Magnetic Levitation Along The Eastern Seaboard Reduction in Air Travel and Greenhouse Gases

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ABSTRACT: This paper summarizes parts of a feasibility study prepared by the Maryland Transit Administration for the Federal Railroad Administration on a proposed magnetically levitated train project. Initially the project would connect Camden Yards in downtown Baltimore with Union Station in Washington DC with a stop at BWI Thurgood Marshall Airport. Ultimately, the Project would extend along the U.S. eastern seaboard north to Boston and south to Charlotte. The paper contains an evaluation of potential air travel reduction along the east coast if maglev service were available and estimates of reductions in energy consumption and carbon dioxide greenhouse gas emissions resulting from the proposed maglev service along the eastern seaboard.

1 INTRODUCTION

Recent press articles have reported that air travel is one of the fastest growing producers of emissions linked to global warming. With Al Gore's film, "An Inconvenient Truth," focusing attention on climate change, there appears to be an opening to start a public discussion on the environmental impact of flying. In Britain, for example, the conservative party leader David Cameron recently said he favored a tax on short haul flights as a way to curb the growth of emissions. Eurostar, the operator of high speed train service linking London to Paris and Brussels, is running ads in travel publications asserting that a journey on high speed rail produces only a fraction of the carbon dioxide emissions of a comparable flight. British Airways has started a program whereby travelers can opt to pay a surcharge when booking their tickets in an effort to offset carbon emissions caused by their flights, and British Airways donates the money to sustainable energy programs. Sir Richard Branson, the owner of the Virgin Groups, reported that he plans to invest up to $3 billion in profits from Virgin airline and rail companies in alternative energy projects.

The Maryland Department of Transportation (MDOT) in cooperation with the U.S. Federal Railroad Administration (FRA) has been evaluating —through a series of feasibility studies and environmental impact statements—the impacts of constructing and operating a magnetically levitated train, or Maglev, between Baltimore, Maryland, and Washington, D.C., with extensions north along the northeast seaboard to Philadelphia, New York, and Boston and south through Richmond, Virginia and Charlotte, North Carolina. To date, studies have focused on passenger ridership, revenues, and costs, as well as comparative travel times, and environmental and social impacts. The studies include an evaluation of potential air travel reduction along the east coast if Maglev service were available, and a comparison of energy consumption between Maglev and conventional modes of travel. A summary of the findings and conclusions of these portions of the studies are presented below, together with a discussion of potential reductions in carbon dioxide emissions along the U.S. eastern seaboard resulting from diversion of travelers in autos and aircraft to Maglev. The eastern seaboard travel study is contained in the report. “Baltimore – Washington MAGLEV Project Description” by the Maryland

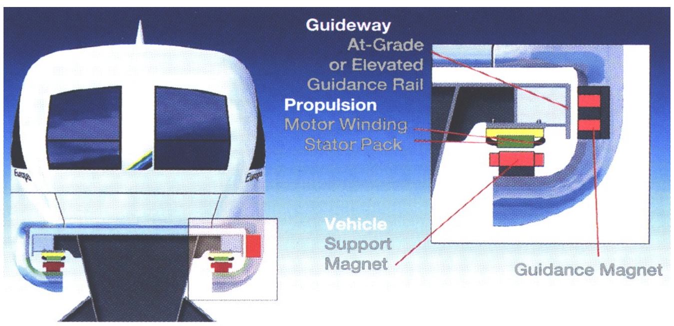

Figure 1. Maglev System Technology

2 TECHNOLOGY OVERVIEW

Maglev is short for "magnetic levitation" and a Maglev train is operated by non-contact electromagnetic systems that actually lift, guide, and propel the vehicle forward on a special guideway (see photo) at speeds up to 500 km/h (310 mph).

The Maglev study included an evaluation of Maglev technologies, and as a result, the German technology produced by Transrapid International (TRI) was selected for proposed implementation. Transrapid technology uses conventional electromagnets and forces of attraction to levitate and guide the vehicle along the guideway. The TRI Maglev vehicle wraps around the guideway to securely hold and guide the vehicle. The vehicle is supported and guided by electromagnetic forces between electromagnets attached to the guideway and permanent magnets housed on the underside of the vehicle. The gap between the top of the guideway and the underside of the vehicle is electronically maintained at about 1 cm (0.4 in) while the vehicle is levitated (Figure 1).

