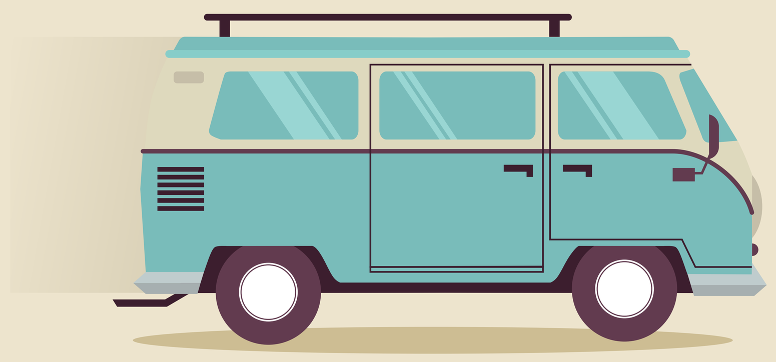
Spring 2016

Environmentally Sustainable Transportation Solutions for Sarah Lawrence College

Katherine Labadie
Sarah Lawrence College

Yuci Zhou
Sarah Lawrence College



ENVIRONMENTALLY SUSTAINABLE TRANSPORTATION SOLUTIONS FOR SARAH LAWRENCE COLLEGE

by Katherine Labadie and Yuci Zhou

INTRODUCTION

Transportation is a key component of campus sustainability. Transportation is responsible for about 32 percent of U.S. carbon dioxide emissions, and toxic tailpipe emissions, such as benzene, butadiene, and diesel, which can cause elevated risks of cancer. Additionally with transportation there is a potential for environmental damages upstream with oil drilling, risks of oil spills, and nonpoint source water pollution.

The negative effects of transportation on the environment can be ameliorated at Sarah Lawrence College with increased transportation efficiency in the short term and investment in zero-emissions vehicles in the long run. Stronger bicycle programs, fixed routes for the campus shuttle system, and education on sustainable transportation in general can help Sarah Lawrence to reduce emissions from transportation in the short run. Then, over time, investment in more energy efficient vehicles on campus can drastically reduce Sarah Lawrence's carbon footprint. By switching to more energy efficient vehicles, such as the Nissan LEAF SUV or the seven passenger Nissan e-NV200, the college can drastically reduce its greenhouse gas emissions, improving air quality on campus. Overall, efforts to create a more sustainable campus transportation system can reduce greenhouse gas emissions, improve air quality, and promote health and well-being at Sarah Lawrence College.

SHORT-TERM SOLUTIONS

BICYCLE PROGRAMS

Bicycle programs are beneficial to colleges not only because they reduce the college's impact on the environment, but also because they improve the health and wellness of the staff and students. Studies of adolescents show that increased physical activity has the potential to reduce depression and increase academic performance. Sarah Lawrence College has a small bike share program already established on campus; however, the program is not heavily utilized by the students. Creating designated bike paths on and around campus would promote use of this program and cycling in general around campus. Providing a bike maintenance and repair program would also reduce barriers keeping students from taking advantage of this established program.

CHANGES IN SHUTTLE SYSTEM

Establishing fixed routes for the campus student shuttle system would also help to reduce the campus' carbon footprint. If the shuttles had direct, fixed routes, and designated pick up and drop off stops for students, then the annual milage of these vehicles could be reduced. For the dispatching of the vehicles, a combination system of ad hoc and scheduled pickups could help avoid repeated pickups at a single location. If the shuttles were, on occasion, dispatched in set intervals, for example every ten to fifteen minutes minutes on cold, late nights, repeated pickups could be avoided and each shuttle would be more likely to fill up with students. Such planning would also be time efficient. Fixes routes and shuttle schedules would reduce the waiting time for students and subsequently increase their satisfaction with the program.

EDUCATION ON CAMPUS SUSTAINABILITY

Even with sustainable transport programs in place, if students and staff are not informed on these programs they will not be very effective in helping the campus become more environmentally efficient. Education on how to use the campus' bicycle programs, the fixed schedule and routes of the student shuttle system, and the on-campus rideshare program (Zipcar) could help the campus collectively run more sustainably. Students should also be educated on the parking permit system already at Sarah Lawrence. If more students were aware of the costs of the permits, they would be less likely to bring personal vehicles on campus in the first place. These sustainability measures incentivize alternatives to using personal vehicles on campus. If students and staff are more knowledgeable on these programs, if the barriers surrounding the use of these programs are reduced, they will be more likely to utilize them.

Education on state idling laws, could help reduce the number of idling vehicles on campus, subsequently reducing the college's carbon footprint. While student shuttles are not in transit and when public safety vehicles are stationed on Kimball Avenue, the car's engine is usually left running. New York State Environmental Conservation Law prohibits heavy duty vehicles from idling for more than five minutes at a time.

LITERATURE CITED

Aldrete-Sanchez, Rafael, and Jeffrey Shelton, Ruey (Kelvin) Cheu. 2010. "Integrating the Transportation System with a University Transportation Master Plan: Best Practices and Lessons Learned." Texas Department of Transportation Research and Technology Implementation Office: Austin, TX.

Brix, Andrew, and Trevor Brydon, Elijah Davidian, Keely Dinse, Richard K. Norton, Sanjeev Vidyarthi. 2007. "Transforming the University Campus into a Sustainable Community." Planning for Higher Education Vol.35 No.4: 22-39.

Bull, Fiona, and Max Bulsara, Billie Giles-Corti, Terri Pikora, Tya Shannon, Trevor Shilton. 2006. "Active commuting in a university setting: Assessing commuting habits and potential for modal change." Transport Policy 13: 240-253.

