | 0.271809 |
| 9 | 5 | 773 | 0.621057 |
| 10 | 4 | 732 | 0.406433 |
| 11 | 5 | 752 | 0.610016 |
| 12 | 6 | 791 | 0.799473 |
| 13 | 8 | 819 | 1.126109 |
| 14 | 5 | 748 | 0.604020 |
| 15 | 5 | 796 | 0.684267 |
| 16 | 5 | 660 | 0.435252 |
| 17 | 4 | 709 | 0.442119 |
| 18 | 9 | 644 | 0.746958 |
| 19 | 8 | 783 | 1.004474 |
| 20 | 6 | 659 | 0.502784 |
| 21 | 9 | 642 | 0.741815 |
| 22 | 5 | 454 | 0.197858 |
| 23 | 7 | 797 | 0.914480 |
| 24 | 7 | 832 | 1.024737 |
| 25 | 5 | 627 | 0.408427 |
| 26 | 11 | 564 | 0.712687 |
| 27 | 10 | 241 | 0.113574 |
| 28 | 8 | 798 | 1.016797 |
| 29 | 6 | 775 | 0.672162 |
| 30 | 9 | 636 | 0.726494 |
| 31 | 7 | 816 | 0.985201 |
| 32 | 7 | 867 | 0.990674 |
| 33 | 8 | 621 | 0.648253 |
| 34 | 3 | 680 | 0.277218 |

Continued on the following page.

| TABLE 8-3A SUMMARY RESULTS FROM ENERGY DISSIPATION TEST – SOUTH HAYWARD TO RICHMOND STATION (CONTINUED) | | | |
|---|---|---|---|
| **Sample Number** | **Sample Duration** (s) | **Average Voltage** (V) | **Dissipated Energy** (kWh) |
| 35 | 8 | 613 | 0.599770 |
| 36 | 6 | 803 | 0.799373 |
| 37 | 9 | 612 | 0.642918 |
| 38 | 6 | 793 | 0.754650 |
| 39 | 10 | 635 | 0.774589 |
| 40 | 6 | 328 | 0.137702 |
| 41 | 10 | 456 | 0.415540 |
| 42 | 2 | 436 | 0.083715 |
| 43 | 10 | 698 | 0.934461 |
| 44 | 11 | 606 | 0.791434 |
| 45 | 8 | 825 | 1.088129 |
| 46 | 7 | 770 | 0.781387 |
| 47 | 10 | 592 | 0.685982 |
| 48 | 2 | 382 | 0.064094 |
| 49 | 12 | 695 | 1.138750 |
| 50 | 14 | 461 | 0.611866 |
| 51 | 9 | 634 | 0.707080 |
| 52 | 11 | 787 | 1.336893 |
| 53 | 15 | 444 | 0.574751 |
| 54 | 6 | 648 | 0.487114 |
| 55 | 7 | 512 | 0.355904 |
| Total | | | 34.837792 |

| TABLE 8-3B SUMMARY RESULTS FROM ENERGY DISSIPATION TEST – RICHMOND TO SOUTH HAYWARD STATION | | | |
|---|---|---|---|
| **Sample Number** | **Sample Duration** (s) | **Average Voltage** (V) | **Dissipated Energy** (kWh) |
| 1 | 7 | 486 | 0.330022 |
| 2 | 8 | 748 | 0.893295 |
| 3 | 15 | 611 | 1.132231 |
| 4 | 5 | 419 | 0.182639 |
| 5 | 10 | 751 | 1.149582 |
| 6 | 8 | 678 | 0.753388 |
| 7 | 10 | 638 | 0.779676 |
| 8 | 9 | 768 | 1.037752 |
| 9 | 16 | 442 | 0.616221 |
| 10 | 5 | 708 | 0.520445 |
| 11 | 8 | 600 | 0.604317 |
| 12 | 5 | 704 | 0.514804 |
| 13 | 10 | 641 | 0.837988 |
| 14 | 17 | 708 | 1.704067 |
| 15 | 8 | 739 | 0.830504 |
| 16 | 10 | 598 | 0.700248 |
| 17 | 4 | 359 | 0.113382 |
| 18 | 8 | 345 | 0.180498 |
| 19 | 2 | 367 | 0.048361 |
| 20 | 7 | 676 | 0.675136 |
| 21 | 24 | 426 | 0.869708 |
| 22 | 9 | 606 | 0.690724 |
| 23 | 18 | 691 | 1.698529 |
| 24 | 9 | 615 | 0.710249 |
| 25 | 4 | 400 | 0.127898 |
| 26 | 4 | 433 | 0.135092 |
| 27 | 9 | 730 | 0.980920 |
| 28 | 9 | 613 | 0.705342 |
| 29 | 4 | 332 | 0.083491 |
| 30 | 9 | 789 | 1.119327 |
| 31 | 6 | 506 | 0.327788 |
| 32 | 9 | 609 | 0.681194 |
| 33 | 5 | 408 | 0.172723 |
| 34 | 4 | 637 | 0.307985 |

Continued on the following page.

| TABLE 8-3B SUMMARY RESULTS FROM ENERGY DISSIPATION TEST – RICHMOND TO SOUTH HAYWARD STATION (CONTINUED) | | | |
|---|---|---|---|
| **Sample Number** | **Sample Duration** (s) | **Average Voltage** (V) | **Dissipated Energy** (kWh) |
| 35 | 3 | 643 | 0.231244 |
| 36 | 12 | 649 | 1.027480 |
| 37 | 8 | 685 | 0.730585 |
| 38 | 10 | 614 | 0.753389 |
| 39 | 6 | 245 | 0.069475 |
| 40 | 12 | 631 | 0.985541 |
| 41 | 7 | 679 | 0.607708 |
| 42 | 9 | 633 | 0.735768 |
| 43 | 5 | 408 | 0.159939 |
| 44 | 10 | 775 | 1.248301 |
| 45 | 8 | 751 | 0.924763 |
| 46 | 10 | 625 | 0.811851 |
| 47 | 5 | 757 | 0.526118 |
| 48 | 11 | 465 | 0.492413 |
| 49 | 4 | 659 | 0.381967 |
| 50 | 4 | 447 | 0.151984 |
| 51 | 4 | 367 | 0.112843 |
| 52 | 6 | 279 | 0.086845 |
| **Total** | | | **32.253736** |

# 7. REFERENCES

**EEM No. 1 - High Efficiency Lighting for C1 Cars and New Cars**

Plan Layout – Lighting BART Drawing SD-0104829.

Inverter Ballast Drawing 0101921.

Plan Layout – Lighting (BART) 42DA- 110 "C" Car Drawing ICD108009.

BART REHAB "A" AND "B" VEHICLE LIGHTING INSTALATION Drawing 5D79038.

Advance electronic dimming ballasts, http://www.advancetransformer.com/.

Grainger 2005-2006 Catalog No. 396.

**EEM No. 2 - Direct Cooler Air to the Inlet of HVAC Condensers**

"BART Qualification Test Report" – C Car, 1986. (BA0401)
*A report detailing the testing of BART C Cars' HVAC system under various conditions. The power consumption for the various HVAC system components (compressor, condenser fan, evaporator blower) was recorded for each condition.*

BART Document BARVE4G02571 Section 7: Heating, Ventilation and Cooling (C1 Car)
*Document specifying the requirements for air comfort (heating, ventilation and cooling) subsystem and equipment to be provided for C1 cars. Includes design conditions, general comfort requirements, etc.*

Soferval, "Qualification Test Report – Test Title: Performance of HVAC System (Energy Consumption) Installed on BART C Car", Alsthom Atlantique, 1987. (BA3382)
*A report detailing the measurement of the energy consumption of BART C Cars' HVAC system in the Environmental Test Chamber. The power consumption for the various HVAC system components (compressor, condenser fan, evaporator blower) was recorded. Performance curves of the HVAC compressor were also included in this document.*

**EEM No. 3 - Install Higher Efficiency HVAC Units on C Cars and New Cars**

"BART Qualification Test Report" – C Car, 1986. (BA0401)
*A report detailing the testing of BART C Cars' HVAC system under various conditions. The power consumption for the various HVAC system components (compressor, condenser fan, evaporator blower) was recorded for each condition.*

Soferval, "Qualification Test Report – Test Title: Performance of HVAC System (Energy Consumption) Installed on BART C Car", Alsthom Atlantique, 1987. (BA3382)
*A report detailing the measurement of the energy consumption of BART C Cars' HVAC system in the Environmental Test Chamber. The power consumption for the various HVAC system components (compressor, condenser fan, evaporator blower) was recorded. Performance curves of the HVAC compressor were also included in this document.*

**EEM No. 4 - Optimize Outside Air Intake into Cars**

"BART Qualification Test Report" – C Car, 1986. (BA0401)
*A report detailing the testing of BART C Cars' HVAC system under various conditions. The power consumption for the various HVAC system components (compressor, condenser fan, evaporator blower) was recorded for each condition.*

ABB Daimler-Benz Transportation "Qualification Test Report – Test Title: HVAC Capacity Qualification Test" – A2/B2 Cars, 1998.
*A report detailing the testing of BART A2/B2 Cars' HVAC system under various conditions. The power consumption for the various HVAC system components (compressor, condenser fan, evaporator blower) was recorded for each condition. The HVAC system performance (energy efficiency ratio) was also recorded under the various operating conditions.*

BART Document BARVE4G02571 Section 7: Heating, Ventilation and Cooling (C1 Car)
*Document specifying the requirements for air comfort (heating, ventilation and cooling) subsystem and equipment to be provided for C1 cars. Includes design conditions, general comfort requirements, etc.*

Soferval, "Qualification Test Report – Test Title: Performance of HVAC System (Energy Consumption) Installed on BART C Car", Alsthom Atlantique, 1987. (BA3382)
*A report detailing the measurement of the energy consumption of BART C Cars' HVAC system in the Environmental Test Chamber. The power consumption for the various HVAC system components (compressor, condenser fan, evaporator blower) was recorded. Performance curves of the HVAC compressor were also included in this document.*

**EEM No. 5 - Install Daylight Controls on the Fluorescent Lamps**

Plan Layout – Lighting BART Drawing SD-0104829.

Inverter Ballast Drawing 0101921.

Plan Layout – Lighting (BART) 42DA- 110 "C" Car Drawing ICD108009.

BART REHAB "A" AND "B" VEHICLE LIGHTING INSTALATION Drawing 5D79038.

Illuminating Engineering Society of North America, "The IESNA Lighting Handbook Reference & Application," 9th Edition, Illuminating Engineering Society of North America, 2000.

Astronomical Applications Department, U.S. Naval Observatory, "SAN FRANCISCO, CA Rise and Set for the Sun for 2006."

Advance electronic dimming ballasts, http://www.advancetransformer.com/.

xantrex power electronics, http://www.xantrex.com/.

WattStopper lighting controls, www.wattstopper.com/.

**EEM No. 6 - Install Variable Frequency Drives on HVAC Supply Fans**

ABB Daimler-Benz Transportation "Qualification Test Report – Test Title: HVAC Capacity Qualification Test" – A2/B2 Cars, 1998.
*A report detailing the testing of BART A2/B2 Cars' HVAC system under various conditions. The power consumption for the various HVAC system components (compressor, condenser fan, evaporator blower) was recorded for each condition. The HVAC system performance (energy efficiency ratio) was also recorded under the various operating conditions.*

BART Document BARVE4G02571 Section 7: Heating, Ventilation and Cooling (C1 Car)
*Document specifying the requirements for air comfort (heating, ventilation and cooling) subsystem and equipment to be provided for C1 cars. Includes design conditions, general comfort requirements, etc.*

"BART Qualification Test Report" – C Car, 1986. (BA0401)
*A report detailing the testing of BART C Cars' HVAC system under various conditions. The power consumption for the various HVAC system components (compressor, condenser fan, evaporator blower) was recorded for each condition.*

Electric Power Research Institute, Adjustable Speed Drives Directory, Table 3.1, p18, 1991
*Table was extracted from here which shows the comparative energy consumption of an adjustable speed drive control and damper control.*

Soferval, "Qualification Test Report – Test Title: Performance of HVAC System (Energy Consumption) Installed on BART C Car", Alsthom Atlantique, 1987. (BA3382)
*A report detailing the measurement of the energy consumption of BART C Cars' HVAC system in the Environmental Test Chamber. The power consumption for the various HVAC system components (compressor, condenser fan, evaporator blower) was recorded. Performance curves of the HVAC compressor were also included in this document.*

Vuchic, Vukan R. "Urban Transit: Operations, Planning and Economics", Wiley & Sons, 2005.
*We extracted a typical transit passenger loading profile from this report. Based on this passenger volume profile, flow profiles for the various BART cars have been developed.*

**EEM No. 7 - Use Permanent Magnet (PM) Motors for Car Propulsion**

BART Motor Replacement Performance Modeling, DRS Technologies. Mark Harris, Product Line Manager and Applications Engineering, (317) 845-8423, mharris@drs-ept.com

Power Propulsion Drawing TRR 339708

Westinghouse Type 1463BA Traction Motor (DC propulsion motor curve)

Qualification Test Report: Energy Consumption Test on Test Track, Test Set Number: Q.09.01.4.301 Revision B and C

Qualification Test Report: Car Energy Consumption Test, Test Set Number: Q.09.01.4.301 Revision B

**EEM No. 8 - Use Ultracapacitors for Regenerative Braking Energy Storage**

Maxwell Technologies, http://www.maxwell.com. Scot Thompson, Strategic Account Manager, (858) 503-3328, sthompson@maxwell.com

Power Propulsion Drawing TRR 339708

Bruke, Andrew, "Ultracapacitors: Why, How, and Where is the Technology," 2000, Institute of Transportation Studies (University of California, Davis), http://repositories.cdlib.org/itsdavis/UCD-ITS-REP-00-17.

Destraz, B., Barrade, P., Rufer, A., "Power Assistance for Diesel – Electric Locomotives with Supercapacitive Energy Storage," 2004 35th Annual IEEE Power Electronics Specialists Conference.

# 8. QUALIFICATIONS

## 8.1 Analysis Methodology

This energy assessment report is based on the site visit by BASE staff and PG&E Account Service Representative. In the course of development of this report the assessment team surveyed all energy consuming devices and the associated documentation to the extent possible. In the survey, nameplate data of equipment were extracted, and selected measurements such as the power draw of major electrical consuming equipment were made.

Based on the observations, survey and measurements, energy efficiency opportunities (EEMs) have been formulated and analyzed. These EEMs, or majority of them, were also discussed with BART personnel.

The assumptions used to arrive at the energy consumption and cost savings for the recommended EEMs are provided in the report. These assumptions are intended to be conservative and are often arrived at in consultation with Customer personnel.

Three important factors that affect energy consumption and savings are operating hours, utility factor of the machinery (actual hours of operation of a machine divided by the hours of operation of the department), and load factor (actual energy draw divided by the nominal draw). The operating hours used in this report are based on the information provided by the customer and should be taken as average. Cost estimates are based on contacts with equipment manufacturers and contractors to the extent possible. We **recommend** that the customer consult various suppliers for competitive bids for implementation of EEMs whenever deemed appropriate.

We have not evaluated these EEMs for other factors that could impact the ultimate implementation of the EEMs, such as future expansion capability, regulatory compliance and permitting, ease and cost of maintenance, etc.

### 8.2 Liability Disclaimer

PACIFIC GAS AND ELECTRIC COMPANY'S (hereinafter the "Company") AND/OR ITS CONSULTANTS' REVIEW OF THE DESIGN, CONSTRUCTION, OPERATION, OR MAINTENANCE OF THE CUSTOMER'S COMMERCIAL AND/OR INDUSTRIAL SITE, AND ANY AND ALL REPORTS PROVIDED TO CUSTOMER SHALL NOT CONSTITUTE ANY RESPRESENTATION AS TO THE ECONOMIC OR TECHNICAL FEASIBILITY, OPERATIONAL CAPABILITY, OR RELIABILITY OF THE OPTIONS PRESENTED PURSUANT TO THE ENERGY EFFICIENCY SITE SURVEY CONDUCTED ON CUSTOMER'S SITE. THE CUSTOMER SHALL IN NO WAY REPRESENT TO ANY THIRD PARTY THAT THE COMPANY'S ENERGY EFFICIENCY REVIEW OF THE CUSTOMER'S SITE, INCLUDING, BUT NOT LIMITED TO, THE COMPANY'S AND/OR ITS CONSULTANT'S REVIEW OR ANALYSIS OF THE DESIGN AND/OR THE DESIGN, CONSTRUCTION, OPERATION OR MAINTENANCE OF THE SITE, IS A REPRESENTATION BY THE COMPANY AS TO THE ECONOMIC OR TECHNICAL FEASIBILITY, OPERATIONAL CAPABILITY, AND RELIABILITY OF CUSTOMER'S SITE AND/OR THE OPTIONS PRESENTED PURSUANT TO THE ENERGY EFFICIENCY SITE SURVEY PERFORMED AT CUSTOMER'S SITE.