The Maryland Transportation Administration (MTA), a modal administration of MDOT has selected the proven Transrapid technology for the Baltimore-Washington Maglev Project and has worked closely with engineers and designers from TRI. Additional information can be obtained through the project’s website (**www.bwmaglev.com**) which features a link to TRI. The Transrapid website that illustrates the technology in action can be accessed through **www.transrapid.de**.

Maglev Vehicle TR08
Courtesy of Transrapid International-USA, Inc.

3 MAGLEV CORRIDOR ANALYSIS AND IMPACT ON AIR TRAVEL

The introduction of Maglev service along the Eastern Seaboard corridor, anticipated to be fully operational by 2040, offers great opportunities to expand, improve, and add capacity to existing transportation networks. Corridor service is expected to create network synergies that enhance the utility and investment worthiness of the proposed Baltimore-Washington Maglev.

Transportation is critical to regional and national economies and a key component in the efficient flow of people, information, and freight. Maglev will improve travel along the corridor with its speed, station locations (which in most cases offer direct downtown-to-downtown access), its attractiveness as an alternative to air travel, and as a means of transporting freight in a new manner that is fast and efficient. This section focuses on the potential of introducing Maglev passenger services between

Charlotte and Boston and addresses diversion to Maglev from air travel.

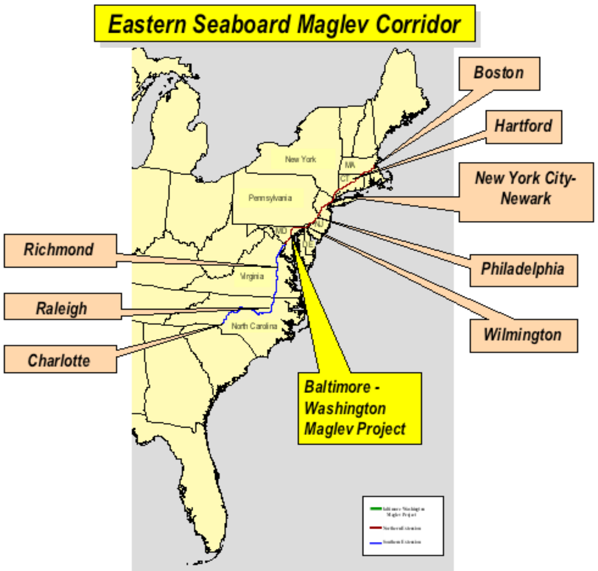

Figure 2. Eastern Seaboard Maglev Corridor

3.1 Description of the Eastern Seaboard Maglev Corridor

Maglev would operate between Charlotte and Boston and run for approximately 800 miles (Figure 2). For the most part, it would parallel Amtrak's Northeast and Carolinian/Piedmont Southeast Corridors. Passenger and freight service speeds are expected to average approximately 200 mph, based on an operations simulation train performance calculation of the TR08 Maglev train. The conceptual passenger service operating plan, consistent with assumptions in the report by the U.S. Federal Railroad Administration "*High Speed Ground Transportation for America, 1997*", would consist of 166 Maglev trains per day in each direction in the Northeast corridor, and 65 trains per day in the Southeast corridor. Twelve stations are assumed to serve the corridor and, where possible, provide downtown-to-downtown service. These are listed below.

Charlotte, North Carolina	Wilmington, Delaware
Greensboro, North Carolina	Philadelphia, Pennsylvania
Raleigh, North Carolina	Newark, New Jersey
Richmond, Virginia	New York, New York
Washington, D.C.	Hartford, Connecticut
BWI-Airport, Maryland	Boston, Massachusetts
Baltimore, Maryland	

3.2 Travel Time Comparisons

Travel time comparisons between Maglev and Acela/ Amtrak, air service, and autos between three city pairs are provided in Table 1. In every instance, Maglev provides a faster trip time: Maglev is 2.5 to 3.5 times faster than Acela service; approximately four times faster than auto travel time; and, with boarding times included for each mode, Maglev travel time is less than air travel time, especially for shorter trips.