Havlick, Spenser W., and Will Toor. 2004. "Transportation and Sustainable Campus Communities: Issues, Examples, Solutions." Washington D.C.: Island Press.

Kaplan, David H. 2015. "Transportation Sustainability on a University Campus." International Journal of Sustainability in Higher Education Vol. 16 No. 2: 173-186.

LONG-TERM INVESTMENTS

The college should invest in zero-emissions vehicles in the long term. According to the cost benefit analysis (CBA) below, investment in electric vehicles for student transportation not only reduces the college's carbon footprint, but also can be more cost effective.

A cost-benefit analysis seeks to measure all the costs and benefits of a proposed project over time. It takes into account the changes of goods and services, their present value, and converts them into a common monetary unit by discounting future costs and benefits.

The CBA looks at the costs of doing business-as-usual (not replacing any vehicles), replacing all the vehicles in ten years, five years, and all at once. As one can see in fig. 2, replacement plans are far less costly for the college, regardless of the plan's time span. Among the plans, a one-time replacement costs the least and could save about $0.5 million over 10 years, followed by a 10-year replacement plan and a 5-year one.

FIG.1 CAMPUS FLEET OVERVIEW

	Number
Honda Pilot	5
Chryster Town and Country	3
Ford Transit	4
Ford E350	11

FIG.2 PROPOSED ALTERNATIVE FLEET OVERVIEW

	Number	Price	Annual Fuel Cost
Nissan LEAF SV	8	$ 34,200	$ 274
Nissan e-NV200 (7-passenger)	30	$ 20,870	$ 336

FIG.3 RESULT OF THE COST-BENEFIT ANALYSIS

	Present Value of Total Cost
Business as Usual	$ 1,676,744
Replace all at once	$ 1,175,481
Replace in 5 years	$ 1,184,235
Replace in 10 years	$ 1,199,223

Header graphic designed by Freepik. Poster designed by Katherine Labadie and Yuci Zhou.

Environmentally Sustainable Transportation Practices on College and University Campuses:

Transportation Solutions for Sarah Lawrence College

Katherine Labadie and Yuci Zhou

Economics of the Ecological Crisis

May 9, 2016

Abstract

This paper discusses the importance of general sustainability practices on college and university campuses, specifically the importance of environmentally sustainable and efficient campus transportation services. The paper looks at how promoting bicycle programs, creating fixed shuttle routes and improving schedules, increasing education on campus sustainability, and investing in more sustainable vehicles can reduce emissions on college campuses. These sustainability efforts are analyzed looking at Sarah Lawrence College to determine how these practices can aid the institution's environmental efforts.

Introduction

Transportation is a key component of campus sustainability. Transportation is responsible for about 32 percent of U.S. carbon dioxide emissions, and toxic tailpipe emissions, such as benzene, butadiene, and diesel can potentially lead to elevated risks of cancer (American Lung Association 2003). Not to mention the potential for environmental damages upstream with oil drilling, risks of oil spills, and nonpoint source water pollution (Toor and Havlick 2004, 1).

The negative effects of transportation on the environment can be ameliorated at Sarah Lawrence College with sustainability practices that increase transportation efficiency in the short term, as well as long-term investments in sustainable vehicles. Stronger bicycle programs, fixed routes for the campus shuttle system, and education on sustainable transportation in general could help Sarah Lawrence in reducing emissions from transportation in the short run. Stronger bicycle programs will reduce the college's impact on the environment, and improve the health and wellness of the staff and students through physical activity. If fixed shuttle schedules are introduced, the annual milage on the Sarah Lawrence College vehicles could be reduced.

Education on sustainable transportation has the potential to ensure that the New York's idling law is followed on campus, as well as the potential to get more students using the campus' environmentally sustainable transit programs, such as the bike share or Zipcar programs.

Then, over time, investment in more energy efficient vehicles on campus can drastically reduce Sarah Lawrence's carbon footprint. By switching to more energy efficient vehicles, such as the Nissan LEAF SUV or the seven passenger Nissan e-NV200, the college can drastically reduce its greenhouse gas emissions, improving air quality on campus, and save approximately $0.5 million over 20 years. Overall, efforts to create a more sustainable campus transportation system can reduce greenhouse gas emissions, improve air quality, and promote health and well-being at Sarah Lawrence College, as well as help lessen environmental damages on a broader scale.

Sustainability and Higher Education

Colleges and Universities play crucial roles in fostering a culture or social norm of sustainability. These institutions of higher education consist of and connect many acres of buildings and land. Colleges and Universities, like any other campus space, can have a huge impact on the degradation or sustainability of the earth depending on their methods of waste disposal, buying practices, and energy consumption.

In addition to all of this land and and all of these buildings, college and university campuses are full of young minds. In the United States alone, 14.5 million students attend institutions of higher education (Barlett 2004, 5). These students lifestyle choices and habits are heavily influenced by their education and their university's or college's practices. Furthermore, colleges and universities often have influence in the outside communities. College campuses are often the largest employers in the surrounding area (Balsas 2003, 36). Programs and commitments to environmental sustainability on college and university campuses can have large impacts on environmental health on a broader scale.

The power of higher education in environmental sustainability is reflected in the first Earth Day in 1970, which was facilitated by college students. Then in 1990 with the Talloires Declaration, the first official statement made by university administrators recognizing the importance of a commitment to environmental sustainability. However, there are many obstacles in developing more sustainable practices in the world of higher education. Major obstacles that colleges and universities face are financial limitations and lack of interest and commitment from stakeholders (Barlett 2004, 6). In order for a university or college to change towards a more sustainable future the college needs to be united in their sustainability efforts: there needs to be strong personal relationships across campus, strong leaders to head these programs, and a high level of support from administration and board members.

