Commuting from U.S. Brownfield and Greenfield Residential Development Neighborhoods

Amy Nagengast[1]; Chris Hendrickson, Hon.M.ASCE[2]; and Deborah Lange, M.ASCE[3]

Abstract: Whereas brownfield development is of widespread interest, there is scant literature on the environmental impacts of brownfield developments relative to conventional developments. We assembled a set of two residential brownfield and two conventional greenfield developments for a sample of U.S. cities including Baltimore, Chicago, Milwaukee, Minneapolis, Pittsburgh, and St. Louis. Using the travel time and modes of transportation information from the 2000 U.S. Decennial Census, we analyzed the long-term commuting impacts from the two types of developments. Relative to greenfield development neighborhoods, we find that the brownfield development neighborhoods are closer to center cities, have higher public transportation use for commuting, comparable average travel times to work, and lower energy and greenhouse gas emissions for commuting. Future work will extend these results to consider other differential impacts of the two types of developments. **DOI:** **10.1061/(ASCE)UP.1943-5444.0000072.** © *2011 American Society of Civil Engineers.*

CE Database subject headings: Energy Consumption; Public Transportation; Travel Time; Travel Modes; Brownfields; Emissions; Life Cycles; Residential location.

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Introduction

With population growth and urban sprawl on the rise, cities are paying special attention to effective use of limited available land. The Environmental Protection Agency's Smart Growth program aims to "help communities grow in ways that expand economic opportunity, protect public health and the environment, and create and enhance the places that people love" (U.S. EPA 2010). Furthermore, the U.S. Department of Transportation's (DOT) Livability Initiative promotes the integration of quality transportation to areas that enrich citizens and communities (U.S. DOT Federal Highway Administration 2010). This multidisciplinary focus of these federal agencies reflects the importance of sustainable development through the interrelationships between land use and transportation.

One example of land and mobility intersections can be examined through brownfield development sites. Brownfields are properties with the presence (or suspected presence) of hazardous substances or contaminants (U.S. EPA 2009). Brownfield remediation and development are intended to improve environmental quality and reduce pressure for development of green spaces. A variety of grants and support programs are available to spur brownfield development in the United States at the federal, state, and local levels (Wernstedt et al. 2006; Lange and McNeil 2004). Brownfield development requires assessment of environmental risks and, in most cases, remediation activities before development is possible. However, brownfield development might take advantage of existing infrastructure such as water and sewer distribution and collection networks, roads, and power supply. Furthermore, brownfield development results in significant benefits to the surrounding citizens through reduced health risks, neighborhood improvement, and transportation externalities (De Sousa 2002).

Transportation is an integral component of sustainable development. The topic is now expanding beyond mobility into discussions surrounding human health and ecosystem protection (Deakin 2001). To help understand the role of transportation in sustainable growth, we compare the travel time, energy, and greenhouse gas emission impacts of commuting from a sample of brownfield and greenfield development neighborhoods. Our intent is to investigate the various long-term effects of brownfield developments relative to conventional greenfield developments. Commuting is an important component of such long-term effects. Our analysis is based on U.S. Census tracts that include brownfield and greenfield residential developments as well as surrounding housing.

Sample of Brownfield and Greenfield Development Neighborhoods

Brownfield developments range widely in size and intended use. For example, numerous brownfield developments involve remediation and reuse of individual gasoline service stations; larger brownfield developments may be former industrial plants that are converted to office parks or golf courses.

For this study, we sought a sample of representative U.S. brownfield and greenfield residential developments. We restricted our sample to metropolitan areas for which knowledgeable local representatives could identify two relatively large brownfield developments and two comparable greenfield development areas. The chosen developments were to have occurred in the past 20 years and include approximately 100 or more housing units. Our final

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[1] Ph.D. Candidate, Brownfields Center, Carnegie Mellon Univ., Pittsburgh, PA 15213 (corresponding author). E-mail: anagenga@andrew.cmu.edu

[2] Professor, Dept. of Civil and Environmental Engineering, Carnegie Mellon Univ., Pittsburgh, PA 15213.

[3] Executive Director, Steinbrenner Institute for Environmental Education and Research (SEER), Carnegie Mellon Univ., Pittsburgh, PA 15213.

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sample set is based on suggestions from local urban planners and community economic and development organizations that were contacted via e-mail and telephone. The final sample set includes developments in Baltimore, Chicago, Milwaukee, Minneapolis, Pittsburgh, and St. Louis.