Table 1. Maglev-Corridor Travel Time Comparison with other Modes (in minutes)

	Maglev	Air	Auto	Acela
Charlotte to Washington	115	135	445	*
Washington to New York	70	130	270	180
New York to Boston	55	125	225	195

Modal trip time adjustments:

15-minutes access, check-in, and boarding time added to Maglev and Acela

60-minutes access, check-in, and boarding time added to air

No additional time added to auto

* Amtrak Acela service not available from Charlotte to Washington.

3.3 Sources of Trips

The demand forecast conducted for the Corridor projects 65 million annual riders on Maglev along the Charlotte to Boston corridor in 2040 with an estimated 178,100 riders per day. Revenues are estimated at $4.5 billion in 2040 in current dollars.

While the majority of Maglev trips, about 36.40 million passengers in 2040, are expected to be diverted from auto, the predominant mode for long-distance travel in the corridor, about 5% of forecasted Maglev travel, or 3.06 passengers in 2040, will be diverted from air travel (Figure 3).

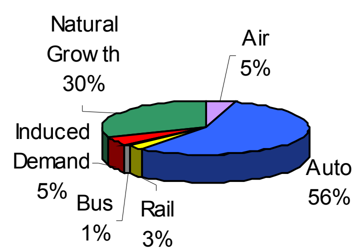

Figure 3. Sources of Corridor Maglev Trips, 2040

3.4 Potential Impact of Maglev on Air Travel

The five percent portion of the Maglev market that is diverted from air to Maglev represents a significant portion of projected air travel trips within the corridor. The FAA 1996 10 percent sample of air passengers was used to identify air trips within the corridor. Based on the analysis, trips with and without Maglev are shown in Figure 4. Recent updated projections from the Maryland Aviation Authority (MAA) suggest that the Project-level forecasts of air travel may be conservative, which would also indicate a larger potential future market for Maglev. Using an industry average airplane passenger load of 90.6 people, the diversion to Maglev would be equivalent to 33,800 fewer aircraft departures required for travel within the corridor in 2040. This diversion to Maglev could result in less air traffic, less energy consumption, less emission of greenhouse gasses, improved air schedule adherence, and fewer delays for aircraft operators and air passengers along the study area portion of the east coast.

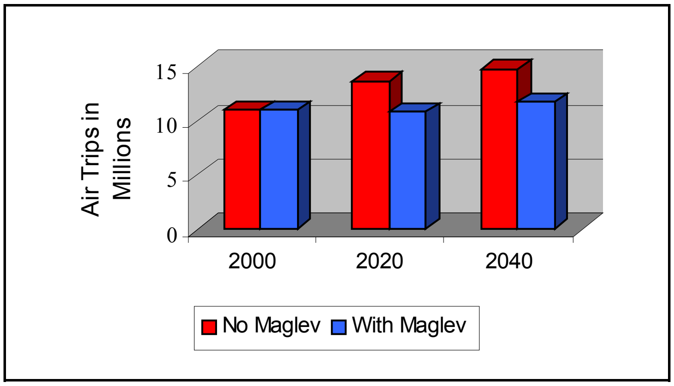

Figure 4. Air Travel Diversion to Maglev, 2000, 2020, 2040

4 ENERGY CONSUMPTION

Relative energy consumption estimates in terms of British Thermal Units (BTU) per passenger mile for magnetic levitation, high speed rail, aircraft, auto, metro rail, and commuter rail are shown in Figure 5. The figures for the TR08 Maglev from Hamburg to Berlin of several hundred miles in length would be equivalent to Maglev operation along the eastern seaboard. The figure shows that the energy consumption of magnetic levitation service from Hamburg to Berlin would be about 1,800 BTUs per passenger mile, as compared to the following transportation modes: 4,600 BTUs per passenger mile for both U.S. airline domestic operations and passenger automobiles; 2,200 BTUs per passenger mile for Amtrak metroliner service from New York to Washington; and 5,500 BTUs per passenger mile for commuter rail operation. It should be noted that the energy consumption of Maglev service between Baltimore and Washington is higher than from Berlin to Hamburg because of the relatively short distance between Baltimore and Washington (39 miles) and shorter train (three cars). A short train on a short route is more energy intensive and less efficient than a long train on a long route due to greater accelerating or braking distances relative to the total distance, shorter distances for cruising, and lower passenger capacity.