Helpful measures to get universities and colleges running sustainably include ecological missions, policy measures, and investment in the best available technology for environmental sustainability. A written statement of goals or mission for campus sustainability clearly defines what the university strives to achieve to aid the health of the environment. Once a mission is in place, policy measures can be crafted by administration, staff, and students to meet these goals. In addition to policy regulations, it is helpful for colleges and universities to invest in the best available technology for environmental sustainability that is affordable to the college so the infrastructure for the campuses energy use, waste disposal, etc. has the least environmental impact possible.

Transportation and Sustainability

Transportation is a key component of overall campus sustainability. Many students and staff at colleges and universities commute to campus and travel around campus in personal vehicles. The personal automobile has become the dominant mode of travel in the United States, more than 95 percent of personal trips are taken by car (Toor and Havlick 2004, 1). In addition to commuters, college and university campuses often own their own vehicles for campus maintenance, security, and student transit.

According to the American Lung Association's 2003 State of the Air Report, more than 142 million people living in the U.S. breath in unhealthy amounts of ozone pollution, which is linked to heart and lung diseases (2003). Transportation is responsible for a large proportion of greenhouse gas (GHG) emissions, about 32 percent of U.S. carbon dioxide emissions is from transportation (American Lung Association 2003). Furthermore toxic tailpipe emissions, such as benzene, butadiene, and diesel can potentially lead to elevated levels of cancer for people that live near major roads and highways (American Lung Association 2003). Not to mention the potential for environmental damages upstream in the process with oil drilling, risks of oil spills, and nonpoint source water pollution (Toor and Havlick 2004, 1).

The negative effects of transportation on the environment can be ameliorated with short sustainability and energy efficiency practices and long term investments in zero-emissions vehicles. Promoting bike programs, establishing fixed schedules and routes for the shuttle system, and developing education programs on the importance of on campus sustainable living in general are ways in which Sarah Lawrence College can reduce emissions from transportation.

Bike Programs and Active Transit

One of the easiest short term solutions to make campus transportation more sustainable is to promote bike programs and other modes of active transit for students traveling within and around campus. Active transit encompasses any form of transportation that involves physical activity, walking and cycling are both good examples. Active transit is beneficial on college campuses not only because it reduces demand for parking and reduces the college's impact on the environment, but also because it improves the health and wellness of the staff and students. Studies of adolescents show that increased physical activity has the potential to reduce depression and increase academic performance (Field et al., 2001, 105). Additionally, reducing exposure to traffic, with increased active transport, is likely to create more positive perceptions of the area for students and staff, as well as for residents living near the campus (Bull 2006, 241).

Sarah Lawrence College has a small bike share program already established on campus; however, the program is not heavily utilized by the students. Creating designated bike paths on and around campus would promote use of this program and cycling in general around campus. According to a study of 18 U.S. cities, there is a correlation between the miles of bike paths and the percentage of commuters who cycle (Bull 2006, 245). Putting bike paths around campus will make it easier for students to get from class to class on bike, and less reliant on shuttle systems or personal vehicles. Then if colleges and universities partner with local government to increase the number of bike paths around the campus and throughout the local community, it will be easier for commuter students and staff to bike to campus rather than drive.

In addition to providing cycling and walking pathways for students, colleges and universities can support students who prefer modes of active transit by providing bicycle repair and education services on campus. Reducing the barriers that keep students from using active modes of transport is more effective than simply promoting the benefits of active modes (Bull 2006, 249). In order to successfully promote active transit, campuses must reduce the barriers and increase the convenience of active modes and reduce the convenience and cost-effectiveness of driving (Bull 2006, 249).

Changes to Student Shuttle System

Establishing fixed routes for the campus student shuttle system would also help to reduce the campus' carbon footprint. If the shuttles had direct, fixed routes, such as from the library to Hill House, and designated pick up and drop off stops for students, then the annual milage of these vehicles could be reduced. For the dispatching of the vehicles, a combination system of ad hoc and scheduled pickups could help avoid repeated pickups at a single location. If the shuttles were, on occasion, dispatched in set intervals, for example every ten to fifteen minutes minutes on cold, late nights, repeated pickups could be avoided and each shuttle would be more likely to fill up with students, further reducing the campus' ecological footprint.

Education on Campus Sustainability

Education on campus sustainability in general could help Sarah Lawrence College run with less of a carbon footprint. Even with sustainable transport programs in place, if students and staff are not informed on these programs, they will not be very effective in helping the campus become more environmentally sustainable. Education on how to use the campus' bicycle programs, the fixed schedule and routes of the student shuttle system, and the on-campus rideshare program, Zipcar can help the campus collectively run more sustainably. Students should also be educated on the parking permit system already at Sarah Lawrence. If more students were aware of the costs of the permits, they would be less likely to bring personal vehicles on campus in the first place. These sustainability measures incentivize alternatives to using personal vehicles on campus. If students and staff are more knowledgeable on these programs, if the barriers surrounding the use of these programs are reduced, they will be more likely to utilize them (Bull 2006, 249).

Education on state idling laws, could help reduce the number of idling vehicles on campus, subsequently reducing the college's carbon footprint. While student shuttles are not in transit and when public safety vehicles are stationed on Kimball Avenue, the car's engine is usually left running. New York State Environmental Conservation Law (ECL) prohibits heavy duty vehicles from idling for more than five minutes at a time (Department of Environmental Conservation). Education on state idling laws for student van drivers and public safety officers could help reduce the number of idling vehicles on campus.