# 9. UTILITY INCENTIVES AND REBATES

This section provides information regarding utility incentives and rebates that are available to PG&E commercial, industrial and agricultural customers.

Section 9.1 provides the potential incentives for various eligible energy efficiency measures under the 2006 Nonresidential Retrofit – Demand Response (NRR-DR) Program.

Section 9.2 consists of a listing of the rebates for various energy efficient equipment under the 2006 Energy Efficiency Rebates for Your Business program.

Section 9.3 presents an overview of the Demand Response Programs that customers may wish to participate in to receive incentives for reducing their electric load when called for. A summary of the various demand response programs that are available and the incentives for each program are included in this section.

Section 9.4 provides an introduction to the Self Generation Incentive Program established by the California Public Utilities Commission (CPUC). This section also gives the financial incentives that are available to customers for installing qualifying self generation equipment.

### 9.1 Nonresidential Retrofit Incentives

Some energy efficiency projects may qualify for energy efficiency incentives through the PG&E Nonresidential Retrofit – Demand Response (NRR-DR) program. Please contact your PG&E account manager or visit the PG&E website at <http://www.pge.com/biz/rebates/2006_incentive_application/index.html> for details regarding this program.

The following table provides an overview of the potential incentive rates available based on the measure category.

| 2006 NONRESIDENTIAL RETROFIT PROGRAM INCENTIVES | |
|---|---|
| **Measure Category** | **Incentive Rate** |
| Lighting<br>(Fluorescent, Other Lighting or Lighting Controls) | $0.05 per kWh saved |
| Motors and Other Equipment | $0.08 per kWh saved |
| Air Conditioning and Refrigeration | $0.14 per kWh saved |
| Natural Gas | $0.80 per therm saved* |

* The incentive may range from $0.60 to $1.00 per therm.

Eligible measures are installation of new, high-efficiency equipment/systems or retrofits and replacements of existing equipment. Energy efficiency measures must exceed applicable government and/or industry minimum efficiency standards to qualify for incentives and must operate and produce verifiable energy savings for at least five years. The eligible incentive per measure is up to 50% of the measure cost, with a cap of $350,000 per project.

### 9.2 Demand Response Programs

The following table provides a general overview of the demand response programs available to customers that reward them for reducing their electric load during periods of extreme usage. More details regarding these programs can be found on the PG&E's website at http://www.pge.com/biz/demand_response/. Your PG&E account manager can also provide you with more details regarding these programs.

**SUMMARY OF DEMAND RESPONSE PROGRAMS FOR 2006**

| Title | Program Requirements | Reduction Required | Reward | Requested Participation | Non-Compliance Penalty |
|---|---|---|---|---|---|
| Demand Bidding Program (E-DBP) | 50 kW minimum load reduction | Voluntary | Market Price Trigger | California Independent System Operator (CAISO) Alert for the next day | None |
| Base Interruptible Program (E-BIP) | Average monthly demand > 100 kW<br><br>Minimum load reduction of 100 kW but no more than 50% of average peak load | Binding | Option A: $7/kW-month<br><br>Option B: $3/kW-month | California Independent System Operator (CAISO) Alert on day-of basis | Option A: $6/kWh (over firm service level)<br><br>Option B: $2.50/kWh (over firm service level) |
| Critical Peak Pricing (E-CPP) | Monthly maximum demand > 200 kW<br><br>No minimum load reduction | Voluntary | Lower prices during summer non-peak periods | Maximum of 12 days per summer season | Higher prices during critical peak periods* |
| Optional Binding Mandatory Curtailment Plan (OBMC) | Ability to achieve a minimum of 15% circuit load reduction from established baseline | Binding | Exemption from rolling blackouts | Price and system conditions | $6/kWh penalty |
| Scheduled Load Reduction Program (E-SLRP) | Reduction of the greater of 15% of baseline or 100 kW | Binding | $0.10/kWh | 4 hr/wk minimum during summer | No incentive or removal from program |
| Demand Reserves Partnership (CPA-DRP) | None | Binding | A capacity or reservation payment as well as an energy payment for performance | Maximum 24 hours per month or a total of 150 hours per year | Established in advance by customer/ Demand Reserves Provider |

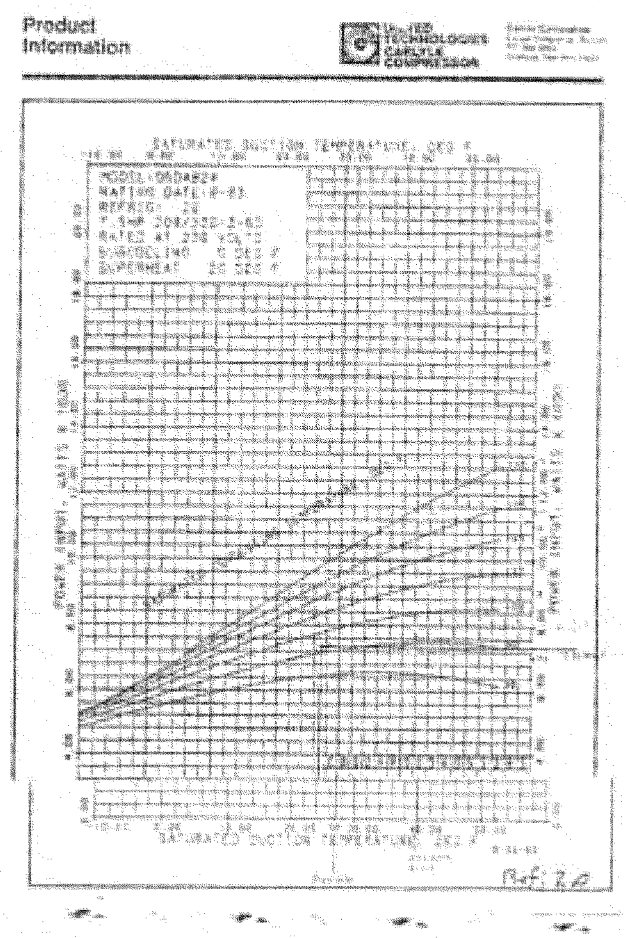
* Bill protection for new customers making participation in the program risk-free for the initial 12 months of participation

## 10. Appendix A - Selected Referenced Documents

This section contains copies of some of the documentation that have been referred to in this report. They are arranged per energy efficiency measure as follows:

- EEM No. 2 - Direct Cooler Air to the Inlet of HVAC Condensers
  - HVAC Compressor Performance Curve
- EEM No. 3 - Install Higher Efficiency HVAC Units on C Cars
  - BART C1 and C2 Cars HVAC ENERGY SAVING ANALYSIS
- EEM No. 7 - Use Ultracapacitors for Regenerative Braking Energy Storage
  - Ultracapacitor datasheet
- EEM No. 8 - Use Permanent Magnet (PM) Motors for Car Propulsion
  - Simulation methodology and results provided by DRS Electric Power Technologies personnel

## HVAC Compressor Performance Curve



**Wabtec/StoneAir, "BART C1 & C2 Cars HVAC Energy Savings Analysis", 2006.**

Stone Air

BART C1 & C2 CARS

# HVAC ENERGY SAVING ANALYSIS

## Wabtec/Stone Air

| | | |
|---|---|---|
| Modified : | Oleg Goureev<br>Project Leader | |
| Verified : | Daniel Simounet<br>Program Manager | DRAFT |
| Approved: | Daniel Simounet<br>Program Manager | |
| | Name / Title | Signature / Date |

| Document No. | 200610417 | Revision | 4 |
|---|---|---|---|
| | | Date (yyyy/mm/dd) | 2006/10/12 |

## Table of Contents

# HVAC THAT SAVES ENERGY

## 1 Overview

There are few ways to control and save energy in HVAC system. Mainly all methods related on hardware efficiency, reducing the losses and improving the control. The following proposal will show various ways to achieve the energy saving goal using the combination of various tools available on the market and applicable to the railroad industry. Some of the methods may require testing and prototyping prior to be implemented on revenue cars.

## 2 Improved Temperature Control Algorithm

### 2.1 HVAC operation modes cycle control

PID control logic allowing reduce energy consumption:
depending on the temperature sensor location, the temperature readings may be affected by door cycling that brings some amount of ambient air inside the car. This influence can force HVAC unit to increase heat or cooling capacity while there is no real demand to do that. The special PID algorithm will prevent waste of energy while doors are cycling.

Risk: low (software driven solution)
Advantages:

- energy saving
- increased reliability by reducing unnecessary component cycling

### 2.2 Humidity sensing

Most of the energy consumption comes from cooling operation when both passenger and solar loads does not contribute to the temperature control. While during cold season, both passenger and solar loads are positive factors contributing to energy saving, it is the opposite during the hot season operation. Therefore the proprietary Stone Air control algorithm allows managing energy consumption based on the real temperature and humidity conditions.

Reheat on demand – the reheat during cooling mode will only be activated if humidity level exceeds certain level. Therefore in case of low passenger load or/and during dry-air weather conditions there will be much less energy consumption.

Risk: low (software driven solution)
Advantages:

- energy saving
- increased reliability by reducing unnecessary component cycling
- better passenger comfort due to real humidity control

### 2.3 Flexible set points based on ASHRAE recommendations

Set points to be provided as a function of human-body filling, i.e. the humidity will cause set-point shift to colder temperature during summer while dry air will force set-point shift to warmer temperature. The bracket (range) where temperature may be changed is to be determined, but it can be in the range of ±2°F. Increasing setting point for 2 °F during summer season and reducing setting point for 2 °F during winter will results in 8324 BTUH which represent 7% of the reduction of the energy consumption.

Risk: low (software driven solution)
Advantages:

- energy saving
- better passenger comfort based on real human body requirements

### 2.4 Fresh Air Intake

Fresh air intake is usually calculated based on maximum number of passengers and on the assumption that the car has no other fresh air intake during operation. In case if number of passengers is less than the maximum car capacity or if doors are cycling every few minutes, the fresh air intake coming from fresh air duct may be reduced to avoid additional energy losses required to condition extra amount of fresh air in the system. This can be achieved by measuring temperature profile over the time along with humidity variation profile. All this allows estimate passenger load and adjust fresh air intake accordingly using motorized fresh air damper. Closing the fresh air intake during the low or less passenger requirement in during cooling operation will change the total cooling requirement from 6.08 to 3.33 tons. This reduction will reduce the cooling energy consumption down to about 50%.

Risk: medium (motorized fresh air damper installation required, cost impact)
Advantages:

- energy saving

## 3 Improved HVAC efficiency

### 3.1 Optimize Mechanical System Design

#### 3.1.1 Condenser coil design improvement

The existing condenser coils have been in service since 1985. However, such a big coil, (5 rows, 48" finned length, and 26" high), has only 5 circuits. Based on Stone Air's experience, the refrigerant pressure drop across the coil will be very high. Theoretic analysis indicate that this very high pressure drop will result in the waste of large amount of energy, making the compressor work in difficult conditions and reducing the system cooling performance. If the number of circuits are increased, the system cooling capacity could be improved.

Changing the condenser coil from 5 circuits to 10 circuits will:

- Increase the cooling capacity for 0.5 ton, which represents 7.1% increase.
- Decrease the energy required to operate this large cooling capacity by 4.5%.

- Increase EER value from 8.4 to 9.1
- Greatly reduce pressure drop across condenser coil from 31.59 psi to 2.24 psi.

It should be pointed out that the coil circuit change will only change the coil internally. The outside dimensions and connection dimensions of the 10-circuits coil are the same as the dimensions of 5-circuits coil.

### 3.2 Scroll compressor versus reciprocating compressor

Initial study shows the benefits of using scroll compressors instead of reciprocating:

- weigh reduction
- higher EER
- more reliable
- less service required
- field-proved solution

All together these factors contributes to more efficient energy distribution and additional maintenance savings.

### 3.3 Two-speed evaporator blower.

The dehumidify using the refrigeration method will follow the following two important rules

1. Reduce the amount of air flow through evaporator coil, and
2. Increase enthalpy difference between air inlet and outlet.

In the actual design there is no problem to reduce the moisture in the air during full cooling operation while there is a problem during the partial cooling operation since compressor has not enough time to remove moisture prior the temperature drops too low and force system to switch into ventilation. Stone Air's recommends select a two-speed motor for best performance and energy savings. Combining with humidity control algorithm the significant energy savings can be achieved at low extra cost.

Risk: medium-low (additional contactor required in the control box, cost impact, field-proved design)
Advantages:

- energy saving
- efficiency improvement

### 3.4 PermaFrost and other chemical materials

Some materials were developed to improve HVAC refrigerant system efficiency. One of these materials is the PermaFrost that improves system efficiency by reducing refrigerant flow restriction caused by oil attached to the inner layer of the system.

Risk: medium (requires on-car testing)
Advantages:

- energy saving

| Contract Specifications | | | BART 7 Tons (108 pass., 100% FA) | BART 7 Tons (54 pass., 0% FA) | BART 7 Tons (0 pass., 0% FA) |
|---|---|---|---|---|---|
| Fresh Air Condition | Dry Bulb | °F | 100 | 100 | 100 |
| | Wet Bulb | °F | 69 | 69 | 69 |
| | Atmospheric pressure | psia | 14.696 | 14.696 | 14.696 |
| | Relative humidity | % | 19.80% | 19.80% | 19.80% |
| | Dew-point temperature | °F | 51.6 | 51.6 | 51.6 |
| | Humidity ratio | lbw/lba | 0.0081 | 0.0081 | 0.0081 |
| | Enthalpy | Btu/lb | 33.00 | 33.00 | 33.00 |
| | Volume | cf/lb | 14.29 | 14.29 | 14.29 |
| | Fresh Air Flow Per Car | CFM | 800 | 800 | 0 |
| Return Air Condition | Dry Bulb | °F | 76 | 76 | 76 |
| | Relative humidity | % | 55% | 55% | 55% |
| | Atmospheric pressure | psia | 14.696 | 14.696 | 14.696 |
| | Wet-bulb temperature | °F | 64.79 | 64.79 | 64.79 |
| | Dew-point temperature | °F | 58.69 | 58.69 | 58.69 |
| | Humidity ratio | lbw/lba | 0.01067 | 0.01067 | 0.01067 |
| | Enthalpy | Btu/lb | 29.80 | 29.80 | 29.80 |
| | Volume | cf/lb | 13.73 | 13.73 | 13.73 |
| | Return Air Flow Per Car | CFM | 3200 | 4000 | 4000 |
| Passenger | Number of Passengers | Qty | 108 | 54 | 0 |
| | Load per passenger | Btu/hr | 450 | 450 | 450 |
| | Sensible Heat Ratio | % | 49% | 49% | 49% |

| | | | Sensible Heat | Latent Heat | Sensible Heat | Latent Heat | Sensible Heat | Latent Heat |
|---|---|---|---|---|---|---|---|---|
| Cooling Capacity Requirement | Fresh Air | Btu/hr | 19348 | 4584 | 0 | 0 | 0 | 0 |
| | Passenger Heat | Btu/hr | 23814 | 24786 | 11907 | 12393 | 0 | 0 |
| | Lighting load | Btu/hr | 8538 | | 8538 | | 8538 | |
| | Carbody | Btu/hr | 31131 | | 31131 | | 31131 | |
| | Solar internal heat load | Btu/hr | 20800 | | 20800 | | 20800 | |
| | Blower Motor (2x2.0 HP) | Btu/hr | 12265 | | 12265 | | 12265 | |
| | Required Capacity per car | Btu/hr | 115895 | 15942 | 84641 | 12393 | 72734 | |
| | | Btu/hr | 131837 | | 97034 | | 72734 | |
| | | Tons | 9.7 | 1.3 | 7.1 | 1.0 | 6.1 | 0 |
| | | Total Tons | 10.99 | | 8.09 | | 6.06 | |
| | | 10% more Tons | 12.09 | | 8.89 | | 6.67 | |
| | Required Capacity per unit | Btu/hr | 57948 | 7971 | 42320 | 6197 | 36367 | 0 |
| | | Btu/hr | 65919 | | 48517 | | 36367 | |
| | | Tons | 4.8 | 0.7 | 3.5 | 0.5 | 3 | 0 |
| | | SHR | 0.88 | | 0.87 | | 1.00 | |
| | | Total Tons | 5.49 | | 4.04 | | 3.03 | |
| | | 10% more Tons | 6.04 | | 4.45 | | 3.33 | |

**Maxwell** HTM Power Series 125v BOOSTCAP® Ultracapacitor Modules

## P Series: HTM Power
### 125 Volt Module

- [illegible]
- [illegible]
- [illegible]

**Features:**

- [illegible]
- [illegible]
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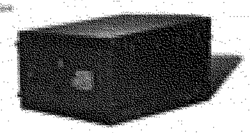
- [illegible]

**Applications:**

- [illegible]



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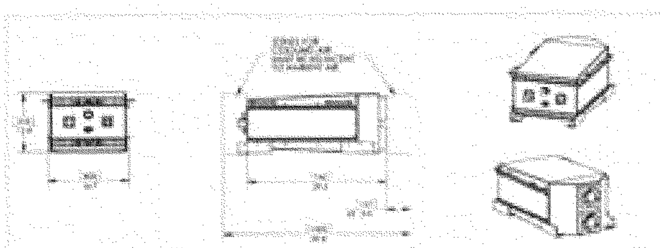

HTM Power Series 125v BOOSTCAP® Ultracapacitor Modules [illegible]

DRS TECHNOLOGIES

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7/18/2006

BART Motor Replacement Performance Modeling

[illegible]
Fax [illegible]
[illegible]

Ricardo A. [illegible]
Electrical Engineer
BASE Energy, Inc.
(415) 543-1600

Ref: BART car Efficiency Performance Test Package
1) Qualification Test Procedure Car Energy Consumption Test Q.09.01.4.301 Rev B 10/14/93
2) Qualification Test Report, Composite, Energy Consumption, Rev B 10/14/93
3) Qualification Test Report, Composite, Regeneration Efficiency, Rev 0 10/30/93
4) Qualification Test Report, Energy Consumption Test on Test Track, Rev C, 03/14/99
5) Ohio Semitronics, INC. Equipment Certifications
6) Davis Formula, Train Resistance Equations

Ricardo:

I have completed the evaluation of permanent magnet machine efficiency as compared to induction machine performance based on the information you supplied me, as referenced above. The following report lays out my analysis methods and calculations as well as conclusions.