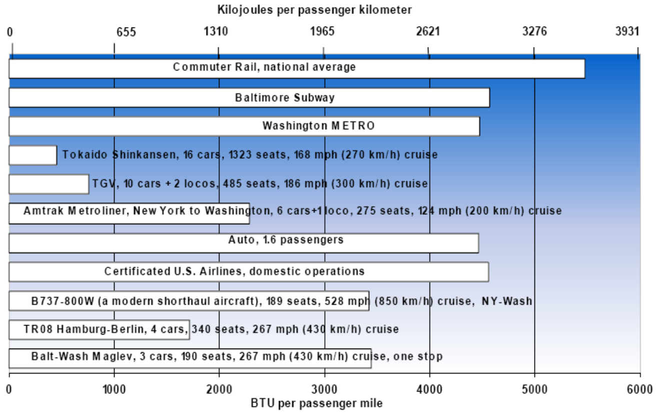

Figure 5. Energy Intensiveness Comparison
Source: "Baltimore-Washington Maglev Project Description", MTA, June, 2000.

Based on this inter-modal comparison, Maglev would consume about a third of the energy of domestic airline operation and passenger automobile usage and a quarter of the national average for commuter rail operation. Relative levels of greenhouse gas emissions are commonly assumed to mirror energy consumption ratios; since Maglev system operation requires less energy, the Maglev would produce less greenhouse gas emissions than its conventional counterparts.

5 GREENHOUSE GAS EMISSIONS

Transport accounts for about 14 percent of global Greenhouse Gas (GHG) emissions, making it a major contributor to global climate change (Figure 6). This is equivalent to 18 percent of global CO_2 emissions and 24 percent of Carbon Dioxide (CO_2) emissions from energy-related sources. Within this sector, road transport, at 72 percent of the sector and 10 percent of global GHG emissions, accounts for the largest share. Aviation (domestic and international) amounts to about 12 percent of transport emissions, and 2 percent of overall GHGs.

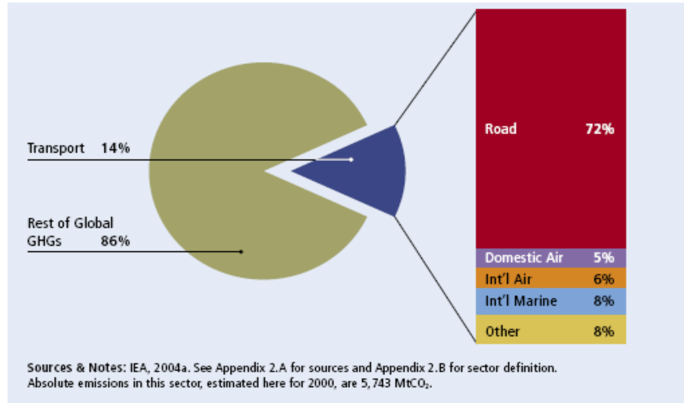

Figure 6. GHGs from Transportation

These statistics were derived from the World Resources Institute Report "Navigating the Numbers: Greenhouse Gas Data and International Climate Policy", 2005.

Transport emissions are expected to increase by about 40% from 2002 to 2020 (Figure 7).