In order for sustainability plans to be implemented, the college should identify potential partnerships for funding and administrations (Toor and Havlick 2004). Federal funding and collaborative administration with local government are all possible options, while private fundings could provide more flexibility. At Sarah Lawrence, an Office of Campus Sustainability could be in charge of searching for federal funding, grants, and loans for the college's sustainability efforts. Offices around campuses collaborating with the already established Sarah Lawrence Sustainability Committee could also aid the school's environmental goals. Implementing all of these plans in a multi-tiered transportation management program can reduce Sarah Lawrence College's carbon footprint and improve the environmental health of the broader community.

Long Term Solutions - Vehicle Efficiency

Besides student and faculty-owned commuting vehicles, “the campus fleet”, vehicles that are owned and operated by college and university campuses, have huge impacts on campuses ecological footprints. These vehicles, are typically either used for student transportation or for college administration departments, such as the public safety department. Regardless of their functions, these vehicles are centrally administered by the college and generally operate within the territory of the campus or nearby communities.

One way to improve vehicle efficiency is by using alternative fuels. Most motor vehicles use gasoline, which is not only nonrenewable, but also an emitter of significantly more greenhouse gases than most alternative fuels. The main strategies for implementing alternative fuel technologies are integrating the use of electricity into vehicles and implementing other hydrocarbon alternatives to fossil fuels.

Battery electric vehicles, fuel cell vehicles, plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs) are vehicles that rely on fuels other than hydrocarbons. Fuel cell vehicles use hydrogen fuels along with oxygen from the air to produce electricity (U.S. Environmental Protection Agency and U.S. Department of Energy). PHEVs and HEVs recycle energy from the wheels of the vehicle, using them to turn a motor, which generates electricity PHEVs also have batteries that can be charged from an outside electric power source; however, HEVs can only make use of the energy from engine combustions to generate electricity (U.S. Environmental Protection Agency and U.S. Department of Energy).

Battery electric vehicles have the lowest GHG emission throughout the lifetime of the vehicle, followed by fuel cell vehicles, plug-in hybrid electric vehicles, and hybrid electric vehicles (Nigro 2013, 2). The sustainability of electricity in vehicles that require plug-in charges is not related to the production process of electricity itself. Although electricity is mainly produced by fossil fuel combustion in the United States, electric motor engines are far more efficient than conventional gasoline vehicles (U.S. Environmental Protection Agency and U.S. Department of Energy). The GHG emissions from vehicles that incorporate electricity usage are lower than the GHG emissions for conventional vehicles over time.

Other usages of hydrocarbons as alternative fuels to gasoline and diesel include biodiesel, liquefied petroleum gas (LPG), natural gas, and biologically-generated alcohols. For alcohols, methanol is mostly manufactured from carbon-based feedstock and natural gas, and ethanol by sugar and starch crops, mainly corn in the United States (Toor, Havlick 2004, 224-6). Biodiesel is mostly produced from agricultural feedstock. While the GHG emissions of burning these hydrocarbons are not necessarily lower than gasoline and diesel (U.S. Energy Information Administration), the ecological footprint is, in fact, reduced because the net GHG emission is close to zero (Toor and Havlick 2004, 224-6), since the process of carbon fixation is provided by photosynthesis.

The suitability of alternative fuel technologies for colleges and universities is highly dependent on the cost of infrastructure and availability of resources on the college or university campuses. Infrastructure improvements for a transition to alternative fuels normally include new models of vehicles, charging stations for electric or hybrid cars, and the cost of purchasing alternative hydrocarbon fuels due to their low availability compared to gasoline and diesel. Biodiesel and natural gas are hard to obtain from public fueling stations since they are not popular in most of the states in the U.S. Thus, campuses would need to establish their own network to obtain these fuels (U.S. Department of Energy). For campuses with a huge amount of vehicles, this option may be viable, but it is certainly not an option for small-sized campuses.

The cost of electric or hybrid vehicles mainly comes from replacing old vehicles with new models, which cost range from around $20,000 for HEVs to $40,000 for battery electric vehicles. However, there are one-time tax credits for purchasing these vehicles, which could be as high as $7,500 (International Revenue Service 2009). While the costs of battery replacement could be as high as $8,000 per vehicle for every three to six years, electric and hybrid vehicles offer substantial fuel savings over lifetime (Toor and Havlick 2004, 224-6). Implementing electric or hybrid vehicles is a practical solution for campuses of various sizes but is more likely to be favored by small campuses. Even if fuel cells emit zero greenhouse gasses, the infrastructures are too expensive so that this technology is not a good choice for colleges and universities (Toor and Havlick 2004, 224-6).

Despite the challenges discussed above, it is possible for college campuses to implement alternative fuel technologies. First of all, since campus vehicles are often centrally administered, it is easy for them to be replaced in bulk and to be centrally fueled, thus reducing the cost. For alternative fuel vehicles, the travel distance of a single fuel refill or energy recharge is less than that of traditional gasoline vehicles. While this is often seen as a hindrance for alternative fuel vehicles to be popularized, it does not significantly impact campus vehicles because they do not need to make long-distance travels (Toor and Havlick 2004, 222), campus vehicles typically only travel within the campus or to nearby communities.Thus, campus-owned vehicles could be a frontier to demonstrate the positive influence of alternative fuel technologies.