## Basic Approach and Calculations

Since BASE and BART desired an analysis of the advantages of PM machines based on actual operating profile and allowing a direct comparison with existing equipment, the data from ref 4 above was used. The data enable the development of a system model of a BART car on the test track. Two alternate models were developed, one for a permanent magnet machine, the other for an induction machines, this enabled the results to be checked against actual test data.

The model developed is a simple physics representation of a complex system (a three car train on a real world track). The modeled results provide an indication of the differences to be expected between an induction machine based system and one using permanent magnet machines. The modeled Induction machine performance was used along with test track data to enable a preliminary estimate of the Wh per car mile savings to be expected of a PM based system.

The test profile chart from the data package was translated by hand to a data table of speed vs. time that could be used as input to the performance model. Tractive losses were calculated based on the mass of one car, the change in kinetic energy at each time step was calculated, the losses in the motor given the power required to overcome the tractive losses and the change in kinetic energy, the input energy to the motor was used to calculate the losses in the converter. Then all of these losses were summed. The regenerative energy was developed in a similar way, during deceleration the kinetic energy change at each time step less the sum of the tractive, motor, and converter losses, is the energy available to the rail.

**Test profile, speed and time:**

The copy of the paper tape from the data-logger was used to generate a speed vs. time table in Excel, this was then transferred to a table in MathCad. There were 52, ½ second time steps, maximum speed achieved was approximately 38 mph. Chart 1 shows the resulting graph.

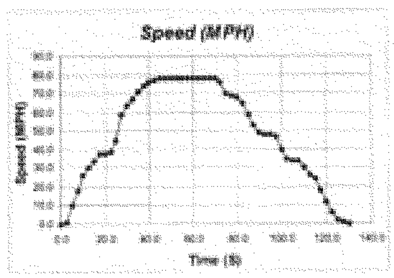


Chart 1: Speed / Time chart from the test data

**Tractive losses per car:**

The Davis Formula was used to generate a curve of tractive forces (losses) vs. speed. The equation used calculated tractive effort in lbs/axle.

$$1.3\frac{W}{N} + 29 + \frac{0.045VW}{N} + \left[0.0024 + \frac{0.00034(C-1)}{C \cdot N}\right] A \cdot V^2$$

| | | |
|---|---|---|
| Weight in tons per car | W | 31.5 |
| Velocity in MPH (max of 84) | V | Speed |
| Total frontal area sq ft | A | 110.25 |
| Number of cars in the train | C | 10 |
| Number of axles per car | N | 4 |

This calculation was used to generate a tractive effort vs. speed graph, which was then used to generate a curve equation. Where Speed was in units of mph and the output in lbf.

$$58.191e^{0.0161 \cdot Speed}$$

This equation was used to develop the power required to maintain a speed, and the average power of two adjacent time steps was used to calculate the energy losses.

**Kinetic energy change:**

Kinetic energy was calculated as:

$$\frac{1}{2} M V^2$$

This ignores the rotational energy in the axles. The kinetic energy at each time step was calculated and the energy required to change the KE state was taken to be the difference between those two numbers.

**Losses in the motors:**

Basic speed vs. efficiency models for both a PM motor and an induction motor were developed. The efficiency vs. speed graph that resulted was converted to a curve in a curve fitting program.

The PM machine equation is: x = percentage of maximum RPM (*100)

$$\frac{a \cdot b + c \cdot x^{d}}{b + x^{d}}$$

a = 0
b = 631
c = 97.3
d = 1.23

The IM equation is: x = % max RPM

$$\frac{a \cdot b + c \cdot x^{d}}{b + x^{d}}$$

a = 0
b = .023
c = .98
d = 1.98

The IM curve is particularly simplistic, assuming that speed is the only component of efficiency (true for a PM), in fact an IM is also sensitive to load, with efficiency going down with torque. Since the load is rarely anywhere near peak the IM would be significantly less efficient than estimated here.

**Losses in the Converter:**

Converter losses are made up of two principle components; fixed losses due to passive components, contacts, device drops, gate drives, control electronics, etc. and variable losses which are due primarily to the switching and conduction losses in the semiconductor devices with a small component of transient losses in capacitors and inductors. The variable losses are proportional to current, which is equivalent to torque. Converter efficiency at max power was set at 97%, a good figure for a modern converter. This 97% figure was multiplied by the power to a single axle to find the total converter losses. These were apportioned 30% fixed, 70% variable, and the variable component was modulated by the torque at the wheels. This was then multiplied by 4 to get the total losses per car.

**Total Losses:**

For the portion of the test run under acceleration and constant speed:

Total losses =Tractive losses +Motor Losses + Converter Losses + Increase in car KE

Model Losses were:

A) Permanent Magnet Machine based system model predicted ~1330Wh.
B) Induction machine based system model~1580Wh.

This 250 Wh difference is indicative of the performance differences between PM and IM based systems. But the numbers are significantly lower than those measured on the track (as was expected). Rotational inertia and the load variable efficiency hit in the IM machine were ignored and would have had a significant impact on the numbers.

These numbers provide a basis for an estimate of system level performance improvement. The IM number and the actual test result were used to scale the PM numbers. This was then converted to a Watt hour per car mile number and finally a Watt hour per car mile savings number:

A) Actual measured energy consumption on the BART test track: 4048 Wh per car mile
B) Expected PM Motor System Energy consumption on the same track: 3868 Wh per car mile
C) **Expected savings of a PM Motor System: >180 Wh per car mile**

**Regenerative Energy:**
For the portion of the test run under deceleration

Regenerated = Kinetic Energy - Tractive losses - Motor Losses - Converter Losses

Model regenerated energy was:
A) Permanent Magnet Machine based system model predicted ~4570Wh
B) Induction machine based system model ~4190Wh

This number is a lot higher than the system test measurement of ~1940Wh; however the method of calculation is highly simplified and not well suited to calculating regenerated energy. Once more it does provide a measure of the differences to be expected between modern PM and IM based systems.

Scaled from the IM model and the actual test data, energy regeneration through a PM based machine, could be expected to be **~2100 Wh a 9% improvement**. Actual equipment could well do better.

## PM Technology Advantages and Differences

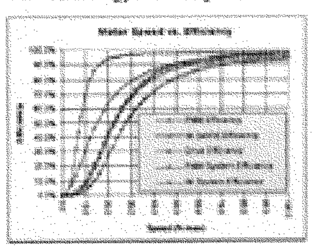

*Chart 2: Motor Speed vs. Efficiency for IM & PM motors / systems*

For traction applications the two principle attributes of PM machines are efficiency and 'torque density' i.e. comparatively modest size and weight in comparison to other machines. The efficiency advantage is shown in Chart 2, a graphical assessment of a PM machine vs. an equivalent IM machine. The efficiency of the motor drive (controller) is also graphed along with the 'system' efficiencies of a combined motor and drive. This clearly shows that the drive has a large impact on the actual efficiencies seen in operation and while a PM based system will be more efficient, the difference will not be as definitive as between the two machines. Modern drives are generally able to control a PM machine with no difficulty, often with no additional hardware (in a sensor-less configuration). Generally because of the lower current requirement in a PM (higher efficiency) the system will be able to operate above the 'normal' rating.

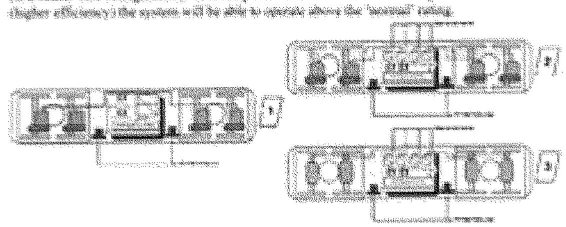

Figure 1: Baseline Induction (or DC) light rail car configuration (1) vs. PM based (2) & (3)

The most fundamental difference between PM machines and general purpose induction machines is that PM machines are inherently synchronous, the impact of this is shown in Figure 1, when you compare configuration 1 (induction or DC machines) to either configuration 2 or 3 (PM machines). The diameters of the steel tires on a car are not going to be exactly matched. Consequently the axles do not turn at the same speed. This has no impact on a DC or Induction machine but will cause major problems in a PM machine based system with a single drive. Efficiency would be severely compromised and damage to the components would be frequent.

The solution to this 'synchronicity' problem is to have 4 separate sensorless motor drive output stages for the PM machine based propulsion system. This solves the problem, and has the added benefit of completely eliminating the need to match the wheel diameters between axles. In addition the drive system can monitor the wear on the tires (and identify flat spots or out of round issues) and provide this information to the maintenance staff. This will allow condition based maintenance and decrease the need for extra axle assemblies, providing large cost savings to the maintenance shop.

Figure 1 configuration 3 shows that PM motors have the potential to simplify the propulsion system even more radically. A PM machine is simply a rotating structure with powerful magnets fixed to it, that is then encased by a static (stator) structure that provides the variable electromagnetic field for drive. Currently there is a gear fixed to the axle, a PM system could have the magnets attached to the axle and the stator would fit around and support the axle, this would eliminate the need for the gearbox and simplify the mounting. While the powerful magnets of a modern PM certainly require care in handling, there are multiple ways of shielding them for those times that the axle has to be removed from the stator for servicing. This style of (PM) machine, while larger not a geared motor, would fit easily in the BART car and would provide multiple system advantages.

## Conclusion

The energy consumption and regeneration calculations above show that a Permanent Magnet Motor based propulsion system for the BART car refurbishment program would provide large real operational savings. A savings of >150Wh per car mile for every one of the cars upgraded, plus an improvement of 9% or better in regenerated energy would have significant advantages to BART and PG&E.

PM machine prices continue to decrease, and because they are inherently smaller and lighter (using less copper, iron and aluminum) than IM machines they may well end up costing about the

*Fast Track Performance Modeling [illegible].doc*
*Page 6 of 6*

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same as similarly rated PM machines (given that the magnet materials will always be much more expensive). By the time the BART refurbishment program begins the cost of PM machines may have come down to near parity with high quality induction machines and the drives will be common to both types of machine. The largest impediment to PM machine acceptance is a certain lingering sense of the exotic and the fact that Induction machines and their [illegible] are common, reliable and well understood by everyone in industry. The obvious PM opportunity is the significant systemic savings that PM machines bring.

## In Closing

I regret the time it has taken to get you this report. This is a new area for me and the company and there is a lot to learn. Your help and understanding along with the data packages you have provided have been of great value. I hope that you can at least use this report as an addendum to the main report you submitted to PG&E.

If you or anyone else at BASE, PG&E or BART has questions, please feel free to call at any time.

Regards

Mark Harris
Product Line Manager and Applications Engineering
DRS Technologies
Cell: (978) 395 5518 Land: (317) 845 8423 e-mail: mharris@drs-ept.com

# 11. Appendix B - Ultracapacitor Implementation Addendum

## 11.1 Introduction

### Objectives

The objective of this study as an Addendum to BART Energy Audit Report is to examine the implementation strategy for incorporating ultracapacitor energy storage devices into BART's existing regenerative braking system. The four main topics addressed in this study include:

1. Research the practical implementation of rail-side and on-board ultracapacitors for use with the regenerative braking system.
2. Economic feasibility analysis and cost estimation of the required interfacing electronics (boost converter).
3. Qualitatively identify the potential benefits and drawbacks of incorporating ultracapacitors at the rail-side, as well as quantify the costs and payback for implementing this option.
4. Qualitatively identify the potential benefits and drawbacks of incorporating ultracapacitors on-board, as well as quantify the costs for implementing this option.

Based on the above research and analysis, the best option (in terms of cost effectiveness) will be assessed based on retrofitting existing BART cars and implementation of this recommendation on a future fleet.

### Limitations

This addendum to the Energy Efficiency Assessment of Bay Area Rapid Transit (BART) Train Cars is a very preliminary study on the potential costs and benefits of retrofitting BART's existing regenerative braking system with ultracapacitors. The component sizing and cost estimate for the DC/DC boost converter represent an approximation (ball park) of what the potential capital costs may be. In no way should the initial boost converter requirements and specifications outlined in this report be treated as a design document.

The qualitative discussions presented in this addendum may serve as an outline and initial assessment of the potential impact of upgrading the existing regenerative braking system with ultracapacitors on the BART system.

### Implementation Summary

Based on the preliminary findings in this study, the following conclusions may be drawn:

1. **Ultracapacitor Life:** A rail-side system is expected to have a life cycle of 30 years, which is approximately 30% longer than the expected 23 years life cycle of an on-board system.
2. **Capital Costs:** A rail-side system may have a slightly higher initial capital cost than an on-board system. It is expected that the capital cost for a rail-side system will be approximately $94,674,648, which is approximately 10% more expensive than an on-board system ($85,923,684).
3. **On-Board vs. Rail-Side:** It is recommended to install a rail-side system if BART is considering retrofitting the existing fleet, however if ultracapacitors are only to be used in a future fleet, it is recommended to install them on-board. If ultracapacitors are used to retrofit the existing fleet there may be other costs (besides capital costs) associated with an on-board system which have not been included in this study. Some of these additional costs may include reengineering a cooling system under the car, reprogramming the automatic traffic control software, etc.

**Research Material**

The following list outlines all the research material (along with a brief description) used to analyze the feasibility and economic analysis for implementing a rail-side or on-board ultracapacitor bank as electrical energy storage for regenerative braking. Original documents are attached in the Appendix at the end of this addendum.

1. ***Energy Storage: Onboard or in Substations?*, Bombardier, June 2005**
   This is a Power Point presentation on a study performed by Bombardier that compared implementing ultracapacitor based regenerative braking on-board with rail-side.

2. ***Energy Storage Devices in Railway Systems*, Martyn Chymera, Alasdair Renfrew, Mike Barnes, University of Manchester, UK, School of Electrical and Electronic Engineering , Manchester M60.**
   This journal article discusses the use of ultracapacitors to improve voltage regulation and energy efficiency in railway networks.

3. ***Energy Recuperation in Transportation*, Dr. Adrian Schneuwly, epn-online, www.epn-online.com**
   This is an online article that describes Rail-Side Regenerative Braking systems that have been successfully implemented in Europe.

4. ***Energy Storage Onboard of Railway Vehicles*, Dr. Michael Steiner, Dr. Johannes Scholten, Power Electronics Specialists Conference, 2004, PESC 04.2004 IEEE 35th Annual, Volume 1, Issue 20-25, June 2004**
   This paper describes the energy efficiency advantages of an on-board energy storage device (ultracapacitors) for use with regenerative braking.

5. **Maxwell Technologies, http://www.maxwell.com.**
   Datasheet on a particular ultracapacitor

6. **Power Propulsion Drawing TRR 339708**
This is the power propulsion schematic for a BART car.

7. **Bruke, Andrew, "Ultracapacitors: Why, How, and Where is the Technology," Institute of Transportation Studies (University of California, Davis), http://repositories.cdlib.org/itsdavis/UCD-ITS-REP-00-17.**
This is a paper that details the state of the ultracapacitor technology.

8. **Destraz, B., Barrade, P., Rufer, A., Power Assistance for Diesel – Electric Locomotives with Supercapacitive Energy Storage," 2004 35th Annual IEEE Power Electronics Specialists Conference.**
This paper examines the applicability of ultracapacitors in a diesel-electric locomotive. It also compares the ultracapacitor performance with other traditional electrical energy storage devices.