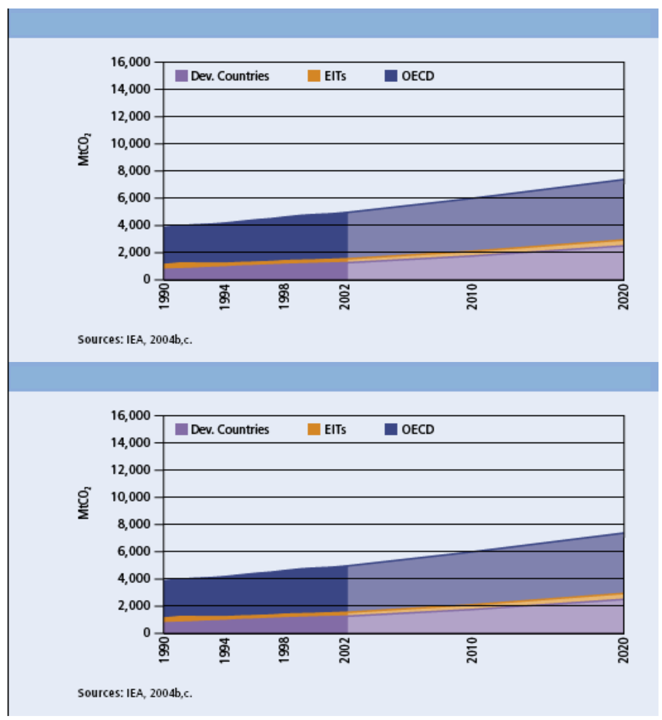

Figure 7 GHGs from Transportation, Trends, and Projections

With respect to energy sources, transport is dominated by oil, which amounts to 96 percent of energy supply and 97 percent of emissions (Figure 8). Gas accounts for about 3 percent, and biomass 0.5 percent (with 68 percent of biomass used in transport coming from one country, Brazil).

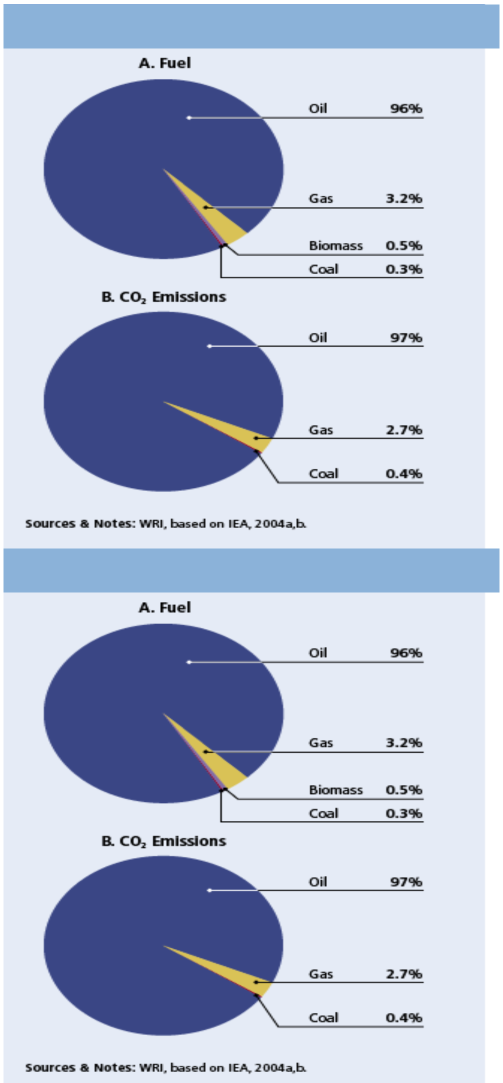

Figure 8. Transportation Energy Sources and Emissions (shares by fuel)

Figure 9 shows transport-related CO_2 emissions of the top emitting countries, in both absolute and per capita terms. Together, these countries account for 87 percent of global emissions from this sector, with the five largest emitters accounting for two-thirds of the global total. The United States far outranks all other countries, with 35 percent of global emissions, about twice the EU's total and seven times the emissions of the next highest country, Japan. The U.S., Australia, and Canada are prominent in their high per capita emissions. As with electricity, cross-country differences in transport emissions own largely to wide variations in per capita consumption patters. The predominant mode of transport in China's urban areas, for instance, is public transit, cycling, and walking, whereas in the U.S. and Europe, automobiles are predominant.

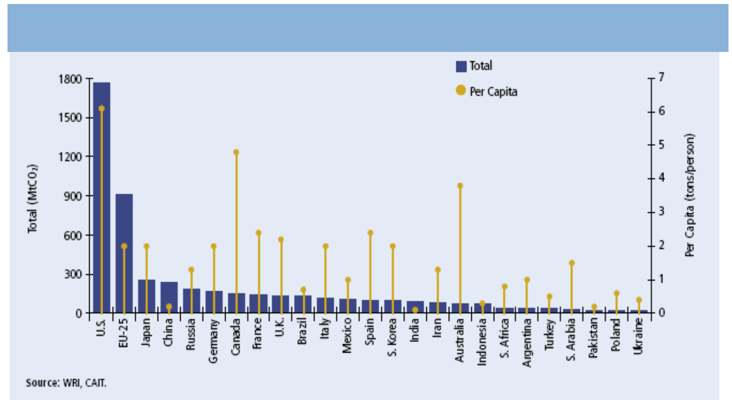

Figure 9. Transportation Emissions by Country - Absolute and Per Capita (shares by fuel)

In some countries, transport is the fastest growing source of GHG emissions. From 1990 to 2002, transport-related emissions grew 20-25 percent in most industrialized countries, but much faster in many developing countries (Figure 10). The fastest growth was in South Korea, Indonesia, and China, where transport emissions doubled. Among major emitters, CO_2 from this sector declined only in Russia and Ukraine.