Universities that are successful in implementing alternative fuel technologies often use natural gas to replace gasoline or diesel. The University of British Columbia, Emory University, University of California–Davis, James Madison University, and University of New Hampshire have all replaced gasoline and diesel with natural gas to fuel their vehicles. Another alternative is using biodiesel to replace gasoline and diesel. The University of Montana and University of Colorado–Boulder replaced fossil fuels with biodiesel. However, among these choices, natural gas is the most convenient, as using biodiesel depends entirely on supply (Toor and Havlick 2004). The University of Montana relies on a local biodiesel producer for supply, and University of Colorado–Boulder constructed a processor of biodiesel. Natural gas is an easier alternative fuel to implement because it is more readily available than biodiesel.

According to the cost-benefit analysis (CBA) below, investment in electric vehicles for student transportation not only reduces the college's carbon footprint, but also can be more cost effective. The CBA below looks at the costs of doing business-as-usual (not replacing any vehicles), replacing all the vehicles in ten years, replacing the vehicles in five years, and replacing the vehicles all at once. As seen in Table 2, a ten year replacement plan costs the least for the college, followed by a five year replacement plan, and a one-time replacement. According to the CBA carrying on with current transportation practice, business-as-usual, is the most costly for the college. The CBA looks at the costs of doing business-as-usual (not replacing any vehicles), replacing all the vehicles in ten years, five years, and all at once. As one can see in fig. 2, replacement plans are far less costly for the college, regardless of the plan's time span. Among the plans, a one-time replacement costs the least and could save about $0.5 million over 10 years, followed by a 10-year replacement plan and a 5-year one.

Cost-Benefit Analysis for an Alternative Campus Fleet

A cost-benefit analysis is made to find out the best alternative to our college's current campus fleet. Since the key is to reduce the ecological footprints of Sarah Lawrence community, the proposed alternative plans all focus on replacing our campus vehicles with electric ones.

Table 1 provides an overview of the annual cost of campus fleet at Sarah Lawrence, excluding maintenance vehicles. Due to our limited knowledge of our campus fleet and the unusual operation manner, maintenance vehicles are excluded from the analysis.

The alternative plan is based on how the vehicles currently are operated in and around the campus. Vehicles the college currently owns have distinct functions and serve different purposes. According to the perceptions of public safety, the fleet functions to expand the student body's opportunity to not only utilize the space of the college equally, but also to explore the area around the college, especially the culturally diverse and dynamic New York City. Thus, as shown in Table 2, the alternative plans make sure that the number of vehicles that could fulfill these functions do not change. In the CBA, we choose to substitute the SUVs the college owns with Nissan Leaf SV, a plug-in electric SUV; besides, the minivans and vans are substituted with Nissan e-NV200, a plug-in electric 7-passenger minivan.

In analyzing the costs of changing into a new, more sustainable fleet, the investment for infrastructure is considered first and foremost. The vehicles can be charged easily with existing electricity supply and the chargers come with purchases. Hence, the only investment involved in the transition is the purchase of new models of vehicles. Although the vehicles are usually priced higher than similar-functioned vehicles that rely on fossil fuels, all electric vehicles can receive federal tax credits as high as $7,500. Besides lower fuel costs compared to traditional gasoline vehicles, electric vehicles also have lower maintenance costs.

A very important factor to take into consideration is how the costs are valued over time. In other words, there is a discount rate involved in the analysis, and it determines the present value of the costs and benefits. Besides, the fuel prices are also expected to change over time: gasoline price will rise, and electricity price will fall slightly. Thus, how the investment allocates over time changes the present value of the alternative plan. In the cost-benefit analysis, three different ways to eliminate fossil fuels are considered – purchasing all the electric vehicles at once, purchasing the electric vehicles over five years, or purchasing them over ten years.

Although the business-as-usual situation does not involve investment on new vehicle models, there are still replacements made annually. In the analysis, the replacement plan derives from the limited information that the college public safety department provided to the research team. The college public safety official provided us with the information regarding the annual replacement plan of vans; however, we could only estimate the replacement plan of SUVs and minivans based on the number of these types of vehicles. This investment constitutes a significant amount in the total cost of the business-as-usual situation.

A summarize of the cost-benefit analysis is available in Table 3, and the full data is available in Table 4. Comparing the costs of four different situations, it is clear that the alternatives can reduce the cost over the 20 years. Among the three alternative plans, replacing all the vehicles at once costs the least, following by replacing all of them in five years, and then in ten years. The plan that costs the least also reduces emission the fastest, since only the electric vehicles that are put into place could effectively reduce carbon emission of the fleet. The upstream externalities of electricity generation are not accounted for in the analysis, because the production of electricity is a convoluted process that involves many different types of externalities.

The possibility of using a loan to finance the investment is not considered in this cost-benefit analysis. There are many possibilities for the college to obtain finance for such a program, including donations, which do not require the college to pay the money back with interests. The interest rates and other costs for obtaining different loans could also be different. Besides, the loan could provoke other side effects for the college administrations. Thus, the possibility of obtaining a loan should be put into a holistic view of the college's big picture.

Undoubtedly, it is worthwhile for the college to transition from regular gasoline vehicles to electric ones. However, how the college decides between cost-effectiveness and increased emissions reduction depends on the consideration of the college administration. This analysis is only to provide an overview of the different possibilities to reduce the ecological footprints of the campus fleet.