## 11.2 Implementation of Ultracapacitors for Energy Storage of Regenerative Braking

### General Implementation Requirements:

Successful interconnection of the ultracapacitor module to the BART propulsion system will require an electronic interface to interconnect the ultracapacitor bank to the third rail (if installed at the rail-side) or directly to the propulsion system (if installed on-board). The electronic interface consists of a DC/DC boost converter system capable of:

- Transferring power from the propulsion system (regenerated energy during braking) to the ultracapacitor module while in braking mode.
- Transferring power from the ultracapacitor module (stored energy) to the propulsion system while in acceleration mode (through the third rail or directly to the propulsion system).
- The ultracapacitor bank voltage should not exceed 1,000 $V_{DC}$, the third rail nominal voltage. While power is being withdrawn from the ultracapacitor bank, the voltage should not decrease below 333 $V_{DC}$ to help maintain the current and voltage ripples low while keeping the boost converter's component size to a minimum. Having smaller rating components will keep the boost converter weight and cost low.
- The boost converter should be sized to handle the maximum power transfer (equivalent to four 150 hp motors). Sizing the boost converter to transfer 448 kW (equivalent to 600 hp) will help ensure that all energy being regenerated can be safely transferred to the ultracapacitor banks, without need to dissipate "excess" energy on braking resistors.

Preliminary calculations on the boost converter design and implementation cost estimations are shown in the Appendix. It is estimated that a boost converter sized to transfer power between the propulsion system of one car and the ultracapacitor bank will cost (capital cost), approximately $11,100 per car.

**Implementation Option 1: Rail-Side Configuration**

A rail-side configuration involves distributing and placing the ultracapacitor banks at strategic locations throughout the BART network. These banks may be installed at the points of PG&E interconnection close to the third rail in places where trains typically stop, or at the individual train stations. In this study, it is assumed that the ultracapacitor banks will be installed at the train stations.

A brief qualitative discussion on electrical losses, overall BART electrical system capacity, train performance and maintenance issues are presented below. Following this discussion a preliminary capital cost analysis of a rail-side system is presented.

**Electrical Losses**
Installing the ultracapacitor banks at the train stations will result in slightly lower system efficiency when compared to an on-board system. The decrease in efficiency is due to the transportation of regenerated energy from the propulsion motors to the capacitor banks located in the train station. It is estimated that the maximum distance that the energy would need to be transferred is approximately 3 miles, equivalent to approximately one half the distance between the furthest apart stations. However, since details on the third rail conductor were not available, it is not possible to estimate the potential losses. Based on a presentation given by Bombardier[****] which compares a rail-side vs. on-board system, the transmission losses in the third rail are approximately 5% of the regenerated energy.

**BART Electrical System Capacity (3rd Rail)**
Rail-side ultracapacitor banks may slightly increase the electrical load on the third rail. The increased electrical load on the third rail is due to the additional available regenerated energy, which used to be dissipated by the braking resistors, that needs to be transferred between the car propulsion system and the ultracapacitor banks in the train stations. However, this slight increase in electrical load is not expected to significantly affect BART's electrical system capacity. This is under the assumption that the third rail has been designed with enough capacity to transfer the additional regenerated energy.

**Train Car Performance**
Since a rail-side system involves installing the ultracapacitor banks off-board, the weight of the ultracapacitor banks will not be added to the train car. Based on the ultracapacitor data sheet, the required 28 modules per car would add approximately 3,000 lbs to the car's overall weight, which represents a weight increase of approximately 5%. Although implementation of a rail-side system may allow removing the existing braking resistors from the train cars (thus making it lighter), it is strongly suggested to keep them on-board for redundancy of the electrical braking system.

**Maintenance and Upgrades**
In a rail-side system it is not necessary to pull train cars out of service when there is need to maintain the electronic braking system, resulting in an increase in train car availability.

[****] *Energy Storage: Onboard or in Substations?*, a presentation by Bombardier, June 2005

Additionally, since the rail-side system is relatively independent of the train cars, as the BART fleet gets upgraded with new cars, the ultracapacitor and DC/DC converter system will remain as part of BART's infrastructure, which would result in less expensive trains.

**Cost Analysis**
Effective implementation of this recommendation will require installing two large regenerative braking systems at each train station capable of absorbing the kinetic energy of two, 10-car trains (one system per train). Therefore a total of 560 ultracapacitor modules†††† would be required per train station, which would cost approximately $1,612,800. Additionally a rail-side system would require two large boost converters at each train station capable of transferring power between the train cars and the storage devices, costing approximately $221,980 per station. Installing a rail-side system in all 43 train stations will cost approximately:

| | |
|---|---|
| (24,080) Ultracapacitor Modules | $ 69,350,400 |
| (86) DC/DC Boost Converters | $ 9,545,140 |
| Installation Costs (20% of above costs) | $ 15,779,108 |
| **TOTAL** | **$ 94,674,648** |

The implementation cost estimation of a boost converter capable of transferring the regenerated energy from a whole train (10 cars) was estimated based on the cost of a converter sized for a single car and multiplied by a factor of ten, which is a very conservative estimate.

Based on the life expectancy of ultracapacitors and an average number of stops that the train is expected to make in the period of one year, it is estimated that a rail-side system would have an average life expectancy of approximately 30 years‡‡‡‡.

**Implementation Option 2: On-Board Configuration**

An on-board configuration involves installing a dedicated ultracapacitor bank and DC/DC boost converter under each BART train car.

A brief qualitative discussion on electrical losses, overall BART electrical system capacity, train performance and maintenance issues are discussed below. Following this discussion a preliminary cost analysis of an on-board system will be quantified.

**Electrical Losses**
Installing on-board ultracapacitor banks will result in increased system efficiency when compared to a rail-side system. The increase in efficiency is due a reduction on the electrical distance which energy must travel between the ultracapacitor bank and the propulsion motors. As stated in the Rail-Side Configuration Section, an on-board system may result in approximately 5% increase in system efficiency when compared to a rail-side system.

†††† Please refer to the Bay Area Rapid Transit (BART) Train Cars Energy Efficiency Assessment for details.
‡‡‡‡ Detailed calculations are shown in the Appendix under Ultracapacitor Bank Life Expectancy.

**BART Electrical System Capacity (3rd Rail)**
On-board ultracapacitor banks may significantly decrease the electrical load on the third rail. A decrease in the third rail electrical load allows for an increase on the number of car trains that may simultaneously run on the tracks by making longer trains (with consideration to station size) or by running more trains (with consideration to train scheduling).

**Train Car Performance**
Since an on-board system would require installing the ultracapacitor bank and DC/DC boost converter underneath a train car, the new system will result in a slight increase in the overall car weight (approximately 5% weight increase). As a result of the increased car weight, it will be necessary to update the automatic train operator parameters that control train acceleration and braking rates as well as the leveling the train cars with station height. This system update would need to be carried out on all 669 cars in the fleet. An additional effect of increasing the car's weight is that it will require additional power to accelerate the train.

**Maintenance and Upgrades**
Maintaining an on-board system involves pulling train cars out of service, which may reduce the overall car availability. Additionally, as old train cars are decommissioned the on-board regenerative braking system would leave along with the cars, which may result in retiring the ultracapacitor storage system too early.

**Cost Analysis**
To effectively implement this recommendation will require installing a capacitor bank under each train car (a total of 669 cars in the fleet) capable absorbing the car's kinetic energy. Therefore a total of 28 ultracapacitor modules[§§§§] would be required per car, and would cost approximately $80,640. Additionally an on-board system would require a boost converter on each train car capable of transferring power between the propulsion system and the ultracapacitor bank, costing approximately $11,100 per car. Installing an on-board system in all 669 train cars will cost approximately:

| | |
|---|---|
| (18,732) Ultracapacitor Modules | $ 53,948,160 |
| (669) DC/DC Boost Converters | $ 7,425,900 |
| Installation Costs (40% of above costs[*****]) | $ 24,549,624 |
| **TOTAL** | **$ 85,923,684** |
| **Cost per Car** | **$128,436/car** |

Based on the life expectancy of ultracapacitors and an average number of stops that the cars are expected to make in the period of one year, it is estimated that an on-board system would have an average life expectancy of approximately 23 years[†††††].

§§§§ Please refer to the Bay Area Rapid Transit (BART) Train Cars Energy Efficiency Assessment for details.

***** It is expected that the installation cost of an on-board system will be at least twice as expensive as the installation cost of a rail-side system. Installing an on-board system will require retrofitting 669 different ultracapacitor systems, whereas installing a rail-side system will require installing only 86 different systems.

††††† Detailed calculations are shown in the Appendix under Ultracapacitor Bank Life Expectancy.

It should be noted that an on-board system may require adding an air intake system under the train cars for additional cooling purposes. Based on temperature measurements under a train car, the temperature climbed up to 20 °F higher than ambient when the braking resistors where used. Although the braking resistors may not be used as often (once the ultracapacitors are installed), the observed temperature rise suggests that there is no adequate air circulation under the train car, which may result in inadequate ventilation for the boost converter.

**Conclusions**

Both, on-board and rail-side systems have been successfully implemented in light rail systems. References to technical journals and magazine articles that describe both implementation strategies are listed at the beginning of this document (full documents are attached to the Addendum).

When deciding between on-board or rail-side implementation of ultracapacitors, it must be determined whether the system will be installed on the current fleet or incorporated on future cars. Table 1 compares the advantages and disadvantages of implementing either a rail-side or on-board side ultracapacitor regenerative braking system.

TABLE 1 ADVANTAGES/DISADVANTAGES OF BOTH IMPLEMENTATION STRATEGIES

| Implementation | On-Board | Rail-Side |
|---|---|---|
| System Efficiency | X | |
| Electrical Capacity | X | |
| Train Performance | | X |
| Maintenance and System Upgrades | | X |
| Air Cooling Requirements | | X |
| System Life Expectancy | | X |
| Retrofit Implementation Costs | | X |
| New Fleet Implementation Costs | X | |

X = advantage.

From Table 1, with consideration of implementation costs and life expectancy, a rail-side system would be advantageous if BART plans to retrofit the existing fleet; however if the energy storage system is going to be implemented on a future fleet, it may be less expensive to install them on-board.

## 11.3 Appendix

### DC/DC Boost Converter (DC Transformer)

A DC-to-DC boost converter is the analog of an AC step-up transformer. Through the use of power electronics the converter is able to step-up a DC voltage. To accomplish this, the boost converter requires two passive energy storage devices, an inductor and a capacitor, as well as a thyristor (a type of transistor), which is used as a switch. A basic boost converter‡‡‡‡‡ circuit is shown in Figure 1 below.

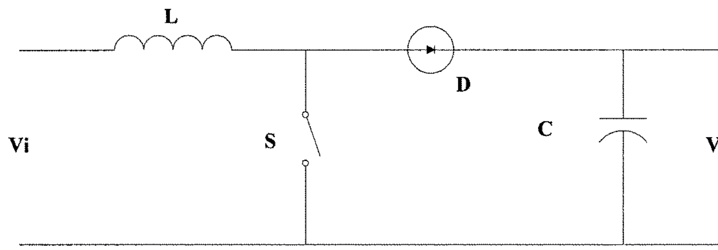


Figure 1 – Basic DC/DC Boost Converter

**Boost Converter Operation**

When Switch S is closed, the power supply feeds Inductor L at a voltage $V_i$. Once Inductor L is fully charged, Switch S opens and the inductor releases its energy through diode D to Capacitor C. As charge is accumulated in Capacitor C, voltage $V_o$ starts to increase until it settles on its steady state value. The output voltage $V_o$ is controlled by regulating the percent of time that Switch S stays on during each switching cycle. Diode D prevents the energy stored in Capacitor C to discharge back to $V_i$ or to ground (through Switch S). Instead energy can only be released to the load, which is at the higher voltage $V_o$.

**The Boost Converter, Ultracapacitor Bank and Third Rail**

To effectively use the regenerated energy from the ultracapacitor bank, it is necessary to release the energy from a lower potential (the voltage across the ultracapacitor bank, $V_i$) to the third rail ($V_o$) which is at 1,000 V dc. Since capacitor voltage decreases as it discharges, the boost converter should actively monitor and regulate the output voltage $V_o$ to 1,000 V dc by controlling the percent of time that Switch S remains closed. From Figure 1, above, the ultracapacitor bank would be connected across the terminal indicated labeled $V_i$, and the third rail would be connected across the terminal labeled $V_o$.

**First Order Boost Converter Prototype**

‡‡‡‡‡ *Power Electronics, Converters, Applications, and Design,* Mohan, Undeland, and Robbins, Second Edition, 1995

Component sizing on the boost converter shown in Figure 1 should be determined based on the boost effect requirements with consideration of the maximum electrical load (four 150 hp motors). To correctly size the inductor, capacitor, diode and thyristor (switch) it is necessary to first determine the switching frequency ($f_s$).

*Switching Frequency*

The limiting factor when determining the switching frequency depends on how fast the thyristor (switch S) can turn on and off. Based on a thyristor manufacturer's datasheet (IXYS Corporation), one of their models which is rated at 1,250 V dc which can conduct up to 600 A (equivalent to a 600 kVA load at 1,000 V dc) has a slew rate (turn-on time) of approximately 1,000 V/μs. Limiting the turn-on time to be no more than 10% of the switching frequency, the maximum switching frequency, $f_s$, can be calculated as follow:

$$f_s = \frac{Vo}{SR} \times 10\%$$

Where,

$V_o$ = third rail voltage, 1,000 V dc
SR = thyristor slew rate, 1,000 V/μs

Therefore the switching frequency is estimated as follows:

$f_s$ = (1,000 V)(0.10) / (1,000 V/μs)
$f_s$ = 100 kHz

*Inductor*

Inductor L should be sized to carry the maximum amount of current that may be required by the load while maintaining the current ripple to no more than 5%. Ignoring the voltage drop across Switch S and Diode D, then the required inductance value, L, that will keep the current ripple to less than 5% can be calculated as follows:

$$L = \frac{Vi\left(1 - \frac{Vi}{Vo}\right)}{fs \times \Delta i}$$

Where,

$V_i$ = lowest voltage across the ultracapacitor bank, 333V dc
$V_o$ = third rail voltage, 1,000 V dc
$f_s$ = switching frequency, 100 kHz
$\Delta i$ = current ripple, 24.85 A (5% of maximum load, 497 A)

Therefore the inductance is calculated as follows:

| | | |
|---|---|---|
| L | = | [(333 V dc)(1 – (333 V dc)/(1,000 V dc)] / [(100,000 Hz)(24.9 A)] |
| L | = | 89 μH (rated at 497 A, which is the maximum propulsion load) |

*Capacitor*

Capacitor C should be sized to maintain the nominal third rail voltage of 1,000 V dc to within 5%. While Switch S is on and Inductor L is charging, the load will be supplied energy by Capacitor C. As Capacitor C discharges, its terminal voltage will begin to decrease. The capacitance value, C, needed to maintain the boost converter output voltage within 5% of the nominal 1,000 V dc can be calculated as follows:

$$C = \frac{\left(1 - \frac{Vi}{Vo}\right) \times Io}{fs \times \Delta Vo}$$

Where all variables are the same as in the inductor sizing, except

| | | |
|---|---|---|
| $\Delta V_o$ | = | voltage ripple, 50 V (5% of 1,000 V) |
| $I_o$ | = | maximum output current, 497 A |

Therefore the capacitance at the output of the boost converter should be:

| | | |
|---|---|---|
| C | = | [(1 – (333 V dc)/(1,000 V dc)](497 A) / [100,000 Hz)(50 V dc)] |
| C | = | 66 μF (rated at 1,000 V dc) |

*Diode*

Diode D should be rated to carry the maximum load current plus the current ripple and be able to withstand a peak inverse voltage of 1,250 V.

**Modified Boost Converter Prototype**

The basic boost converter configuration shown in Figure 1, due to Diode D, is unidirectional, energy can only be transferred from the ultracapacitor bank to the third rail. Adding a second thyristor (switch) across Diode D will allow the boost converter to transfer energy both ways, to and from the ultracapacitor bank. Figure 2 on the next page illustrates the modified prototype.

While in regeneration mode, the thyristor between L and C will remain closed, while the second thyristor will be open. On the other hand, when power is needed from the ultracapacitor bank, the thyristor between L and C will remain open, while the other thyristor cycles on and off as needed.

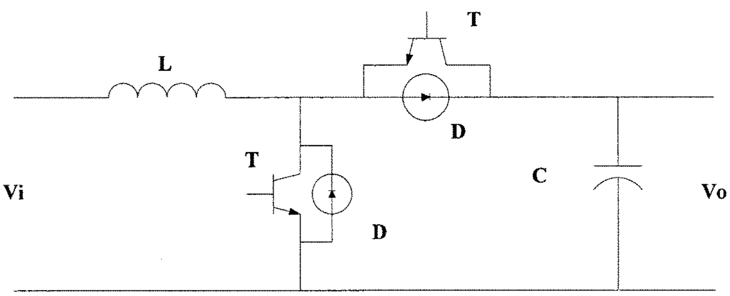


Figure 2 – Modified Boost Converter Prototype

**Boost Converter Cost Estimation**

Based on the component sized for the prototype boost converter and manufacturer's quotes, the boost converter for each car can be estimated as follows:

| | |
|---|---|
| (2) Thyristors | $ 312 |
| (1) Inductor | $ 3,500 |
| (1) Capacitor | $ 30 |
| (2) Diodes | $ 500 |
| Microcontroller and sensors | $ 2,000 |
| Protective Circuit (12% of above costs) | $ 1,586 |
| **Subtotal 1** | **$ 7,928** |
| Engineering (25% of Subtotal 1) | $ 1,982 |
| **Subtotal 2** | **$ 9,909** |
| Overhead and Profit (12% of Subtotal 2) | $ 1,189 |
| **TOTAL** | **$ 11,099** |
| **Cost per Station** | **$221,980** |

Therefore, it is estimated that a boost converter sized to transfer energy between the ultracapacitor bank and the third rail will be approximately $11,100 per car.