The distance to center city for each development is listed in Table 1 for greenfields and Table 2 for brownfields. Distances to center city were obtained from online map directions and represent roadway distances with the shortest travel time. Additional information on the brownfield and greenfield developments can be found in the supplemental information.

Greenfield developments are, on average, 24 mi (38 km) from center city and six times further from the center city than the average for brownfields. This result is not surprising. Greenfield developments are built where land is available and relatively inexpensive, which typically means the outskirts of metropolitan areas. Brownfield developments occur where earlier development has already taken place and the property was subsequently vacated, so we expect they would be closer to the center city and supporting infrastructure.

With closer proximity to the urban core, we expect that brownfield residents may have fewer vehicle miles of travel (VMT) overall. Paull's analysis of the Maryland Historic Tax Credit Program notes that compact development has been correlated to a reduction of 20–40% in VMT compared to sprawl (Paull 2009). The Transportation Research Board (TRB) report on driving and the built environment also identified reductions in VMT for compact city development (National Research Council 2009). Shammin et al. (2010) found that compact living had roughly 18% lower energy intensity than sprawling developments.

Modal Shares and Commuting Time

At an aggregate level, commuting modal shares in the U.S. Census Bureau data (2000) are divided into: individual automobile, public transportation, motorcycle, bicycle, walked, and other modes (Fig. 1). Of the various modes in the census data, only the individual automobile, public transportation, and walking had substantial use in both brownfield and greenfield developments.

For individual vehicle transportation, residents of greenfield developments use their personal vehicles 97% of the time for travel to work, with 8% carpooling and 89% driving alone. In brownfield neighborhoods, the commute to work by personal automobile is substantially less, at 72%. Of those individuals who drive individual vehicles, almost twice as many carpool (15%) as compared to greenfields residents (8%). Commuting modal shares are summarized in Fig. 2, with the full analysis in the supplemental information.

The second main type of commuting mode is public transportation, responsible for 2% of the trips to work by residents in greenfield neighborhoods and 18% for brownfield neighborhoods. Finally, the share of commuting by walking is 1% for greenfields and 8% for brownfields. These transportation differences are likely a result of the greater attractiveness and availability of public

Table 1. Distance to Center City for Sample of Greenfield Developments

State	County	Development name	Distance to city center (mi)	Distance to city center (km)
PA	Butler	Cranberry Heights	28	44
PA	Washington	Peters Township	14	22
IL	Dupage	Woodland Hills Unit 11	35	56
IL	Dupage	Reflections at Hidden Lakes	25	39
MO	St. Louis	Villages at Liberty Gardens Addition	21	34
MO	St. Louis	Lafayette Trails	34	54
WI	Waukesha	Bristlecone Pines (Village of Hartland)	25	40
WI	Waukesha	Springbrook North (City of Waukesha)	38	61
MD	Howard	Waverly Woods	18	29
MD	Howard	RiverHill Village	24	38
MN	Dakota	Itokah Valley Townhomes 4th Addition	18	29
MN	Hennepin	Creekside Estates Apartments	9	14
	Average distance		24	38

Table 2. Distance to Center City for Sample of Brownfield Developments

State	County	Development name	Distance to city center (mi)	Distance to city center (km)
PA	Allegheny	Summerset at Frick Park	6	9
PA	Allegheny	Waterfront	6	10
IL	Cook	Homan Square	5	8
IL	Cook	Columbia Pointe	9	14
MO	St. Louis City	Lofts at the Highlands	5	8
MO	St. Louis City	Welsh Baby Carriage Phase 1	2	2
WI	Milwaukee	Trostel Square, Beerline Development	1	2
WI	Milwaukee	Cherokee Point	7	12
MD	Baltimore City	Clipper Mills	3	5
MD	Baltimore City	Camden Crossing/Koppers	2	2
MN	Hennepin	Heritage Park	2	4
MN	Hennepin	Mill City area	1	1
	Average distance		4	6