Conclusion

The negative effects of transportation on the environment can be ameliorated at Sarah Lawrence College with increased transportation efficiency in the short term and investment in zero-emissions vehicles in the long run. Stronger bicycle programs, fixed routes for the student shuttle system, and education on sustainable transportation in general can help Sarah Lawrence to reduce emissions. Then, over time, investment in more energy efficient vehicles on campus can drastically reduce Sarah Lawrence's carbon footprint. By switching the campus fleet to Nissan Leaf SVs and seven-passenger Nissan e-NV200s, the college can drastically reduce its greenhouse gas emissions, improving air quality on campus, as well as saving approximately $0.5 million over 20 years. Transportation plays a large role in overall campus sustainability as vehicles emit a high level of greenhouse gases, as well as toxic tailpipe emissions. Improving the sustainability of campus transit is not only cost effective, but it also reduces Sarah Lawrence's impact on the environment, and improve the health and wellness of students, faculty, and staff.

Table 1

Overview of Sarah Lawrence Campus Fleet (Excluding Maintenance Vehicles)

Model	No. of the Model We Own	Fuel Cost per Vehicle ($/year)	CO_2 Emissions (tons/year)	Maintenance Cost ($/year)
Honda Pilot	5	1,250	6.075	4,035
Chrysler Town and Country	3	1,300	6.66	2,421
Ford Transit	4	1,100	5.61	3,228
Ford E350	11	2,150	10.26	8,877
Total	23	5,800	28.605	18,561

Sources: U.S. Environmental Protection Agency and U.S. Department of Energy.
Notes: Calculation based on 45% highway, 55% city driving, 15,000 annual miles and current fuel prices. Carbon emissions are priced $20 per ton. Maintenar cost is ¢5.38/mile for gasoline vehicles.

Table 2

Overview of the Proposed Alternative Fleet

New Suggested Model	Market Price ($)	Quantity	Adjusted Price based on Tax Credit ($)	Total Investment ($)	Fuel Cost per Vehicle ($/year)	Maintenance Cost ($/year)
Nissan Leaf SV	34,200	8	26,700	213,600	274	4920
Nissan e-NV200	20,870	30	13,370	401,100	336	18,450

Sources: American Automobile Association, Nick Bunkley, and U.S. Environmental Protection Agency and U.S. Department of Energy.
Notes: Calculation based on 45% highway, 55% city driving, 15,000 annual miles and current fuel prices. Maintenance cost is ¢4.1/mile for electric vehicles.

Table 3
Overview of the Cost-Benefit Analysis

Plan	Present Value of the Total Cost over 20 Years ($)	Total Savings compared to Business-as-Usual ($)
Business as usual	1,676,744.25	0
Replacing all the vehicles at once	1,175,481.33	501,262.92
Replacing the vehicles in five years	1,184,235.16	492,509.09
Replacing the vehicles in ten years	1,199,222.98	477,521.27

Table 4.1
Complete Cost-Benefit Analysis: Business-as-Usual Situation in 20 Years

Year	Fuel and Carbon Emission Cost ($)	Maintenance Cost ($)	Annual Vehicle Replacement Cost ($)	Total Annual Cost ($)
0	38,772.00	18,561.00	72,630.00	129,963.00
1	38,320.29	18,020.39	30,543.69	86,884.37
2	37,873.84	17,495.52	29,654.07	85,023.43
3	37,432.59	16,985.94	28,790.36	83,208.89
4	36,996.48	16,491.21	27,951.80	81,439.49
5	36,565.45	16,010.88	62,651.28	115,227.61
6	36,139.45	15,544.55	26,347.25	78,031.25

Year	Fuel and Carbon Emission Cost ($)	Maintenance Cost ($)	Annual Vehicle Replacement Cost ($)	Total Annual Cost ($)
7	35,718.41	15,091.79	25,579.86	76,390.06
8	35,302.27	14,652.22	24,834.81	74,789.31
9	34,890.98	14,225.46	24,111.47	73,227.91
10	34,484.48	13,811.13	54,043.54	102,339.15
11	34,082.72	13,408.86	22,727.37	70,218.96
12	33,685.64	13,018.31	22,065.41	68,769.37
13	33,293.19	12,639.14	21,422.73	67,355.06
14	32,905.31	12,271.01	20,798.77	65,975.08
15	32,521.94	11,913.60	46,618.43	91,053.98
16	32,143.05	11,566.60	19,604.83	63,314.48
17	31,768.57	11,229.71	19,033.82	62,032.09
18	31,398.45	10,902.63	18,479.43	60,780.51
19	31,032.64	10,585.08	17,941.20	59,558.92
20	30,671.09	10,276.78	40,213.47	81,161.34
Present Value of the Total Cost over 20 Years ($)	1,676,744.25			

Notes: The discount rate is 3%. The annual vehicle replacement is calculated based on an annual purchase of a Ford E350 and a purchase of a Honda Pilot eve
Calculation of the annual fuel cost takes into account of a 1.8% gasoline price escalation rate (EIA, U.S. 2011).

Table 4.2

Complete Cost-Benefit Analysis: One-Time Replacement of All Vehicles

Year	Investment on Vehicle Purchases	Escalated Annual Fuel Cost ($)	Maintenance Cost ($)	Total Annual Cost ($)
0	614700	12,272.00	23,370.00	35,642.00
1	0	11,878.82	22,689.32	34,568.14
2	0	11,498.24	22,028.47	33,526.70
3	0	11,129.85	21,386.86	32,516.71
4	0	10,773.26	20,763.94	31,537.20
5	0	10,428.10	20,159.17	30,587.26
6	0	10,093.99	19,572.01	29,666.00
7	0	9,770.59	19,001.95	28,772.54
8	0	9,457.55	18,448.49	27,906.05
9	0	9,154.54	17,911.16	27,065.70
10	0	8,861.24	17,389.47	26,250.72
11	0	8,577.34	16,882.99	25,460.33
12	0	8,302.53	16,391.25	24,693.78
13	0	8,036.53	15,913.83	23,950.36
14	0	7,779.05	15,450.32	23,229.37
15	0	7,529.82	15,000.31	22,530.13
16	0	7,288.57	14,563.41	21,851.98
17	0	7,055.05	14,139.23	21,194.29
18	0	6,829.02	13,727.41	20,556.43
19	0	6,610.22	13,327.58	19,937.81

Year	Investment on Vehicle Purchases	Escalated Annual Fuel Cost ($)	Maintenance Cost ($)	Total Annual Cost ($)
20	0	6,398.44	12,939.40	19,337.84
Present Value of the Total Cost over 20 Years ($)	1,175,481.33			

Notes: The discount rate is 3%. Calculation of the annual fuel cost takes into account of a -0.3% electricity price escalation rate (EIA, U.S. 2011).