**Ultracapacitor Bank Life Expectancy**

Maxwell Technologies, an ultracapacitor manufacturer, rates the life expectancy of their ultracapacitor at 1,000,000 cycles (charging and discharging the ultracapacitor once is considered one cycle). Therefore, to estimate the life expectancy of an ultracapacitor bank as it applies to BART cars, it is necessary to estimate the number of times a car will accelerate and deaccelerate (or start and stop) in one year. From BART's line maps, it is estimated that on average, train stations are approximately 3 miles apart. Table 2 summarizes the total number of miles traveled by car type in a year, as well as the estimated number of stops per year.

| TABLE 2 – CAR STOPS PER YEAR | | | |
|---|---|---|---|
| **Car Type** | **Number of Cars** | **Car-Miles/yr** | **Car-Stops/yr** |
| C1 | 150 | 116,435 | 38,812 |
| C2 | 80 | 127,020 | 42,340 |
| A | 59 | 122,275 | 40,758 |
| B | 380 | 137,605 | 45,868 |
| **Average** | | | **43,413*** |

*** This is a weighted average.**

*Rail-Side System Life Expectancy*

For a rail-side system, the life expectancy, $LE_{RS}$, for the ultracapacitor bank can be estimated as follows:

$$LE_{RS} = \frac{ULE \times NS \times SS \times TS \times CT}{N \times S}$$

Where,

ULE = ultracapacitor life expectancy, 1,000,000 cycles
NS = number of train stations, 43 stations
SS = number of ultracapacitor banks per station, 2 systems/station
TS = number of trains each system can support, 1 train/system
CT = number of cars per train, 10 cars/train
N = total number of cars in BART's existing fleet, 669 cars
S = average number of cycles per year, 43,413 cycles/yr

Therefore the life expectancy for the ultracapacitor bank installed at the rail-side can be estimated as follows:

$LE_{RS}$ = [(1,000,000 cycles)(43 stations)(2 systems/station)(10 cars/train) (1 train/system)] / [(669 cars)(43,413 cycles/yr)]
$LE_{RS}$ = 30 years

*On-Board System Life Expectancy*

For an on-board system, the life expectancy, $LE_{OB}$, for the ultracapacitor bank can be estimated as follows:

$$LE_{OB} = \frac{ULE}{S}$$

Where all variables are the same as in the rail-side system. Therefore the life expectancy for the ultracapacitor bank when installed on-board each BART car can be estimated as follows:

$LE_{OB}$ = (1,000,000 cycles) / (43,413 cycles/yr)
$LE_{OB}$ = 23 years

Senate Banking Committee Testimony
Strengthening the Ability of Public Transportation to Reduce Our Dependence on Foreign Oil
9-9-08
Keith Parker, Charlotte Area Transit System CEO

Thank you Senator Dole. It is a great pleasure to work so closely with you, Senator Burr and your staffs to bring valuable public transportation projects to the Charlotte region. On behalf of CATS, we thank you for your continued support.

Chairman Dodd, Ranking Member Shelby and members of the Committee, thank you for inviting me to discuss the significance of public transportation and the importance of ensuring its funding in the years to come. I am pleased to be here to share with you the transit phenomenon that is occurring in Charlotte.

According to a recent published report, Charlotte is the best place to live in America. Another recent report indicated Charlotte's housing market, even during these troubled times, is one of the strongest in the Country. And yet another report listed Charlotte as having one of the lowest downtown office vacancy rates in the Nation. Not surprisingly, these successes have convinced many people to move to the area, establishing Charlotte as one of the fastest growing cities in our Country. Charlotte is projected to grow another 50 percent by the year 2030 - the equivalent of adding the entire population of Pittsburgh within our borders.

Unfortunately, these newcomers will not be bringing their roads with them. To deal with our growth, about a decade ago the visionary citizens of the City of Charlotte and Mecklenburg County made a commitment to public transportation. The voters instituted a half percent sales tax to expand mass transportation in Charlotte and Mecklenburg County. The investment has proven to be wise.

In addition to investing in transit, Charlotte voters passed two bond referendums totaling $50 million for access improvements for transit oriented development and neighborhoods along the LYNX Blue Line. Some of the completed improvements include 100 pedestrian crossings, 16 miles of sidewalk, seven miles of bicycle lanes, 300 accessible ramps and one mile of new medians. Transit oriented development is a key component in Charlotte's growth strategy. In fact, property values along the LYNX Blue Line grew at a rate of 12 percent faster than the overall land values in Charlotte. Thousands of residential and commercial development is anticipated along the line.

CATS' ridership has risen almost 100 percent since the sales tax was introduced. In just this past year, July 2007 to July 2008, CATS ridership has increased over 40 percent, possibly establishing us as the fastest growing transit system in America. Our public transit users are helping Mecklenburg County save over 20,000 gallons of gas a day.

CATS ridership is growing among nearly all segments. Local services, express services, seniors, and people with disabilities are all riding the bus in record numbers. However, our greatest growth segment is what we call the choice rider. A choice rider often has two cars or more at home and travels in from the surrounding suburbs. These riders have a choice and they are choosing to take public transportation. In fact ridership on our buses that serve the six counties adjacent to Charlotte has grown so dramatically, that we often have people standing in the aisles because all the seats are taken. Just a few years ago, it would have been unfathomable that middle-class suburbanites would make a choice to ride public transit, even if it means they have to stand the entire trip.

To deal with the ridership growth on the bus system, we are ordering more vehicles. In our most recent bus order, we committed nearly 25 percent of the bus order to hybrid vehicles. We would like to order all hybrid vehicles, but hybrids cost 50 percent more than standard buses and like many transit systems, we have to make a tough choice of either going green or getting more buses on the road to meet the growing demands of the riding public.

Incentives from the federal government would help more transit systems to purchase greener buses. The hybrids CATS has on order are possible due to Congestion Mitigation for Air Quality (CMAQ) funds.

To make our transit system more efficient, CATS has made a commitment to technological improvements. For example, we have installed Automatic Vehicle Locator (AVL) devices on all our buses. AVL has allowed us to improve reliability, reduce or eliminate low performing routes, and enhance the overall customer experience. A little known feature of AVL is that it monitors how the bus is driven; including how much time the bus spends idling. Since implementing a tough anti-idling policy in concert with AVL, CATS has increased its fuel efficiency by over 20 percent, saving taxpayers hundreds of thousands of dollars. Federal assistance for transit systems to increase technology investments can be a real benefit and bring back a solid return.

While we are very proud of the overall success of the bus system, the segment that has received the most attention in Charlotte has been LYNX Light Rail. Again we want to thank Senator Dole, Senator Burr and the Federal Transit Administration for helping us get the line built. This new transportation option for the citizens of our region has truly been a turning point in North Carolina public transportation.

Since opening late last year, LYNX has become an instant icon in the Charlotte area with ridership going well beyond our most optimistic expectations. The success of LYNX has led one local reporter to ask in a recent article– "Is it 2025 yet?" We're here to say it is. Utilizing Federal Transit Administration prescribed guidelines to estimate ridership, LYNX may actually reach year 2025 ridership levels before its first full year of service. First year ridership was estimated at 9,100 average daily riders, with that number rising to 18,100 by 2025. Well, we are already averaging 16,900 daily riders and we are only seven months into service. I would like to challenge you to find another city with a light rail start up system that has achieved a ridership level this quickly.

This success has suddenly made Charlotte a model city in the public transit world. In just six-months, we have hosted a number of cities from around the country and beyond who want to see the LYNX Light Rail. Visitors from places like Tampa, Atlanta, Mobile, Daytona, Oklahoma City, and Ontario, Canada are traveling to Charlotte to see the estimated $1.8 billion in new and proposed developments that have emerged along the light rail line. They've also heard about the tens of millions of dollars in new property tax revenue LYNX is helping to generate. These dollars can be used to hire teachers, police officers and firefighters.

The tremendous use of the LYNX Blue Line is putting early stresses on the system. Sixty-five percent of our park and ride lots are full by 8 a.m. We are already researching opportunities to expand or purchase additional land to keep up with the demand of commuters at light rail park and ride lots. Frequency of service has also been increased to accommodate the rush of riders we have throughout the day. Using more of the rail vehicles to reduce headways also means greater wear and tear on the vehicles in a shorter amount of time.

However, what I like to highlight to our visitors is the substantial impact LYNX has on everyday citizens. Of the city's 173 neighborhoods, the Charlotte neighborhood that has seen the greatest improvement is Wilmore, which is adjacent to the LYNX light rail line. Every two years, the City of Charlotte conducts a Quality of Life Study of its 173 neighborhoods. They assess a neighborhood's health by looking at a variety of measures including crime, property values, education, and teenage pregnancies. Just two years ago, Wilmore was given the City's lowest rating.

Today, by virtually every measure, Wilmore is now a better place to live. Crime is down, dropout rates are down, and residents property values skyrocketed. We are talking about people of modest means watching their homes with an average value of $95,000 increase to $192,000 in just two years.

The LYNX light rail opened during this same time period. Just imagine what that type of equity can mean for a family of modest income. Outside the City's core area, only three other neighborhoods showed improvement since 2006 – all of which are on the LYNX Light Rail Line.

Simply put, the investment in public transportation isn't just about moving people; it's about independence. Public transportation creates sustainable communities that strengthen neighborhoods and lives of everyday citizens.

**STATEMENT OF**

**THE 100 BUS COALITION**

**BEFORE THE**

**COMMITTEE ON BANKING, HOUSING, AND URBAN AFFAIRS**

**OF THE**

**UNITED STATES SENATE**

**ON**

**STRENGTHENING THE ABILITY OF PUBLIC TRANSPORTATION**

**TO REDUCE OUR DEPENDENCE ON FOREIGN OIL**

**SEPTEMBER 9, 2008**

**David W. Kilmer**
**Executive Director, Red Rose Transit Authority**
**Co-Leader 100 Bus Coalition**

Good morning, Chairman Dodd, Ranking Member Shelby and members of the Committee. My name is David W. Kilmer, and I am the Executive Director of the Red Rose Transit Authority in Lancaster, Pennsylvania and Co-Leader of the 100 Bus Coalition representing small public transit systems in urbanized areas over 200,000 in population and operate less than 100 peak buses. I very much appreciate the opportunity to speak with you on behalf of the 100 Bus Coalition and the 150 plus public transit systems we work with on the subject of reducing dependence on foreign oil. This is a critical issue not only for small public transit systems, but for the entire public transit industry.

The recent high fuel prices have had both a very positive and very negative affect on all transit systems throughout the country as people are moving to the use of public transit in record numbers, but the additional cost of fuel has created severe financial strains for small systems. Just this past year, Red Rose Transit experienced a 67% increase in fuel costs going from $1.92 to $3.24 per gallon that added roughly $500,000 to our operating budget. We were fortunate to lock-in at this price in March, 2008, but many transit systems were not as fortunate and are paying $4.00 or more for diesel fuel as many suppliers are reluctant to provide fixed contracts due to the volatility of fuel pricing. To address this added cost, transit systems have no choice but to either increase fares significantly or reduce service, or in many cases both. We increased our fares on average of 11% this past July after increasing the fares last year by 8% and 5% the year before. Had it not been for the passage of the Technical Corrections Bill to SAFTEA-LU this past June, we would have had no choice but to make significant service reductions, plus even a larger fare increase. I would like to thank this Committee for its hard work and support for the Technical Corrections Bill on behalf of the 100 Bus Coalition.

While the increase in ridership does help defray the added cost of fuel, it does not come close to balancing the budget and for RRTA, it would take over a 16% increase in riders to make up the difference. For the Fiscal Year that ended June 30, 2008, we recorded a 4.4% gain in ridership due to high fuel prices and that was the biggest gain in over 20 years as it is difficult for small systems to realize large gains as in large urban areas. To put it in perspective, the typical transit system of the 100 Bus Coalition operates just 37 peak buses and carries roughly 2.3 Million passengers with an average operating budget just over $7.2 Million and receives on average $3 Million in federal funding. Also, to put it in perspective, recent surveys of our riders shows that the typical rider is female between the ages of 18-34, 76% of riders earn less than $30,000 per year, and 51% use the bus to commute to work. More important, 78% of our riders have no other means of transportation. These results are typical for small transit systems and demonstrate the local importance transit has in the communities they serve and on the local economy as a vital means of employees to get to work. Like any good business, we look for any opportunity to reduce our on-going operating costs or potential revenue sources before a decision is made to reduce service. For small systems, every little bit helps, whether it is selling advertising on the side of buses or renting space on radio towers for cellular telephone service. This is why the last resort of transit systems is to reduce service because people lose jobs and the magnitude of the high cost of fuel is leaving many systems with no viable options

With this background, there are several actions that can be taken to make transit more fuel efficient. The most obvious is alternative fueled buses, with many transit systems indicating that hybrid electric buses are a preference as they replace obsolete buses. However, the increased cost of hybrid buses, roughly $250-300 more than conventional diesel buses makes it difficult on budgets as systems evaluate the need to replace old buses on limited or no funds. Several systems, including Winston-Salem, North Carolina; Lubbock, Texas; Oklahoma City, Oklahoma; and Martin County, Florida have all responded with the desire to purchase hybrid buses in order to reduce fuel consumption. This technology has proven to show 30-40% increase in fuel efficiency. For RRTA, the operation of a hybrid fleet would save roughly 154,000 gallons of diesel fuel for a cost savings of roughly $500,000 based on our current contract price of $3.24 per gallon. CITIBUS in Lubbock, Texas is currently out for bid for hybrid buses that will cost roughly $500,000 per bus and only has enough money for three buses, but has an option for ten additional buses if funding becomes available. They estimate that if their whole fleet was converted to hybrid electric they would save 210,000 gallons of fuel per year and save $800,000 in fuel costs. For transit systems of the 100 Bus Coalition, this could translate into annual fuel savings of nearly 25 million gallons. This just shows there is a real potential fuel savings from converting to hybrid buses if the funding was available. Not only would small systems benefit from the fuel savings, but operating new buses is far less costly than operating buses that are already beyond their useful life. One of the major problems facing small systems is the inability to replace old buses because of the lack of funding and we support increasing the federal share to 100% for alternative fueled buses as proposed in SB 3380.

Another issue facing many small systems is their ability to make capital improvements to facilities. RRTA's main operations facility is now 30 years old with antiquated operating systems that are very inefficient. The facility was built in the late 1970's when many public transit systems took over operation of service and like bridges and other infrastructure, are now obsolete and costly to maintain. We are currently moving forward with renovating and expanding our facility and have funds for design and engineering, but no funds for construction. One of the primary goals is for a sustainable design that will include such measures as ground source heat, solar panels, and a waste-oil burner since we generate nearly half our heating oil needs just through oil changes on the fleet. We also plan to install skylights throughout our vehicle storage building and offices to reduce our lighting needs and electric use. These are all proven technologies that will result in significant and immediate reductions in energy use. We estimate that we can reduce our energy consumption by 60-70% with these improvements. The lack of funding is again a major deterrent from implementing such fuel efficiency changes. At present, we estimate we will need $5 Million to renovate and expand our facility that will also include needed security measures. It will take RRTA 4-5 years to save up enough funds for this project and assumes we make no other capital improvements, such as replacing old buses.

As Chairman Dodd stated in his speech on July 31, 2008 on the Senate floor, "My answer is this: we must do all that we can to rebuild America's infrastructure, and we must do it now." Investing in public transit will result in a reduction in dependence on foreign oil. First, we need immediate assistance to deal with the high increases in the cost of fuel as contained in SB 3380. Second, we need a long term vision that includes major investments in our nations infrastructure and public transit is part of the infrastructure. As we approach the authorization of a new transportation policy, it is important that we start thinking outside the box in terms of partnerships with local, state, federal, and the private sector in funding the capital and operating needs of public transit in all its modes. If Congress is truly serious about lessoning the dependence on foreign oil, expansion of public transit services has to be at the forefront. I do not think anyone believes that the price of fuel will drop back to the price of even a year ago or that it will not continue to rise. As I hear from other small systems around the country that are barely making ends meet, while at the same time experiencing record ridership gains, reducing transit service should not be the message of the day nor a policy that should be acceptable because of high fuel prices. I firmly believe that public transit is a vital link to a strong economy and needs a strong investment and eliminating service and the resulting loss of jobs is not the answer. I often joke that one of the prerequisites for being a transit manager is you have to like to ride roller coasters because that is our funding has been for operating and capital at all levels for nearly my entire thirty year career in transit. This makes it very difficult to effectively plan services and often results in tradeoffs between maintaining service and capital needs. One size does not fit all and small systems often get caught in the middle of regulations, such as the 200,000 population threshold. It is hard to explain in a public hearing that we may be forced to reduce service and people will lose jobs because our urbanized area population went over an arbitrary population level. We need a federal policy that recognizes the needs of small transit systems to operate service and the capital investment needed to replace vehicles and improve facilities.