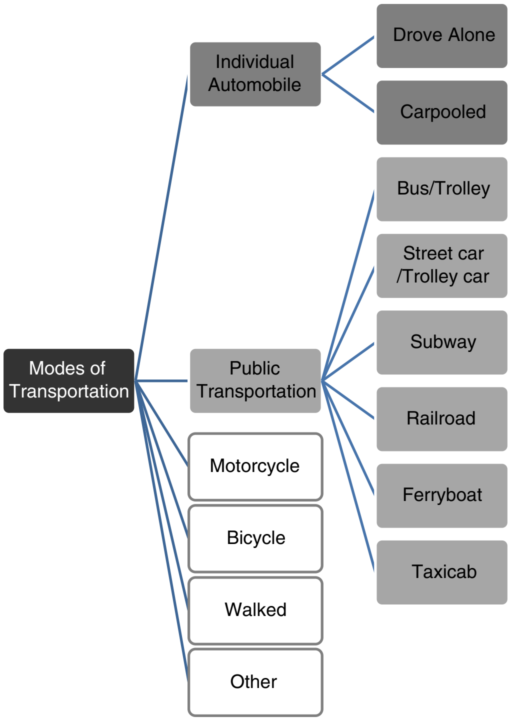

Fig. 1. U.S. Census modes of transportation categories and subcategories

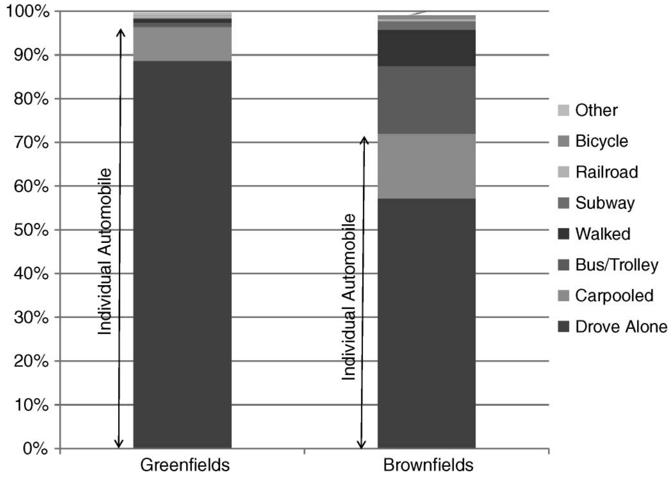

Fig. 2. Greenfield and brownfield disaggregated commuting modal shares

Table 3. Average Total Travel Time to Work One Way (min) and Disaggregated by Mode for Greenfield Neighborhoods Census Tracts

State	Greenfield name	Avg. across all modes	Avg. public	Avg. "other"
PA	Cranberry Heights	30	63	29
PA	Peters Township	28	55	27
IL	Woodland Hills Unit 11	32	75	30
IL	Reflections at Hidden Lakes	29	58	29
MO	Villages at Liberty Gardens Addition	25	44	24
MO	Lafayette Trails	28	0	28
WI	Bristlecone Pines (Village of Hartland)	21	20	21
WI	Springbrook North (City of Waukesha)	30	45	30
MD	Waverly Woods	32	64	32
MD	RiverHill Village	32	73	31
MN	Itokah Valley Townhomes 4th Addition	22	33	22
MN	Creekside Estates Apartments	21	36	20
	Average travel time (min)	28	47	27

Table 4. Average Total Travel Time to Work One Way (min) and Disaggregated by Mode for Brownfield Neighborhoods Census Tracts

State	Brownfield name	Avg. across all modes	Avg. public	Avg. "other"
PA	Summerset Phase 1	19	29	17
PA	Waterfront	26	38	24
IL	Homan Square[a]	50	23	54
IL	Columbia Pointe	30	44	23
MO	Lofts at the Highlands	19	19	19
MO	Welsh Baby Carriage Phase 1	24	48	23
WI	Trostel Square, Beerline Development	15	24	15
WI	Cherokee Point	20	41	20
MD	Clipper Mills	27	38	26
MD	Camden Crossing/Koppers	26	34	24
MN	Heritage Park	30	50	16
MN	Mill City area	31	41	24
	Average travel time (min)	27	36	24

[a] The U.S. Census tract containing the Homan Square brownfield neighborhood has reported travel times across all modes that are unusually high compared to the remaining brownfields and greenfields in Tables 3 and 4. Homan Square development also has a high carpooling rate. For this analysis, we have assumed two persons per vehicle for carpooling.

transportation closer to center cities, as well as shorter average commuting distances from brownfield developments. There might also be greater interest in carpooling, public transportation, and walking among residents choosing to live in a brownfield neighborhood. Fig. 2 shows the overall shares of commuting modes.

While the modal split of the two types of development neighborhoods are quite different (Fig. 2), the average travel time to work is quite similar with 28 min for greenfields and 27 min for brownfields (Tables 3 and 4).