Table 4.3

Complete Cost-Benefit Analysis: Greening the Campus Fleet over Five Years

Year	Investment on Vehicle Purchases	Escalated Annual Fuel Cost ($)	Maintenance Cost ($)	Total Annual Cost ($)
0	122,940.00	33,472.00	19,522.80	52,994.80
1	119,359.22	27,743.70	19,887.96	47,631.66
2	115,882.74	22,048.48	20,215.29	42,263.77
3	112,507.52	16,390.39	20,506.68	36,897.07
4	109,230.60	10,773.26	20,763.94	31,537.20
5	0	10,428.10	20,159.17	30,587.26
6	0	10,093.99	19,572.01	29,666.00
7	0	9,770.59	19,001.95	28,772.54
8	0	9,457.55	18,448.49	27,906.05
9	0	9,154.54	17,911.16	27,065.70
10	0	8,861.24	17,389.47	26,250.72
11	0	8,577.34	16,882.99	25,460.33
12	0	8,302.53	16,391.25	24,693.78
13	0	8,036.53	15,913.83	23,950.36
14	0	7,779.05	15,450.32	23,229.37

Year	Investment on Vehicle Purchases	Escalated Annual Fuel Cost ($)	Maintenance Cost ($)	Total Annual Cost ($)
15	0	7,529.82	15,000.31	22,530.13
16	0	7,288.57	14,563.41	21,851.98
17	0	7,055.05	14,139.23	21,194.29
18	0	6,829.02	13,727.41	20,556.43
19	0	6,610.22	13,327.58	19,937.81
20	0	6,398.44	12,939.40	19,337.84
Present Value of the Total Cost over 20 Years ($)		1,184,235.16		

Notes: The discount rate is 3%. The calculation assumes that the investment is distributed evenly throughout the five years. Calculation of the annual fuel cost takes into account of a -0.3% electricity price escalation rate (EIA, U.S. 2011).

Table 4.4

Complete Cost-Benefit Analysis: Greening the Campus Fleet over Ten Years

Year	Investment on Vehicle Purchases	Escalated Annual Fuel Cost ($)	Maintenance Cost ($)	Total Annual Cost ($)
0	61,470.00	36,122.00	19,041.90	55,163.90
1	59,679.61	33,031.99	18,954.17	51,986.17
2	57,941.37	29,961.16	18,855.41	48,816.56
3	56,253.76	26,911.49	18,746.31	45,657.80
4	54,615.30	23,884.87	18,627.58	42,512.44
5	53,024.56	20,883.04	18,499.85	39,382.89
6	51,480.16	17,907.63	18,363.77	36,271.40
7	49,980.74	14,960.15	18,219.92	33,180.07
8	48,524.99	12,042.03	18,068.87	30,110.89

Year	Investment on Vehicle Purchases	Escalated Annual Fuel Cost ($)	Maintenance Cost ($)	Total Annual Cost ($)
9	47,111.64	9,154.54	17,911.16	27,065.70
10	0	8,861.24	17,389.47	26,250.72
11	0	8,577.34	16,882.99	25,460.33
12	0	8,302.53	16,391.25	24,693.78
13	0	8,036.53	15,913.83	23,950.36
14	0	7,779.05	15,450.32	23,229.37
15	0	7,529.82	15,000.31	22,530.13
16	0	7,288.57	14,563.41	21,851.98
17	0	7,055.05	14,139.23	21,194.29
18	0	6,829.02	13,727.41	20,556.43
19	0	6,610.22	13,327.58	19,937.81
20	0	6,398.44	12,939.40	19,337.84
Present Value of the Total Cost over 20 Years ($)		1,199,222.98		

Notes: The discount rate is 3%. The calculation assumes that the investment is distributed evenly throughout the ten years. Calculation of the annual fuel cost takes into account of a -0.3% electricity price escalation rate (EIA, U.S. 2011).

References

American Automobile Association. "Your driving costs 2010 Edition." Accessed March 5, 2016. http://exchange.aaa.com/wp-content/uploads/2012/04/201048935480.Driving-Costs-2010.pdf.

"Annual energy outlook 2011 with projections to 2035." U.S. Energy Information Administration. Accessed March 5, 2016. http://www.eia.gov/forecasts/archive/aeo11/pdf/0383(2011).pdf.

Aldrete-Sanchez, Rafael, and Jeffrey Shelton, Ruey (Kelvin) Cheu. 2010. "Integrating the Transportation System with a University Transportation Master Plan: Best Practices and Lessons Learned." Texas Department of Transportation Research and Technology Implementation Office: Austin, TX.

"All-Electric Vehicles." *U.S. Department of Energy and U.S. Environmental Protection Agency.* Accessed March 5, 2016. https://www.fueleconomy.gov/feg/evtech.shtml.