In summary, there is a vital role that the federal government can play to reduce dependence on foreign oil through increased capital funding support for replacement vehicles and facility improvements. An immediate action and a crisis for all transit systems, is assistance with the high cost of fuel as contained in SB 3380. For systems in the 100 Bus Coalition, a change in federal regulations to make fuel an eligible expense under preventive maintenance would provide some flexibility to absorb the high cost and would minimize the need to reduce service on the street. For years, the Pennsylvania Department of Transportation has included the cost of fuel under preventive maintenance. This is something that does not require any additional funding and provides the flexibility needed to deal with high fuel costs and could have an immediate impact for small systems. For the long term, there needs to be increased capital investments for vehicles and facilities. Alternative fueled vehicles, either hybrid electric or CNG are more expensive and for a small system it is a balance between the need to replace old costly vehicles with new ones and with limited funding, do you buy three conventional diesel powered buses or maybe two hybrid buses. We need an increased funding source that we can depend on and be able to adequately plan for our capital needs through the discretionary program (Section 5309) rather than hoping you can get an earmark each year because it rarely works for us small systems. Public transit is and should continue to be a partnership between the riders and the local, state and federal governments, with each providing some equity in funding services.

On behalf of the Red Rose Transit Authority and the 100 Bus Coalition, we thank the Committee for your consideration of our views and in these issues facing the public transit industry. We look forward to working with the Committee as you move forward with this issue and the authorization of a new national transportation policy.

**"Strengthening the Ability of Public Transportation to Reduce Our Dependence on Foreign Oil"**

Congressional Testimony of
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Presented before
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Good morning Chairman Dodd, Ranking Member Shelby and members of the Committee. I am pleased to appear before you this morning and very much appreciate the invitation.

The purpose of my testimony today is to discuss some of the broad trends in how Americans travel and the changes brought on by the high costs of energy. In so doing, I would also like to share some thoughts on how federal policy can use public transportation to reduce total energy consumption, while strengthening economic growth.

Mr. Chairman, I support the transit provisions in the substitute to the energy bill (S. 3268) as they are consistent with Brookings' research and policy work on transportation reform. Yet there is much more to do. With the current federal surface transportation law due to expire next year at the same time important climate and energy bills are being considered, Congress has a unique opportunity to promote innovative solutions to help communities grow in more sustainable, inclusive, and competitive ways.

While there is definitely a need for additional resources for the American public transit system, this must be about more than just money. We need an extreme makeover with a fundamentally new approach to almost every aspect of national transportation policy: how we allocate funding, set priorities, apportion responsibilities, engage the private sector, price the system, connect transportation to other policies, and how we move from our current decisionmaking to empirically-grounded policy. To echo a common theme articulated by the national transportation policy and revenue commission – as well as several others – we need a new beginning.[1]

## I. INTRODUCTION

This could not come at a better time. As you know, a perfect storm of energy and environmental sustainability is looming along with high consumer anxiety about the escalating costs of transportation-related items such as gasoline.

These concerns have driven millions of commuters to mass transit at a time of thin and aging transportation capacity, as state and local elected officials increasingly call for federal reforms to improve our infrastructure network and bolster our economic growth. In response, national leaders have offered a range of short- and long-term solutions, such as lifting the ban on offshore drilling or reducing consumer demand through energy conservation.

The U.S. transportation system today consumes 70 percent of the nation's oil and is almost entirely dependent upon petroleum-based fuels.[2] This demand is contributing, in part, to the global rise in the price of oil and the major hit on Americans' pocketbooks. Yet we do not come close to producing the oil we consume and that figure is declining over time, decreasing 17.0 percent since 2000.[3] Only one-quarter of the crude oil consumed in the U.S. is domestically produced. Twice as much is imported and the majority of that from countries considered to be in danger of "state failure" based on a range of social, economic, and political factors.[4] In addition, the transportation sector is responsible for one-third of the nation's carbon emissions and

[1] National Surface Transportation Policy and Revenue Study Commission, "Transportation for Tomorrow," 2008.
[2] Bureau of Transportation Statistics, "National Transportation Statistics," U.S. Department of Transportation, Table 4-3: Domestic Demand for Refined Petroleum Products by Sector, 2007.
[3] Energy Information Administration, "U.S. Imports by Country of Origin," Available: http://tonto.eia.doe.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbl_m.htm.
[4] The rankings come from the 2007 Failed States Index prepared by The Fund for Peace and *Foreign Policy* Magazine. The index employs a rating of 12 social, economic, and political/military indicators as well as other assessments of institutional capabilities. Available: http://www.foreignpolicy.com/story/cms.php?story_id=3865&page=0.

the U.S. continues to rank first among major world economies in per-capita carbon dioxide emissions, roughly double the rate of the United Kingdom and Germany.[5]

A recent Brookings study found that the density of land use patterns in metropolitan areas and transit availability play an important role in determining energy consumption, travel behavior and carbon emissions in our major economic centers.[6] With the right policies in place, denser, walkable, and transit-friendly communities can help reduce vehicle miles traveled (VMT) and therefore help create more affordable and energy-efficient travel options for Americans.

**Table 1: Top and bottom 15 metropolitan areas ranked by vehicle miles traveled per capita, 2006, with carbon emissions from transportation per capita ranking**

| Top 15 | | | Bottom 15 | | |
|---|---|---|---|---|---|
| **VMT per capita** | **Metropolitan Area** | **Carbon Emissions per capita** | **VMT per capita** | **Metropolitan Area** | **Carbon Emissions per capita** |
| 1 | Jackson, MS | 2 | 100 | New York-Northern New Jersey-Long Island, NY-NJ-PA | 100 |
| 2 | Little Rock-North Little Rock-Conway, AR | 5 | 99 | Lancaster, PA | 93 |
| 3 | Richmond, VA | 21 | 98 | Rochester, NY | 97 |
| 4 | Stockton, CA | 36 | 97 | Las Vegas-Paradise, NV | 92 |
| 5 | Harrisburg-Carlisle, PA | 3 | 96 | Honolulu, HI | 99 |
| 6 | Nashville-Davidson-Murfreesboro-Franklin, TN | 8 | 95 | Chicago-Naperville-Joliet, IL-IN-WI | 84 |
| 7 | Bakersfield, CA | 1 | 94 | Cape Coral-Fort Myers, FL | 15 |
| 8 | Columbia, SC | 16 | 93 | Boise City-Nampa, ID | 90 |
| 9 | Chattanooga, TN-GA | 12 | 92 | Buffalo-Niagara Falls, NY | 97 |
| 10 | Palm Bay-Melbourne-Titusville, FL | 17 | 91 | Greenville-Mauldin-Easley, SC | 82 |
| 11 | Madison, WI | 14 | 90 | Portland-Vancouver-Beaverton, OR-WA | 91 |
| 12 | Lexington-Fayette, KY | 20 | 89 | Pittsburgh, PA | 77 |
| 13 | Riverside-San Bernardino-Ontario, CA | 9 | 88 | Fresno, CA | 30 |
| 14 | Knoxville, TN | 11 | 87 | New Orleans-Metairie-Kenner, LA | 80 |
| 15 | Jacksonville, FL | 6 | 86 | Springfield, MA | 86 |

*Source: Brown, Southworth, and Sarzynski, 2008; VMT data and analysis is from a forthcoming Brookings policy brief. Rankings are for the 100 largest metropolitan areas only.*

Studies show that household VMT varies with residential density and access to public transit.[7] Higher residential and employment densities, mixed land-use, and jobs–housing balance are associated with shorter

[5] Gregg Marland and others, "Global, Regional, and National CO2 Emissions," In *Trends: A Compendium of Data on Global Change*, Oak Ridge National Laboratory, U.S. Department of Energy, 2004.
[6] Marilyn A. Brown, Frank Southworth, and Andrea Sarzynski, "Shrinking the Carbon Footprint of Metropolitan America," Brookings, 2008.
[7] John Holtzclaw, "A Vision of Energy Efficiency" American Council for an Energy-Efficient Economy, 2004.

trips and lower automobile ownership and use.[8] In comparing two households that are similar in all respects except residential density, the household in a neighborhood with 1,000 fewer housing units per square mile drives almost 1,200 miles more and consumes 65 more gallons of fuel per year over its peer household in a higher-density neighborhood.[9] Large metropolitan areas such as Riverside, Nashville, and Harrisburg rank among the highest in terms of their amount of VMT and carbon emissions per capita. New York, Chicago, and Portland, OR rank among the lowest (see Table 1).[10]

With the U.S. set to add another 120 million people by 2050 our energy pressures are likely to intensify. As a result of this growth, America will require an additional 213 billion square feet of homes, retail facilities, office buildings, and other built space.[11] How and where we accommodate that growth carries far-reaching implications for our energy security, our economic stability, and the health of our environment—and will go a long way to determining how these places will be able to compete globally in the 21st century.

Unfortunately, as a program with its roots in the middle of the last century, the federal surface transportation program is outdated and out-of-step with the energy and environmental constraints of our time.[12] The broader transportation system in the United States is no longer aligned with the way we live or work, nor with the major economic, energy, and environmental challenges facing the country.

For example, federal transportation dollars continue to be distributed to its grantees based on archaic funding and distributional formulas. There is no reward for reducing the demand for driving, nor overall spending. In fact at the same time Americans are seeking to drive less due to energy and climate concerns, federal formulas actually reward consumption and penalize conservation.

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[8] Mary Jean Bürer, David Goldstein, and John Holtzclaw, "Location Efficiency as the Missing Piece of the Energy Puzzle: How Smart Growth Can Unlock Trillion Dollar Consumer Cost Savings," American Council for an Energy-Efficient Economy, 2004.

[9] Thomas Golob and David Brownstone, "The Impact of Residential Density on Vehicle Usage and Energy Consumption," University of California-Irvine, Institute of Transportation Studies Working Paper WPS05 01, 2008.

[10] Brown, Southworth, and Sarzynski, 2008; VMT data and analysis is from a forthcoming Brookings policy brief.

[11] Arthur C. Nelson, "Toward a New Metropolis: The Opportunity to Rebuild America," Brookings: 2004.

[12] See: Robert Puentes, "A Bridge to Somewhere: Rethinking American Transportation for the 21st Century," Brookings, 2008.

There also continues to be almost no focus on outcomes or performance. So at this moment of transportation crisis, billions and billions of federal transportation dollars are disbursed without meaningful direction or connection to advancing national interests on critical issues such as reducing our dependence on foreign oil.[13]

## II. CURRENT TRANSPORTATION TRENDS

A healthy national economy depends on healthy metropolitan economies—and enhancing mobility for residents by expanding transit options is a critical component. Therefore, for our transportation system to continue to provide a competitive edge, reducing energy consumption by improving the movement of people by multiple means both within and between metropolitan areas should continue to be an explicit national priority. We are already seeing transformations of dramatic scale and complexity when it comes to our transportation system and how Americans are traveling. We know most people can't stop traveling altogether—nor should they—but some can change *how* they travel.

### *1. High gas prices are driving Americans to transit*

After years and years of steady increases, the total amount of driving in the U.S. has slowed down dramatically. In fact, monthly dispatches from the federal highway administration illustrate clearly that as a nation we are driving much less. Cumulative travel for 2008 has decreased by 42.1 billion vehicle miles, the largest drop in driving that this nation has ever seen.[14]

Without a doubt some of this decrease is attributable to skyrocketing gas prices which, although they have fallen in the last two months, are still one dollar per gallon higher than this time last year. Americans now consume 31 million fewer gallons of gasoline each day in 2008 than they did in 2005.[15]

[13] A poll last winter–before the run up in gas prices–found that 69 percent of respondents view our dependence on oil as a high priority issue. By comparison, the percentage of Americans that see health care costs, education, and jobs and the economy as high priority issues are at 68, 64, and 62 percent, respectively. (Source: Harris Interactive December 2007 poll of 1000 likely voters [+/- 3 pts])

[14] U.S. Department of Transportation, "Traffic Volume Trends," Federal Highway Administration, Office of Highway Policy Information, June 2008.

[15] Energy Information Administration, "U.S. Total Gasoline Retail Deliveries by All R&G (Thousand Gallons per Day)," http://tonto.eia.doe.gov/dnav/pet/hist/a103600001A.htm.

Partly as a result, transit ridership is booming, increasing by 74 million trips from March 2005 to March 2008–a gain of nearly nine percent.[16] A recent survey found that 92 percent of transit agencies reported increases in ridership and 91 percent of those attribute at least part of the increase to the increased fuel costs to American drivers.[17] Amtrak's ridership this past July was its highest in any single month in its history.[18]

**Table 2: Select transportation trends and percent change, March 2005 – March 2008**

| | |
|---|---|
| Retail gasoline price | 56.0% |
| Gasoline deliveries | -5.3% |
| Vehicle miles traveled | -2.4% |
| Air passenger boardings | -0.8% |
| Unlinked transit passenger trips | 8.7% |
| Amtrak ridership | 7.4% |

*Various sources*

There is no doubt that these trends are positive for our national quest for energy independence and climate protection. It is also consistent with recent research showing the significant contributions public transportation makes to reducing overall oil and gasoline consumption.[19]

Unfortunately, we also know that transit agencies are not immune from the increases in fuel costs and at the same time are struggling to cope with this increased demand. Perversely, one in five transit agencies are considering *cuts* in service as a result of the increased costs of energy.[20] So at the time when the nation needs functioning, reliable, mass transit we are finding many agencies in severe distress.

*2. Yet, most metropolitan areas are beset with limited transit and overall travel options*

In addition to these struggles, the reality is that the availability and accessibility of public transportation across the country's 100 largest metro areas is seriously lacking.

[16] American Public Transportation Association, "Public Transportation Ridership Statistics," various years.
[17] American Public Transportation Association, "Impact of Rising Fuel Costs on Transit Services: Survey Results," May 2008.
[18] Amtrak, "July 2008 Amtrak Ridership Sets All-Time Monthly Record," Press Release, August, 14, 2008.
[19] See e.g.: Robert J. Shapiro and others, "Conserving Energy and Preserving the Environment: The Role of Public Transportation," American Public Transportation Association, 2002; Phineas Baxandall and others, "A Better Way to Go: Meeting America's 21st Century Transportation Challenges with Modern Public Transit," U.S. Public Interest Research Groups Education Fund, 2008.
[20] APTA. May 2008.

Although nearly every metropolitan area enjoys bus service, more than half is concentrated in just 10 large metros like New York, Miami, and Seattle. Heavy rail—also referred to as subways—exist in only 11 metros like Philadelphia and San Francisco. Commuter rail is in only 14 metropolitan areas, primarily in the Northeast and California. And light rail can be found in only 26, like Salt Lake City, Charlotte, and Denver.

Therefore, based simply on the amount of transit infrastructure available, 54 of the 100 largest metros do not have any rail transit service and also have relatively weak bus systems. This includes large metros like Orlando and Indianapolis; fast growing metros like Raleigh and Jacksonville, FL and slow growing metros like Youngstown and Rochester, NY.

This lack of metropolitan travel options means tens of millions of Americans are tethered to their cars for their daily travel needs. That is, assuming they can afford the high costs of owning a car.

As employment has dispersed throughout metropolitan America, lower income workers are finding themselves increasingly isolated and therefore need to spend higher proportions of their income to reach their jobs. Many simply have *no choice* but to spend $4 for a gallon of gas.

Information drawn from the three most recent years of the American Housing Survey shows that only 55 percent of respondents reported that transit is even available to them. More disturbing is that only one-third of respondents in newly-constructed housing reported that transit was present. Transit was much more readily available in center cities (82 percent) than in suburbs (52 percent).[21]

[21] Data from 2002, 2003, and 2004 are examined for the nation and for the 32 metropolitan areas surveyed during those years. This is similar to the approach in Paul Weyrich and William Lind, "Does Transit Work? A Conservative Reappraisal," Free Congress Research and Education Foundation, 1999.