		% Change	
Country	% of World 2002	1990–2002	Projected 2002–2020*
United States	35.5	24	30
EU-25	18.3	23	31
Japan	5.1	20	–
China	4.8	101	143
Russia	3.7	-29	49
Canada	3.0	21	–
Brazil	2.6	60	77
Mexico	2.1	21	71
South Korea	1.9	120	–
India	1.9	15	92
Australia	1.5	23	29
Indonesia	1.4	109	122
World	100.0	40	50

Notes: CO_2 from international bunker fuels is not included. Growth rates for Russia are from 1992 (not 1990). *Projections are drawn from IEA (2004c). The projected figure for the U.S. includes Canada; Australia includes New Zealand. "–" signifies no data.

Figure 10: CO_2 from Transportation, by Country

By 2020, the International Energy Agency (IEA) expects global transport emissions to increase by 50 percent. Increases of about 30 percent are projected in developed countries (Figure 10). Much higher increases are projected in developing countries, including China (143 percent), India (67 percent), Indonesia (122 percent), Mexico (71 percent), and the Middle East (68 percent).

6 AVIATION

Aviation, as noted above, represents approximately 12 percent of CO_2 emissions from transport when international fights are included (and about 1.6 percent of the world GHG total). Emissions from international flights are more than half of overall air emissions. Air travel – and associated CO_2 emissions – have grown at tremendous rates over the past few decades. Since 1960, passenger traffic has grown at about 9 percent per year, though the rate has slowed in recent years as the industry has matured. Looking ahead, passenger and freight traffic are expected to grow at rates well in excess of GDP growth.

The global warming effect of aviation is larger than suggested by the numbers and emissions trends discussed above, which are based on fossil fuel consumption. The climate impacts of air travel are amplified when ozone-producing Nitrous Oxide (NO_x) emissions, contrail formation, water vapor release, and other high-altitude effects of aircraft use are accounted for. Most of these effects are characterized by high levels of uncertainty, and are difficult to account for. The Intergovernmental Panel on Climate Change (IPCC) estimates that, although aircraft accounted for only 2 percent of anthropogenic emissions in 1992, they produced an estimated 3.5 percent of total radiative forcing from human activities. Changes in climate are driven by natural and human-induced perturbations of the Earth's energy balance. These climate drivers or "forcings" include variations in greenhouse gases, aerosols, land use, and many other factors. IPCC projections suggest that radiative forcing from aircraft may increase by a factor of nearly four by 2050, accounting for 5 percent of total radiative forcing from human activities.

Figure 11 shows the breakdown of total and international air emissions from the top 10 countries in this subsector.

	Total Air			International Air		
Country	**% World**	**(Rank)**	**% Change from 1990**	**% World**	**(Rank)**	**% Change from 1990**
United States	37.2	(1)	7	14.3	(2)	31
EU-25	20.3	(2)	49	30.3	(1)	59
Japan	5.0	(3)	42	6.0	(5)	59
United Kingdom	4.9	(4)	54	6.1	(4)	65
Russia	4.5	(5)	–	8.3	(3)	–
Germany	3.3	(6)	25	5.9	(6)	48
France	3.1	(7)	69	4.1	(7)	52
China	2.8	(8)	611	0.8	(27)	442
Canada	2.4	(9)	19	0.8	(24)	3
Spain	2.0	(10)	75	2.3	(13)	137
World			38			38

Source: Calculations based on IEA, 2004a.

Figure 11. CO2 from Transportation, by Country

7 TRANSPORTATION GREENHOUSE GAS EMISSIONS

The transportation sector accounts for fully 32 percent of U.S. carbon dioxide emissions. Americans drive 1.5 trillion miles per year in automobiles alone, and an additional 600 billion miles in personal trucks and SUVs. Automobiles and light trucks combined consume 115 billion gallons of gasoline and diesel fuel per year, emitting 19.8 percent of total U.S. carbon dioxide emissions. This fraction would be higher if we included all of the energy "embodied" in manufacturing cars, building roads and other infrastructure, mining and processing the materials, and refining and shipping the fuels used in transportation.