It is helpful to look at the disaggregation of the travel time by mode for use in calculating energy consumption and greenhouse gas emissions of the various developments. These average travel times from the U.S. Census Bureau data can be disaggregated by mode into two broad categories: public transportation; and other, as seen in Tables 3 and 4. The "other" category includes: individual automobile; motorcycle; bicycle; walking; and other (Fig. 1). Since the individual automobile is used by most residents (97% greenfields and 72% brownfields), we assumed that the average "other" travel time is representative of private vehicle travel times.

Energy Impacts of Commuting

Scope and Assumptions

In this energy impact analysis, our scope includes the upstream supply chain production of the transportation fuel and the combustion of the fuel during the vehicle use phase. We estimated supply chain fuel production and combustion data for individual automobile and public transportation separately. To calculate these impacts, commuting speed, automobile fuel efficiency, price of fuel and electricity, public transportation information, and upstream supply chain and combustion impacts were required.

Individual Automobile Transportation

Automobile Fuel Energy

In order to quantify the upstream energy required to produce automobile fuel, the economic input-output life-cycle assessment (EIOLCA) U.S. 2002 Producer Price model was chosen (Hendrickson et al. 2006; Carnegie Mellon University (CMU) Green Design Institute 2010). Within the model, we chose the "Petroleum Refineries" sector group for analysis. This specific sector accounts for "establishments primarily engaged in refining crude petroleum into refined petroleum" and associated upstream impacts (CMU Green Design Institute 2010). The EIOLCA model estimated that 31.7 TJ/\$1 million resulted from the supply chain of fuel production (CMU Green Design Institute 2010). Assuming the average price of gasoline in 2001 was \$1.53/gal. [Energy Information Administration (EIA) 2008a], the upstream energy impact translates to approximately 49 MJ/gal.

The energy input for direct gasoline fuel combustion was assumed to be 132 MJ/gal. (EIA 2009). Thus, the total energy for fuel was the sum of upstream (supply chain) and direct use, $49 + 132 = 181$ MJ/gal.

Individual Automobile Combustion Energy Impacts

To estimate the combustion energy of fuel used per commuter in each development, we included the number of people who use individual automobiles, commuting travel time, average commuting speed, automobile fuel efficiency, and the energy in motor gasoline. The number of residents who used individual automobiles and the commuting travel time was from the U.S. Census tract information (U.S. Census Bureau 2000). We assumed those residents who carpooled had only two commuters per vehicle. We modeled the average commuting speed based on the 2009 Annual Urban Mobility Report published by the Texas Transportation Institute for an industry wide car and light truck stock having a fuel efficiency of 20.3 mi/gal. (Schrank and Lomax 2009; U.S. EPA 2005). The average commuting speeds are reported by city and by roadway type for 2007. For this analysis, we assume that the cities commuting time is the average speed based on freeway and arterial street information (Table 5).

Energy used for a vehicle trip is calculated from the average travel time to work (Tables 3 and 4), average travel speed in each city (Table 5), the average vehicle fuel efficiency (20.3 mi/gal.), and the automobile fuel energy (181 MJ/gal.)

$$\mathrm{EVT}_i = t_i \times v_i \times 181/20.3 \qquad (1)$$

where EVT_i = energy per vehicle trip for development i; t = average travel time; and v = average speed. An example calculation for the individual automobile energy intensity per vehicle trip for Cranberry Heights, located near Pittsburgh, is provided in Fig. 3. For this paper, a vehicle trip represents a resident's commuting distance to work one way.

On average, vehicle trips from greenfield developments consume 150 MJ of energy per vehicle trip (0.14 million BTU/year) compared to 130 MJ of energy per vehicle trip (0.13 million BTU/year) from brownfield developments. This difference is directly linked to the variation in individual automobile commuting time and speed, as shown in Tables 3–5. These numbers assume commuters use individual automobiles to and from work 260 d/year. In addition, the energy intensity results for all developments can be found in the supplemental information.

Table 5. Average Commuting Speeds for Cities in 2007 (Schrank and Lomax 2009)

		2007 Traffic speed estimates (mph)		
State	City	Freeway	Arterial street	Average
PA	Pittsburgh	56	32	44
IL	Chicago	41	25	33
MO	St. Louis	53	30	42
WI	Milwaukee	50	32	41
MD	Baltimore	44	28	36
MN	Minneapolis	46	29	38

Table 6. Public Transit Authorities Annual Energy Type Consumption Distribution (NTD 2001)

	Diesel	Gasoline	CNG[a]	Electricity
Chicago	52%	0%	0%	48%
Baltimore	70%	0%	0%	30%
Minneapolis	100%	0%	0%	0%
St. Louis	84%	0%	$< 1\%$	16%
Pittsburgh	90%	0%	0%	10%
Milwaukee	100%	0.3%	0%	0%

[a] CNG = compressed natural gas.