**Table 3: Response to American Housing Survey:** ***Is there public transportation for this area?***

| | | Access to public transportation | | |
|---|---|---|---|---|
| | | **Yes** | **No** | **Not reported** |
| **Housing** | Total occupied units | 55.2% | 41.8% | 3.0% |
| | Owner | 47.6% | 49.4% | 3.0% |
| | Renter | 71.2% | 25.7% | 3.1% |
| | Newly constructed | 33.2% | 62.1% | 4.7% |
| | Moved in past year | 59.3% | 35.7% | 5.0% |
| **Demo-graphics** | Black | 70.5% | 27.2% | 2.3% |
| | Hispanic | 71.7% | 26.0% | 2.3% |
| | Elderly | 52.3% | 45.1% | 2.6% |
| | Below poverty level | 58.0% | 38.9% | 3.1% |
| **Geographic** | Central cities | 81.9% | 15.3% | 2.7% |
| | Suburbs | 51.9% | 44.5% | 3.5% |
| | Rural | 15.7% | 81.9% | 2.4% |
| | Northeast | 66.3% | 30.9% | 2.8% |
| | Midwest | 53.5% | 43.2% | 3.3% |
| | South | 39.8% | 56.9% | 3.3% |
| | West | 72.6% | 25.0% | 2.4% |

*Source: Brookings Analysis of American Housing Survey, 2002-2004*

One reason the metropolitan transportation system—which should serve as the connective tissue within and between metropolitan areas—is woefully incomplete, is due to flaws in federal policy.

Federal transportation policy has long favored highway building over transit investments.[22] Transit projects are evaluated and funded differently than highways. The pot of available federal transit funding is so small that the federal government oversees a competitive process for new transit funding, requiring multiple hypercompetitive bureaucratic reviews that demonstrate a project's cost-effectiveness. Funding is also subject to annual congressional appropriations. Highways do not undergo the same level of scrutiny or funding uncertainty. Also, while highways typically receive up to 80 percent of federal funds (and 90 percent for improvements and maintenance), new transit projects' federal contribution is often less than half of the project cost.[23]

Taken together, these biases ensure that state transportation policy pursued under federal law works against many metropolitan areas' efforts to maintain modern and integrated transportation networks

[22] Edward Beimborn and Robert Puentes, "Highways and Transit: Leveling the Playing Field in Federal Transportation Policy." In Bruce Katz and Robert Puentes, eds., *Taking the High Road: A Metropolitan Agenda for Transportation Reform,* Brookings, 2005.
[23] Puentes, 2008.

*3. The investments that have been made in transit are not having the effect they could*

At the convergence of these trends is the realization that a substantial market exists for a new form of walkable, mixed-use urban development around transit stops in real estate markets as diverse as suburban New Jersey, Atlanta, Dallas and Chicago. Overall, transit-oriented developments (TODs) are designed to weave transit stations into the fabric of the surrounding community, and to increase the role of transit in the transportation system, and more generally the day-to-day life of the surrounding area.

These transit-oriented developments have the potential to lower household transportation expenses, reduce environmental and energy impacts, and provide real alternatives to traffic congestion. Residents who live in transit-oriented housing typically use transit 2 to 5 times more than other commuters in the region. In addition, those households are twice as likely to not own a car at all, and generally own half as many cars as similar households not living in transit rich neighborhoods.[24]

Other research shows the benefit of TOD on household budgets. In just eight cities, more than 100,000 federally assisted housing units sheltering more than 300,000 individuals are located in transit rich neighborhoods. Approximately 65,500 of these units are covered by federal rental assistance contracts expiring before the end of 2012.[25] A recent federal transit administration study shows that families that live in TOD neighborhoods spend just 9 percent of their household budget on transportation, compared to 25 percent for those in automobile-dependent suburbs.[26] While the share of spending on housing is equal, the transportation savings are critically important to low income families for whom transportation eats up a disproportionately large share of their annual income.

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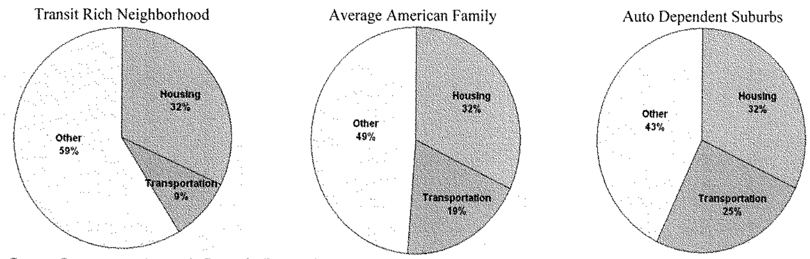
[24] G.B. Arrington, Robert Cervero, and others, "Effects of TOD on Housing, Parking and Travel," Transportation Research Board, Transit Cooperative Research Program Report 128, 2008.

[25] The eight cities are: Boston, Chicago, Cleveland, Denver, New York, Portland, St. Louis, and Seattle. National Housing Trust and Reconnecting America, "Preserving Opportunities: Saving Affordable Homes Near Transit," 2007.

[26] Reconnecting America's Center for Transit-Oriented Development, "Realizing the Potential: Expanding Housing Opportunities Near Transit," Federal Transit Administration and the U.S. Department of Housing and Urban Development, Report CA-26-6004, 2007

**Table 4: Portion of household income spent on housing, transportation, and other by neighborhood type**




*Source: Reconnecting America's Center for Transit-Oriented Development, "Realizing the Potential: Expanding Housing Opportunities Near Transit," Federal Transit Administration and the U.S. Department of Housing and Urban Development, Report CA-26-6004, 2007*

The benefits of TOD could be bolstered by synergies with other policies, notably policies that encourage urban infilling, such as the rejuvenation of brownfields, the development of urban enterprise zones, locating new federal buildings in promising mixed-use, higher-density commercial areas, and the use of alternative mortgage products such as energy efficient and locationally efficient mortgages. The results will give metropolitan areas more flexibility and the nation expanded options for addressing large-scale challenges.

However, many of these benefits are not being realized. Although TOD is now starting to be recognized as a viable type of development, there is still a widespread lack of understanding of its nature, its potential, the challenges it faces, and the tools needed to overcome these challenges.

For one, there is no universally accepted premise about exactly what TOD should accomplish, nor are there standard benchmarks for success. For example, some developments are labeled TOD by virtue of their proximity to a transit station, regardless of how well they capitalize on that proximity or capture the increase in land value. In addition, there are multiple actors engaged in TOD projects including the transit agency, riders, neighbors, developers, lenders, and government at all levels. They often bring different goals to the table, pursue strategies that work at cross-purposes to each other, and lack unifying policy objectives.[27]

[27] Dena Belzer and Gerald Autler, "Transit Oriented Development: Moving From Rhetoric To Reality," Brookings Institution and the Great American Station Foundation, 2002.

In short, TOD requires synergy among many different uses and functions that is difficult to achieve. As a result, TOD almost always involves more complexity, greater uncertainty, and higher costs than other forms of infill development. We need to make TOD easy and non-leveraged investments hard. In other words, we need to flip the system.

The federal government can play a critical role in supporting the planning of such projects and corridors, coordinating with private sector developers and lenders, and promoting metropolitan diversity in project selection. Such considerations would catalyze the nearly $75 billion in public dollars invested in rail transit over the past 11 years and go a long way to reducing energy consumption as an explicit national goal.

## III. POLICY RECOMMENDATIONS

Federal policy can and should play a powerful role in helping metropolitan areas—and so the nation—reduce energy consumption through targeted and prioritized investments in public transit and support of transit-oriented development. The cross-boundary challenges justify a more decisive federal policy that helps metropolitan areas promote energy- and location-efficient development.

Mr. Chairman, to do that I believe we need a systemic change in the way we think about, design, and implement transportation policies. This means the development of a three-pronged strategy to lead, empower, and maximize performance across the nation.

First, the federal government must LEAD and develop a coherent national vision for transportation, and focus on specific areas of national importance such as reducing our dependence on foreign oil. Second, the federal government should EMPOWER states and metropolitan areas to grow in energy-efficient and sustainable ways. Third, the federal government should OPTIMIZE Washington's own performance and that of its partners in order to spend taxpayer dollars better and implement the vision.

In the *short term*, the proposed transit provisions of the substitute energy bill are consistent with this overriding frame.

Emergency transit funding to accelerate capital investments is needed to accommodate ridership increases and provide adequate service to the vast reaches of the country without it. Additional formula funding is needed is avoid service cuts at the precise moment that Americans try riding the bus or train for the first time and evaluate their options. The program to boost the energy efficiency of transit systems—thereby cutting operating costs and helping curb dependence on foreign oil—is also a critically important component.

The proposed Transit-Oriented Development Corridors grant program also provides an empowering model through a competitive process to metropolitan actors with proposals for growing differently. The considerations for evaluating grant recipients are, I believe, the right ones: clear justification and outcome orientation that includes reducing energy consumption; ensuring a metropolitan-wide perspective on choosing the location of the project; coordinating with all actors and promoting public/private partnerships; mixing uses and housing types; and harmonizing transportation with other policy areas such as housing, economic development, and land use.

Over the *long term*, the upcoming reconsideration of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: a Legacy for Users (SAFETEA-LU) provides the perfect opportunity for re-envisioning how transportation policy should help solve the nation's energy and climate challenges.

The federal government should take the lead and establish a clear vision for transportation that includes energy and climate change concerns, and levels the playing field between the modes so energy-efficient investments can become more feasible. A National Infrastructure Bank, which has been championed by this committee, is an important window through which the federal government can partner with states, metropolitan areas, and localities to implement this national vision.

In addition, existing federal transportation formulas should be overhauled so funds are not distributed based on factors that potentially increase energy consumption and greenhouse gas emissions. In order to commit to an evidence-based program, major improvements are needed in how the federal government collects, assembles, and provides data and information. We desperately need a sunshine law for transportation data to better inform decisionmaking at the state and metropolitan levels and to regain the credibility of the public.

To take full advantage of development opportunities around transit stops the federal government must correct the cost-effectiveness index that determines which metropolitan projects receive New Starts funding for rail projects. It needs to move well beyond the overly simplistic short-term calculation of the ratio of capital and operating costs divided by time saved. The long-term ability for the right kind of investments to stimulate efficient high-density transit-oriented development and the environmental and agglomeration benefits that accrue should be sufficiently weighted.

Scrutiny of new transit projects is certainly warranted given the incredibly high demand for scarce funding and the dramatic impact such investments can have on a metropolitan area when done correctly. The federal government must prioritize transit investments in those metropolitan areas where states and localities have made the strongest commitment to making the maximum use of the investment. But there is no reason why new roadway projects using federal funds should not face the same level of scrutiny as new rail projects. Although economic and fiscal considerations are key criteria for evaluating projects, so too should environmental quality and energy efficiency.

We also need a realignment of responsibilities so our major metropolitan areas—say, with a population over two million—are given more direct funding and project selection authority through a new program we're calling METRO (Metropolitan EmpowermenT pROgram). The METRO program should be formula-driven based on population and modeled after the Community Development Block Grant program. The program would consolidate several categorical highway and transit programs.

Another potentially transformative tool to reduce oil consumption in America would be to issue a Sustainability Challenge to all metropolitan actors. Addressing our nation's energy problems will ultimately require innovation and creativity to link fragmented transportation, housing, energy, and environmental policies beyond anything considered so far. This is more than just comprehensive planning by individual jurisdictions; this involves comprehensive and integrated planning and increased investment at the metropolitan scale over a sustained period with the goal of massively transforming the design and workings of the built environment. Metropolitan America simply does not have the scale and the resources to do this alone.

Partnerships of states, metropolitan areas, transit agencies, localities, and the private sector would apply for these competitive grants that would ideally encompass a range of solutions from all modes and would tie-in directly to an articulated set of national transportation outcomes for energy and environmental sustainability rather than simply extrapolating from past trends. Selected places would be provided additional resources (on top of regular block grant allocations) as well as new powers to align disparate federal programs in support of the vision. The mechanism for these grants could be the transportation, energy, or climate bills pending—or soon to be pending—in Congress.

## IV. CONCLUSION

Reducing our dependence on foreign oil, encouraging energy sustainability, and promoting economic efficiency will require major shifts in federal transportation policy. As the relationship between physical growth and energy and environmental objectives becomes more salient, the federal government must use transportation policy to reduce vehicular travel and promote new, bold visions for the role of transit in affecting the location of future residential and commercial development.

Mr. Chairman, in the end my message is simple: a sure-fire way of reducing the impact of higher gasoline prices is to lower consumer demand. And the best way to lower demand is to build more sensible communities that give families greater transportation choices.

*The views expressed in this testimony are those of the author alone and do not necessarily represent those of the staff, officers, or trustees of The Brookings Institution.*

**RESPONSE TO WRITTEN QUESTIONS OF SENATOR REED FROM WILLIAM MILLAR**

**Q.1.** The emphasis of federal transit funding has focused on helping public transportation agencies make capital improvements. While transportation agencies can typically use bonding authority to raise the funds they need for capital improvements, they often have less flexibility to find new sources of revenue to respond to escalating operating costs. For example, the Rhode Island Public Transit Agency is dependent on a share of state gas tax revenue to meet much of its operating overhead. Unfortunately, that revenue stream does not keep pace with inflation, and as gas prices have climbed this year (and as more drivers have turned to public transportation), it has declined.

With increases in energy and other operating costs, are we at a point where we should recalibrate where federal public transit funding is allocated by dedicating at least some support to operations?

**A.1.** Senator Reed, you are correct in observing that public transportation systems need assistance not only for capital projects; they also need help with maintaining their current services. Public transportation systems across the United States are being forced to choose between raising passenger fares or cutting service to make up for shortfalls in local funding related to the current economic downturn and the increased cost of diesel fuel this past summer. The burden is so great that 35 percent of public transportation providers who responded to a recent APTA survey have been forced to cut or are considering cutting the level of passenger service they provide in spite of the growing demand for their services. This could not happen at a worse time. Public transportation ridership has grown dramatically this year, and we need to continue that growth.

To address the current operating environment facing transit providers, it is essential that support for agencies facing increased fuel costs and reduced local funding be retained in any future stimulus or economic recovery legislation. Transit systems need flexibility in any supplemental funding to expand their facilities, acquire new vehicles and simultaneously maintain their current operations.

In the longer term, APTA supports the creation of a new program to leverage state and local transit investment by offering incentives to encourage states and localities to create and expand dedicated funding sources for public transportation that can be used for either capital or operating expenses. Federal incentives that reward states and communities that establish or expand dedicated sources of funding for public transportation would address many of the challenges of the present operating environment, strengthen the federal, state and local partnership that benefits public transportation, and provide a strong base of financial support for future growth in public transportation ridership.

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**RESPONSE TO WRITTEN QUESTIONS OF SENATOR TESTER FROM WILLIAM MILLAR**

**Q.1.** What are the specific challenges—such as economies of scale—that you envision in helping smaller transit districts transition from traditional fuel buses to cleaner power sources? What should be done to help smaller communities address these challenges?

**A.1.** Public transportation systems in the U.S. face two problems in replacing current diesel buses with new clean fuel vehicles. First, transit providers are having great difficulty replacing buses that have exceeded their expected service life. Bus procurements are often the largest capital expenditure made by small and medium-sized transit systems, and transit providers of all sizes must carefully assemble federal, state and local funding commitments before completing a bus order. As transit systems struggle to meet the record growth in demand for transit services, they simply do not have the resources to replace their buses quickly. State and local transit funding, which supports both operating and capital expenses, is being used by agencies to maintain current service levels as demand for transit has increased and to accommodate record increases in transit fuel costs. Meanwhile, despite growth of the federal transit program, federal funding has not kept up with growing transit capital needs or inflation.

A recent study by Cambridge Systematics on public transportation needs found that approximately 19 percent of transit revenue vehicles have already reached their federally established service lives, and an additional 47 percent of the current bus fleet will reach that age within six years. The continued use of vehicles that have exceeded their recommended service life can be associated with less reliability, passenger discomfort, and higher operating and maintenance costs for agencies.

The second problem facing public transportation providers that wish to replace their aging buses with new clean fuel vehicles is that clean fuel buses can be more than twice as expensive as traditional diesel buses. With transit ridership growing at a record rate, transit systems must choose between purchasing additional conventional diesel buses, with which they potentially could expand service, or purchasing a smaller number of clean fuel vehicles. Replacing a transit system's older bus fleet with new clean fuel buses like diesel-electric hybrids or compressed natural gas (CNG)- fueled vehicles can reduce an agency's fuel expenses, improve air quality and reduce maintenance costs, but transit systems cannot afford the higher upfront costs of the new technology. The cost of clean fuel vehicles will eventually fall as producers are able to increase production rates and take advantage of economies of scale, but those savings will be not be realized until clean fuel buses are more widely deployed.

To address both of the challenges described above, APTA has proposed creating a new formula program to help transit agencies to replace vehicles in their fleets that have exceeded the Federal Transit Administration's (FTA) standard for replacement and accelerate the replacement of existing diesel vehicles with new, fuel efficient vehicles. Transit systems of all sizes with aging buses would be eligible for new federal funds to replace their vehicles with clean fuel vehicles.