Table 2 presents estimates of CO_2 emissions per passenger mile for automobiles and competing travel modes. Maglev generates one-fifth the CO_2 amount generated by autos and one-sixth the amount generated by commercial aircraft.

Table 2. Transportation Mode and Energy Consumption and Carbon Dioxide Emissions, 1999

Mode	BTU/Passenger mile (BTU)	CO_2/Passenger mile (lbs)
Commercial Aircraft-domestic	4053	0.647

Automobile (Avg 1.59 persons)	3635	0.569
Transit Bus	4802	0.775
Commuter Rail	2932	0.473
Maglev	1800	0.117
High Speed Rail	2500	0.174

Maglev and High Speed Rail from UK Ultrasound Factbook, 2006; all others from Rocky Mountain Institute "Climate Report" 2006

Carbon Dioxide statistics were derived from the reports by the Rocky Mountain Institute "Individual Opportunities to Cool Global Warming", 2006 and UK Ultrasound Factbook, October, 2006.

8 PERSONAL VEHICLE EMISSIONS

The average American personal vehicle uses 570 gallons of gasoline per year, which results in the emissions of 11,400 pounds of carbon dioxide. Since, on average, each household owns 1.85 vehicles, this means that the average household emits 21,000 pounds of carbon dioxide annually.

9 AIR TRAVEL EMISSIONS

Due to the airline and aircraft manufacturers' great technical and operational progress over the past three decades, airline fuel economy per passenger mile has improved by 61 percent. However, the growth in air travel is outpacing airline fuel efficiency gains – Americans now fly 764 million trips per year (2.85 airplane trips per person, averaging 814 miles per trip) – and energy used by commercial aircraft has nearly doubled in the same period. This jet fuel consumption translates to 13 percent of total transportation sector emissions of carbon dioxide.

Averaging all types of aircraft of different age and trip length and aircraft capacity factors, in domestic and international travel each passenger-mile flown emits 0.566 pounds of carbon dioxide. For domestic travel alone CO_2 emissions are 0.647 lbs. This does not include two other important impacts of commercial aviation non climate. The first is that commercial aircraft emit nitrous oxides (NO_x) and other pollutants at high altitudes. The Intergovernmental Panel on Climate Change (IPCC) estimates that such pollutants increase the climate impact of flying by a factor of at least 2.5 compared to the combustion of jet buildings, facilities, baggage systems, airport service vehicles, concession facilities, aircraft fueling, airport construction, and air navigation and safety operations. In addition, we use a lot of energy in getting to and from airports.

Table 3 shows a reduction in CO_2 emissions of 6.6 trillion pounds from diverting auto and air passengers to the more conserving Maglev mode in 2040. This reduction is equivalent to removing nearly 67,000 cars off the road per day in 2040.

Table 3. Savings in Carbon Dioxide Emissions Resulting From Diversions to Maglev, 2040

	Auto	Air	Total
Passengers diverted to Maglev in 2040 (million)	36.40	3.06	
Average trip length (miles)	300	300	
Diverted passenger miles in 2040 (trillion)	10.800	0.918	
CO_2 emissions per passenger miles (lbs)	0.569	0.647	
CO_2 emissions avoided by diversion to Maglev in 2040 (trillion lbs)	7.450	0.594	8.044
Less Maglev CO_2 emissions in 2040 (trillion lbs)	39.46 million passengers x 300 miles x 0.117 lbs/passenger mile		1.385
CO_2 emissions saved (trillion lbs)			6.659

10 REFERENCES

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11 GLOSSARY

MTA	Maryland Transit Administration
MDOT	The Maryland Department of Transportation
FRA	U.S. Federal Railroad Administration
TRI	Transrapid International
MAA	Maryland Aviation Authority
BTU	British Thermal Units
GHG	Greenhouse Gas
CO2	Carbon Dioxide
IEA	International Energy Agency
NOx	Nitrous Oxide
IPCC	Intergovernmental Panel on Climate Change