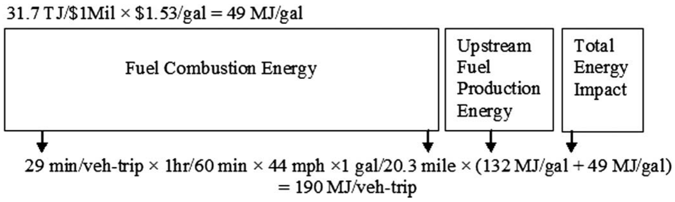

Fig. 3. Individual automobile vehicle trip total energy impact example calculation for Cranberry Heights (near Pittsburgh)

Public Transportation

The other primary mode of commuting besides individual automobile is by public transportation. We estimated energy impacts per public transportation passenger. The National Transit Database (NTD) for 2001 provided annual energy consumption reported in gallons and kW·h and annual ridership information on the six cities' transit authorities containing the paired brownfield and greenfield developments. The distribution of fuel consumption by city can be seen in Table 6.

Public Transportation Fuel Energy

The fuel consumption information from the NTD was first combined with diesel gasoline, motor gasoline, and natural gas emission coefficients from the EIA data to obtain the combustion impacts (EIA 2009). Second, the upstream impacts from fuel and electricity production were calculated using the EIOLCA model identified previously. For fuel production impacts, the same initial EIOLCA factor of 31.7 TJ/\$1 million, as described herein in the "Individual Automobile Transportation" section, was used and scaled by the corresponding 2001 consumer prices for diesel, gasoline, and natural gas (EIA 2008a, b, c).

The energy impact for direct diesel fuel combustion was assumed to be 146 MJ/gal. (EIA 2009). Thus, the total energy for diesel fuel was the sum of upstream (supply chain) and direct use $49 + 146 = 195$ MJ/gal.

The upstream energy impacts from electricity production used the EIOLCA "Power Generation" sector group for analysis. The model output for the power generation sector resulted in 114 TJ/\$1 million from the supply chain of electricity production (CMU Green Design Institute 2010). The model output was scaled by the average retail residential price of electricity in 2001 of $\$0.09/\mathrm{kW}\cdot\mathrm{h}$ (EIA 2008d).

Public Transportation Combustion Energy Impacts

After the upstream supply chain energy impact of fuel and electricity are calculated, the total energy consumed by fuel combustion must be added. For electricity, input energy to produce the electricity is in the supply chain, so direct use consumption is not included because it would be double counting. The use phase of fuel for public transportation agencies is reported by the NTD in gallons per year or $\mathrm{kW}\cdot\mathrm{h}$/year for each energy source. The fuel and electricity consumption distribution percentages from the public transit authorities can be seen in Table 6. The NTD annual energy sources are converted into MJ/year, using the EIA emission coefficients (EIA 2009).

Lastly, the total of annual passenger trips given by the NTD, seen in Fig. 4, is used to compare the public transportation energy intensities per passenger across cities.

Energy used for a passenger trip is calculated from the public transportation agency fuel mix (Table 6), the fuel source energy intensity (EIA 2009), and public transportation annual ridership

$$\mathrm{EPT} = (\Sigma f_i \times e_i)/p \tag{2}$$

where EPT_i = energy per passenger trip for city i; f = fuel type consumption; e = energy intensity of fuel; and p = annual ridership. Assuming a passenger uses public transportation twice a day for 260 d/year gives an annual energy impact for each passenger. Milwaukee has the lowest annual energy impact for each passenger at 6,700 MJ/passenger/year (6.3 MBTU/passenger/year, and Pittsburgh has the highest at 16,000 MJ/passenger/year (15 MBTU/passenger/year. The results for all cities can be seen in Fig. 5. The wide range results from differences in annual public transportation passenger ridership (Fig. 4) and public transportation vehicle energy source distributions (Table 6).