Balsas, Carlos J.L. 2002. "Sustainable transportation planning on college campuses." Department of Landscape Architecture and Regional Planning. University of Massachusetts: Hills North, Amherst, MA.

Basbas, Socrates, and Nikolaos Gavanas, Magda Pitsiava-Latinopoulou. 2013. "Implementation of alternative transport networks in university campuses The case of the Aristotle University of Thessaloniki, Greece." International Journal of Sustainability in Higher Education Vol. 14 No. 3: 310-323.

Barlett, Peggy F., and Geoffrey W. Chase. 2004. "Sustainability on campus: Stories and strategies for change." MIT Press.

Bond, Alex, and Ruth Steiner. 2006. "Sustainable Campus Transportation through Transit Partnership and Transportation Demand Management: A Case Study from the University of Florida." Berkeley Planning Journal 19: 125-142.

Brown, Jeffrey, and Daniel Baldwin Hess, Donald Shoup. 2003. "Fare-Free Public Transit at Universities: An Evaluation." Journal of Planning Education and Research 23: 69-82.

Brown, William M., and Michael W. Hamburger. 2012. "Organizing for Sustainability" New Directions for Student Services No.137: 83-96.

Brix, Andrew, and Trevor Brydon, Elijah Davidian, Keely Dinse, Richard K. Norton, Sanjeev Vidyarthi. 2007. "Transforming the University Campus into a Sustainable Community." Planning for Higher Education Vol.35 No.4: 22-39.

Bull, Fiona, and Max Bulsara, Billie Giles-Corti, Terri Pikora, Tya Shannon, Trevor Shilton. 2006. "Active commuting in a university setting: Assessing commuting habits and potential for modal change." Transport Policy 13: 240-253.

Bunkley, Nick. 2010. "Ford Starts to Ship an Electric Delivery Van." The New York Times, December 7. http://www.nytimes.com/2010/12/08/business/08electric.html?_r=3&hpw.

Field, T., Diego, M., Sanders, C. 2001. "Exercise is positively related to adolescents' relationships and academics." Adolescence Vol. 36:105–110.

Finlay, Jessica, and Jennifer Massey. 2012. "Eco-campus: applying the ecocity model to develop green university and college campuses." International Journal of Sustainability in Higher Education Vol. 13 No. 2: 150-165.

Havlick, Spenser W., and Will Toor. 2004. "Transportation and Sustainable Campus Communities: Issues, Examples, Solutions." Washington D.C.: Island Press.

"How Fuel Cells Work." *U.S. Department of Energy and U.S. Environmental Protection Agency.* Accessed March 5, 2016. https://www.fueleconomy.gov/feg/fcv_PEM.shtml.

"How Hybrids Work." *U.S. Department of Energy and U.S. Environmental Protection Agency.* Accessed March 5, 2016. https://www.fueleconomy.gov/feg/hybridtech.shtml.

John Daggett, John, and Richard Gutkowksi. 2003. "University Transportation Survey: Transportation in University Communities." Transportation Planning Department: City of Fort Collins. Department of Civil Engineering: Colorado State University.

Kaplan, David H. 2015. "Transportation Sustainability on a University Campus." International Journal of Sustainability in Higher Education Vol. 16 No. 2: 173-186.

Nigro, Nick, and Shelly Jiang. 2013. "Lifecycle Greenhouse Gas Emissions from Different Light-Duty Vehicle and Fuel Pathways: a synthesis of recent research." Center for Climate and Energy Solutions.

Pellow, James P., and Brij Anand. 2009. "The Greening of a University: The St. John's Sustainability Initiative." *The Magazine of Higher Learning* Vol. 41 No. 5: 8.

"Plug-in Hybrids." *U.S. Department of Energy and U.S. Environmental Protection Agency.* Accessed March 5, 2016. https://www.fueleconomy.gov/feg/phevtech.shtml.

Shriberg, Michael, and Heather Tallent. "Beyond principles: implementing the Talloires Declaration." *Southwestern University.* Accessed March 5, 2016. http://www.ulsf.org/pdf/ShribergTallentFinal.pdf.

Toor, Will. 2003. "The Road Less Traveled: Sustainable Transportation for Campuses." *Planning for Higher Education*: 131-141.

"Vehicle Cost Calculator Assumptions and Methodology." *U.S. Department of Energy Alternative Fuels Data Center.* Accessed March 5, 2016. http://www.afdc.energy.gov/calc/cost_calculator_methodology.html.

"Voluntary Reporting of Greenhouse Gases Program." *U.S. Energy Information Administration*. Accessed March 5, 2016. https://www.eia.gov/oiaf/1605/coefficients.html.

"2011 Chrysler Town and Country." *U.S. Department of Energy and U.S. Environmental Protection Agency.* Accessed March 5, 2016. https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=31045.

"2012 Azure Dynamics Transit Connect Electric Van." *U.S. Department of Energy and U.S. Environmental Protection Agency.* Accessed March 5, 2016. https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=31893.

"2012 Ford E350 Van FFV." *U.S. Department of Energy and U.S. Environmental Protection Agency.* Accessed March 5, 2016. https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=31877.

"2014 Toyota RAV4 EV." *U.S. Department of Energy and U.S. Environmental Protection Agency.* Accessed March 5, 2016. https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=34425.

"2015 Ford Transit Connect Van 2WD." *U.S. Department of Energy and U.S. Environmental Protection Agency.* Accessed March 5, 2016. https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=35751.

"2016 Honda Pilot 4WD." *U.S. Department of Energy and U.S. Environmental Protection Agency.* Accessed March 5, 2016. https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=36425.