Under the proposed Clean Fuels Aging Bus Replacement Program:

- This new program should replace the existing "Clean Fuel Bus Program" (49 U.S.C. 5308).
- $100,000,000 should be provided in the first year of program, and then grow annually at a proportion equal to the growth of federal transit program overall.
- Funds provided would be in addition to those made available for the Bus and Bus Facilities program. The program should be funded from amounts that would have otherwise been made available under the Clean Fuel Bus program and new funds made available under the federal transit program overall.
- Federal share for the incremental cost of purchasing clean fuel vehicles under this program should be 100 percent. No local match is required for the incremental cost of purchasing a clean fuel vehicle.
- Funds should be apportioned by formula to designated recipients in urbanized areas over 200,000 and to states for distribution to grant recipients in urbanized areas less than 200,000 and rural areas.
- Funds should be apportioned to designated recipients and states under a formula that is based on the relative share of the total cost to replace vehicles within the urbanized area or state that exceed 125 percent of the FTA standard for replacement. Funds should not be made available to transit agencies that do not have vehicles that exceed 125 percent of the FTA standard for replacement.
- Grant recipients would be required to purchase clean fuel vehicles, which include vehicles powered by:

—Compressed natural gas;

—Liquefied natural gas;

—Biodiesel fuels;

—Batteries;

—Alcohol based fuels;

—Hybrid electric; and

—Fuel cells.

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**RESPONSE TO WRITTEN QUESTIONS OF SENATOR REED FROM ANDY DARRELL**

The emphasis of federal transit funding has focused on helping public transportation agencies make capital improvements. While transportation agencies can typically use bonding authority to raise the funds they need for capital improvements, they often have less flexibility to find new sources of revenue to respond to escalating operating costs. For example, the Rhode Island Public Transit Agency is dependent on a share of state gas tax revenue to meet much of its operating overhead. Unfortunately, that revenue stream does not keep pace with inflation, and as gas prices have climbed this year (and as more drivers have turned to public transportation), it has declined.

**Q.1.** With increases in energy and other operating costs, are we at a point where we should recalibrate where federal public transit funding is allocated by dedicating at least some support to operations?

**A.1.** The nation's transit agencies are going broke. We see underfunded transit from the large already transit-rich cities to the relatively small systems throughout America. During this economic crisis, it is ever more critical these systems are able to expand and offer transit options to Americans who are turning to transit like never before. In the short-term, it does no good for transit agencies to receive capital injections if they have no way of paying for their systems' operating costs. In order to meet this rising transit demand, Congress should be able to create an accountable framework by which short-term operating funds can be given to transit agencies who would otherwise be left with buses and subway cars without the fuel or drivers to operate them. And in the long-term, if funding were to be directed at enhancing measures that improve system efficiency, especially at fuel-efficient technologies, transit agencies would not only save money, but also would be less reliant on Congressional funding.

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**RESPONSE TO WRITTEN QUESTIONS OF SENATOR CARPER FROM ANDY DARRELL**

**Q.1.** Are there States where CMAQ (Congestion Mitigation and Air Quality Improvement Program) funds go unspent?

**A.1.** It is true that some CMAQ funds are going unspent. This is due to a complex set of requirements that States and local CMAQ fund requesters must go through to tap into this funding (see *http://edocket.access.gpo.gov/2006/06-9679.htm*). CMAQ funding is so difficult to obtain that only now in a time of real financial stress are some local jurisdictions making the effort to get more of the CMAQ funds from their states. Much of the time, local agencies do not bother because the process is so burdensome and receipt of funding is not assured in the competition for funds at the State level.

In some States, CMAQ funds have gone largely to a few large highway expansion projects, such as adding HOV lanes that have produced dubious air quality benefits. In other states, officials have gamed the mismatch between the higher program authorization funding levels and the lower appropriations funding levels to significantly underspend CMAQ funds while overspending National Highway System and Surface Transportation Program funds to build new highways. Each of these cases represents a lost opportunity to invest CMAQ funds in mass transit, smart transportation management, diesel retrofits, pedestrian and bicycle improvements, and other clean transportation initiatives. The Federal Highway Administration shows the relative amounts of unspent CMAQ funds by state at: *http://www.fhwa.dot.gov/environment/cmaqpgs/msgobsrec1.htm*.

One fix for this problem would be to make at least a portion of CMAQ funds directly available to local governments or metropolitan planning organizations for investments in a list of activities most likely to deliver air quality benefits. Eliminating state DOT pass-through activities, thus giving local air quality agencies a voice in how the funds are allocated, rather than just state transportation agencies, would also go a long way to solving this problem.

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**RESPONSE TO WRITTEN QUESTIONS OF SENATOR CASEY FROM ANDY DARRELL**

**Q.1.** How do mass transit's savings of 4.2 billion gallons of gasoline translate to pollution reduction amounts?

**A.1.** Mass transit in the U.S. saves enough gasoline annually to prevent about 40 million tons of $CO_2$ pollution ($CO_2$ is the main global warming pollutant). That is the equivalent of shutting down thirteen 500 MW coal-fired power plants—more than the entire $CO_2$ emissions of Peru or New Zealand. In addition to. greenhouse gases, reducing gasoline consumption through public transportation also improves air quality by preventing roughly 20,000 tons of smog-forming $NO_x$ and 500,000 tons of carbon monoxide from being emitted.

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**RESPONSE TO WRITTEN QUESTIONS OF SENATOR REED FROM DOROTHY DUGGER**

**Q.1.** The emphasis of federal transit funding has focused on helping public transportation agencies make capital improvements. While transportation agencies can typically use bonding authority to raise funds they need for capital improvement, they often have less flexibility to find new sources of revenue to respond to escalating operating costs. For example, the Rhode Island Public Transit Agency is dependent on a share of state gas tax revenue to meet much of its operating overhead. Unfortunately, that revenue does not keep pace with inflation, and as gas prices climb this year (and as more drivers have turned to public transportation), it has declined.

With increases in energy and other operating costs, are we at a point where we should recalibrate where federal public transit funding is allocated by dedicating at least some support to operations?

**A.1.** From BART's point of view, recalibrating where federal public transit funding is allocated by dedicating at least some support to operations does not help meet the growing need for reinvestment in the nation's transit infrastructure. Instead, we would prefer an increase in targeted capital funds from federal public transit funding.

BART has huge capital needs for which there are inadequate sources of funding—our operating budget is primarily assisted by an imbedded local tax income approved by voters and a relatively high fare box recovery when compared with other transit systems.

For our rail system—which includes subway, elevated structures, stations and significant underwater components—BART is in agreement with the recent Federal Transit Administration (FTA) report "The State of Good Repair" which concludes that capital funds be targeted toward renovation and rehabilitation to meet the increasing rider demand.

BART's declining capital funding and limited bonding authority does not assist this growing need. Being additionally constrained by the regional planning approach of our Metropolitan Planning Organization, whose funding formula method does not respond to a variety of critical capital needs, it is our view that federal public transit funding for capital projects should not be recalibrated to support local transit operational expenses.

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**RESPONSE TO WRITTEN QUESTIONS OF SENATOR REED FROM KEITH PARKER**

**Q.1.** The emphasis of federal transit funding has focused on helping public transportation agencies make capital improvements. While transportation agencies can typically use bonding authority to raise the funds they need for capital improvements, they often have less flexibility to find new sources of revenue to respond to escalating operating costs. For example, the Rhode Island Public Transit Agency is dependent on a share of state gas tax revenue to meet much of its operating overhead. Unfortunately, that revenue stream does not keep pace with inflation, and as gas prices have climbed this year (and as more drivers have turned to public transportation), it has declined.

With increases in energy and other operating costs, are we at a point where we should recalibrate where federal public transit funding is allocated by dedicating at least some support to operations?

**A.1.** Yes, increases in energy and operating costs together with increases in ridership place transit agencies in urgent need of federal operating assistance and other accounting amendments in support of growing transit operations.

In FY2008, ridership on the Charlotte Area Transit System (CATS) was 17.4% higher than the prior year and 12% higher than projections. The rising cost of fuel attracted non-riders to try transit; while CATS safety, customer service and cleanliness has allowed the agency to retain almost 100% of these new riders. In order to accommodate new ridership on both the bus and new light rail system, CATS maximized the use of its resources to meet demand. This caused a gap in available operating income which CATS had to cover by utilizing a portion of funds identified for CATS capital program. Additionally, CATS reallocated a further portion of its capital funding toward the (unbudgeted) purchase of additional rail cars to accommodate the 86% (over Federal formula projections) increase in daily ridership. Overall, this has had a serious impact on CATS' capital program and year-end fund balance.

CATS operating costs are funded primarily by a one half percent Sales & Use Tax, operating assistance from the North Carolina Department of Transportation (NCDOT), farebox and other miscellaneous revenue. The two key sources of revenue, i.e., Sales Tax and State operating assistance are both subject to fluctuations of consumer discretionary spending and gas tax revenue received by NCDOT. In the current economic climate, both sources are trending toward a minimum 6%–8% reduction. Despite budget reduction actions (including a freeze on hiring), CATS may be forced to reduce service, which impacts the most transit-dependent riders.

As more drivers turn to public transportation and local sources of transit revenue are significantly reduced, it is imperative that transit agencies receive federal operating assistance.

Three areas that would assist transit agencies with rising operating costs are:

1. The introduction of a formal, annual Federal operating assistance program.
2. Amendments in General Accounting Standards to allow for capitalization of transit maintenance costs
3. Amendments in the eligibility criteria for use of CMAQ funds in order that these funds might be used for operating costs with no time-period or other restrictions.

We further suggest that Federal operating assistance be distributed by formula, with special incentives for agencies that implement initiatives that positively impact a clean air environment and who demonstrate increases in ridership.

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**RESPONSE TO WRITTEN QUESTIONS OF SENATOR REED FROM DAVE KILMER**

**Q.1.** The emphasis of federal transit funding has focused on helping public transportation agencies make capital improvements. While transportation agencies can typically use bonding authority to raise the funds they need for capital improvements, they often have less flexibility to find new sources of revenue to respond to escalating operating costs. For example, the Rhode Island Public Transit Agency is dependent on a share of state gas tax revenue to meet much of its operating overhead. Unfortunately, that revenue stream does not keep pace with inflation, and as gas prices have climbed this year (and as more drivers have turned to public transportation), it has declined.

With increases in energy and other operating costs, are we at a point where we should recalibrate where federal public transit funding is allocated by dedicating at least some support to operations?

**A.1.** The cost of fuel like other expense items are generally out of the control of transit systems and often result in fare increases and/or service reductions. This is particularly a hardship for small systems that do not receive operating assistance and have limited preventive maintenance expenses. Had it not been for passage of the Technical Corrections Bill to SAFTEA–LU, our system would have been forced to reduce service in addition to the 10.4% fare increase that was implemented on July 1, 2008. As one of the leaders of the 100 Bus Coalition, the use of federal funds for operating assistance has been our primary focus as small transit systems in urbanized areas over 200,000 in population and operate less than 100 peak buses are too small to fully utilize preventive maintenance to make up for the loss of traditional operating assistance. With record fuel prices and ridership on public transit, reducing public transit service is not the answer to achieving energy independence. It has been proven that public transit can make a difference in reducing dependence on foreign oil, reducing congestion, improving air quality, and integral to the future economic development across the country, including creating and sustaining jobs.

Even with the high level of state support in Pennsylvania for public transit, the high costs of fuel and health care alone have diminished the ability to expand services or even maintain existing levels of service. Providing flexibility for the use of federal funds will allow the local communities to decide how to best use these funds. While providing for capital funds is extremely important in the federal program, particularly for replacing buses, systems our size will have the money to replace buses, but not the funds to operate the service, if the federal policies do not change. Without some level of federal operating assistance, the resulting reductions in services and increases in fares will only result in the loss of jobs as those that can least afford to lose their transportation will be the hardest hit, including the elderly and disabled.

There must continue to be a partnership of federal, state, and local governments for the continued funding of public transit to reach the goal of lessening dependence on foreign oil.

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**RESPONSE TO WRITTEN QUESTIONS OF SENATOR TESTER FROM DAVE KILMER**

**Q.1.** You addressed the need to find additional sources of revenue such as selling advertising on the side of buses. While larger urban areas may be able to take advantage of even more innovative and lucrative private sector funding opportunities, what are the options for such additional funding streams in rural areas of the country like much of Montana?

**A.1.** The selling of advertising on the side of vehicles is a very common practice for all transit systems, large or small depending on the policies of each transit authority. Other options also include the selling of advertising on the side of bus shelters and advertising on printed bus schedules or booklets. We have also been successful with leasing space on our radio tower for cellular companies. However, these revenue sources only generate roughly 1% of our operating budget, but every source of additional revenue is important for lessoning the dependence on taxpayers to operate the service.

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**RESPONSE TO WRITTEN QUESTIONS OF SENATOR REED FROM ROBERT PUENTES**

**Q.1.** The emphasis of federal transit funding has focused on helping public transportation agencies make capital improvements. While transportation agencies can typically use bonding authority to raise the funds they need for capital improvements, they often have less flexibility to find new sources of revenue to respond to escalating operating costs. For example, the Rhode Island Public Transit Agency is dependent on a share of state gas tax revenue to meet much of its operating overhead. Unfortunately, that revenue stream does not keep pace with inflation, and as gas prices have climbed this year (and as more drivers have turned to public transportation), it has declined.

With increases in energy and other operating costs, are we at a point where we should recalibrate where federal public transit funding is allocated by dedicating at least some support to operations?

**A.1.** Transportation policy and program governance currently favors particular modes but is indifferent to substantive outcomes. This is an inefficient and unrealistic approach. The term "modality neutrality" should redefine how transportation is perceived and should reinforce that it is a tool to advance broader national goals. In other words, examining particular policy areas through the broad lens of the policy outcomes (e.g. economy, environment, equity) rather than that of a particular mode (e.g., highway, transit, bike/pedestrian, air). Without a doubt specific and different modes are critical to delivery, but that should not be the starting point.

In order to empower metropolitan entities to make good decisions about transportation investments, various transportation options must be compared holistically, equally, and consistently based on their merits. Metropolitan decisionmakers should be able to choose the best set or combination of transportation strategies that meet their views, values, and directions. Thus metropolitan leaders should be able to pursue the best transportation alternatives for their communities, not the alternative that is simply the easiest to get funded or approved. Several reforms are needed.

For one, the federal government should require equal treatment of proposed highway and transit projects. There is simply no reason why new roadway projects using federal funds should not face the same level of scrutiny as new rail projects. Second, the federal agencies should evaluate and rate candidate all new capacity projects (including highways) similar to what it does now for new transit projects. It should create a single review process for all new capacity (roads and rails) and bring back the major investment study requirement for corridor planning. Similarly, long-range financial requirements for highway projects should be disclosed at program level, as they now are for transit projects. What makes sense for a transit project surely also make sense for a roadway project. The financial package should be part of a benefit/cost analysis for all new capacity projects so the federal government can determine which will have return value for the money. Lastly, the existing highway trust fund should be converted into a unified Transportation Trust Fund by doing away with the separate highway and transit accounts. The federal government also must take steps to address the disparities in the federal match ratios between highways and transit. Simply put, the disparity between the 50 to 60 percent federal match for transit and the 80 to 90 percent match for highways is far too dramatic to ensure proper metropolitan and local decisions.

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## RESPONSE TO WRITTEN QUESTIONS OF SENATOR TESTER FROM ROBERT PUENTES

**Q.1.** You stated that the federal transportation dollars are allocated through archaic funding and distributional formulas. And that those formulas reward consumption instead of conservation. Can you elaborate on that point? How can federal funding formulas better reflect an effort to conserve and reduce energy consumption? Also, how would these changes address rural needs?

**A.1.** The formulas for allocating federal highway trust fund dollars are largely made on the basis of highway mileage and use. More than half of the funds authorized in SAFETEA–LU are appointed to states based on the traditional factors: amount of roads, miles driven, and fuel consumed and/or gas tax paid. Less than one-fifth comes from other measures of need such as number of deficient bridges, roadway fatalities, or population in air quality non-attainment areas.

While this may seem intuitive on some level, it also presents obvious problems in that it rewards those places with road expansions and high gas consumption. There is no reward for reducing consumption in any of these formulas. In fact, any investment in transit or promotion of land use to reduce fuel consumption or substitute for lane miles may result in fewer federal dollars.

One method to reorient the funding formulas is to reward the achievement of national priority goals such as GHG and oil consumption reduction. This way federal funds are not distributed based on factors that potentially increase greenhouse gas emissions, overly simplistic equity provisions, or on the basis of earmarking. Serious consideration should be given as to whether VMT and gasoline consumption make sense at all as a basis for apportionments. By the same token, bonus allocations should be considered for those states and metropolitan areas that reduce their VMT and gasoline consumption through demand management techniques and strategies.

These changes would address rural needs because a purposeful and responsive federal transportation program would take into consideration the specific needs, opportunities, and challenges of different parts of the country. Channeling transportation and infrastructure funds toward older communities means that greater attention will now be paid to sprucing up and reinvigorating fading rural villages, main streets, and small-town business districts. Establishing a national vision for economic competitiveness will also involve crafting a vision for rural competitiveness. For example, better tailoring of transportation initiatives to local and regional needs should allow rural areas to prosper in more distinctive niches—whether in tourism, freight movement, or higher-value agriculture—instead of pursuing the one-size-fits-all solution. Planning better will allow rural areas to better protect the integrity of all of their communities as well as their signature open spaces.