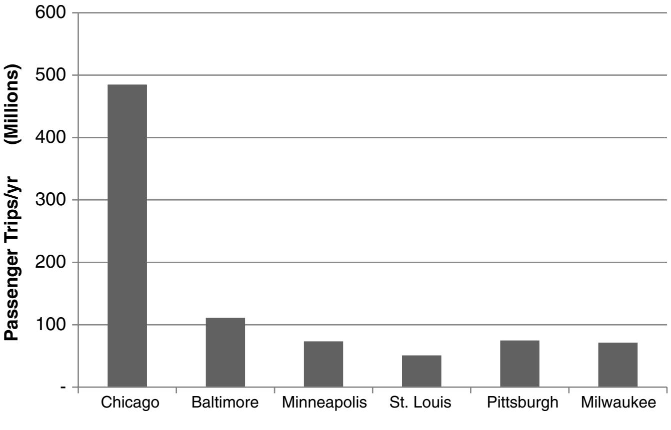

Fig. 4. Public Transportation Authority annual ridership (NTD 2001)

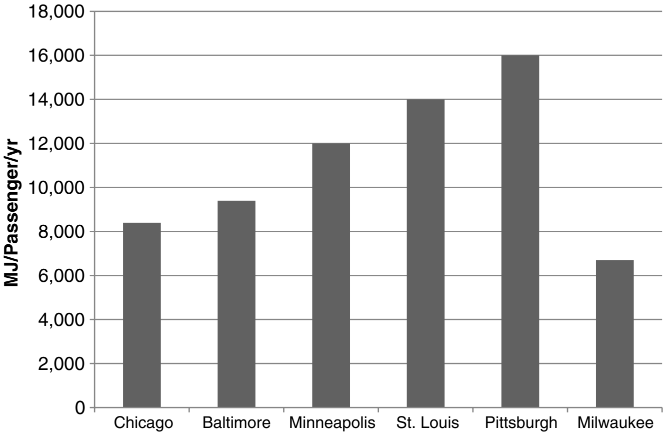

Fig. 5. Public Transit Authority annual energy impact per passenger

Energy Impacts for All Transportation Modes

Combining both individual automobile transportation and public transportation energy impacts consumed by travel to work gives a more complete picture of the differences between greenfield and brownfield developments. The energy use per commuter is calculated as a weighted average of the energy impacts for each mode, with the weights equal to the modal shares

$$\mathrm{EUC}_i = \Sigma_m\{ms_{mi} \times em_{mi}\} \tag{3}$$

where EUC_i = average energy use per commuter for development i; ms_{mi} = modal share fraction for mode m in development i; and em_{mi} = energy use per commuter for mode m and development i. We assumed those residents who carpooled had only two commuters per vehicle trip.

On average for commuting patterns, the greenfield developments consume 75,000 MJ/commuter/year (71 MBTU/commuter/year versus 47,000 MJ/commuter/year (45 MBTU/commuter/year) for brownfields. Therefore, the brownfield developments consume approximately 37% less commuting energy per resident annually than the studied greenfields (Fig. 6). The lower energy requirements are a result of differences in modal share (more walking, carpooling, and public transportation for brownfield commuters) and somewhat shorter travel times for use of private vehicles. Note that the Homan Square brownfield development is an outlier with high travel times and corresponding relatively high energy requirements.

Greenhouse Gas Emission Impacts of Commuting

The same method as presented previously for energy impacts of commuting was recalculated for greenhouse gas (GHG) emissions. The only variations were for upstream GHG emissions for fuel and electricity production and the corresponding emission factors. These upstream impacts were calculated through the same EIOLCA model and sectors described previously in the "Individual Automobile Transportation" and "Public Transportation" sections. The analysis resulted in 2,380 metric tons (t) of $\mathrm{C0}_{2e}/\$1$ million (5.2 million lb $\mathrm{C0}_{2e}/\$1$ million) for upstream fuel production and 9,160 t of $\mathrm{C0}_{2e}/\$1$ million (20 million lb $\mathrm{C0}_{2e}/\$1$ million) for upstream electricity production. The combustion GHG emission factors used for fuel and electricity were from the Energy Information Administration–Voluntary Reporting of GHG program (EIA 2002, 2009). An example calculation of the upstream impacts of diesel and electricity for public transportation for Pittsburgh can be seen in Fig. 7.

Individual automobile use by greenfield residents results in 11,000 lb $\mathrm{C0}_2$ per auto commuter per year, which, on average, is approximately 36% higher than brownfields developments. The average greenhouse gas emissions from public transportation

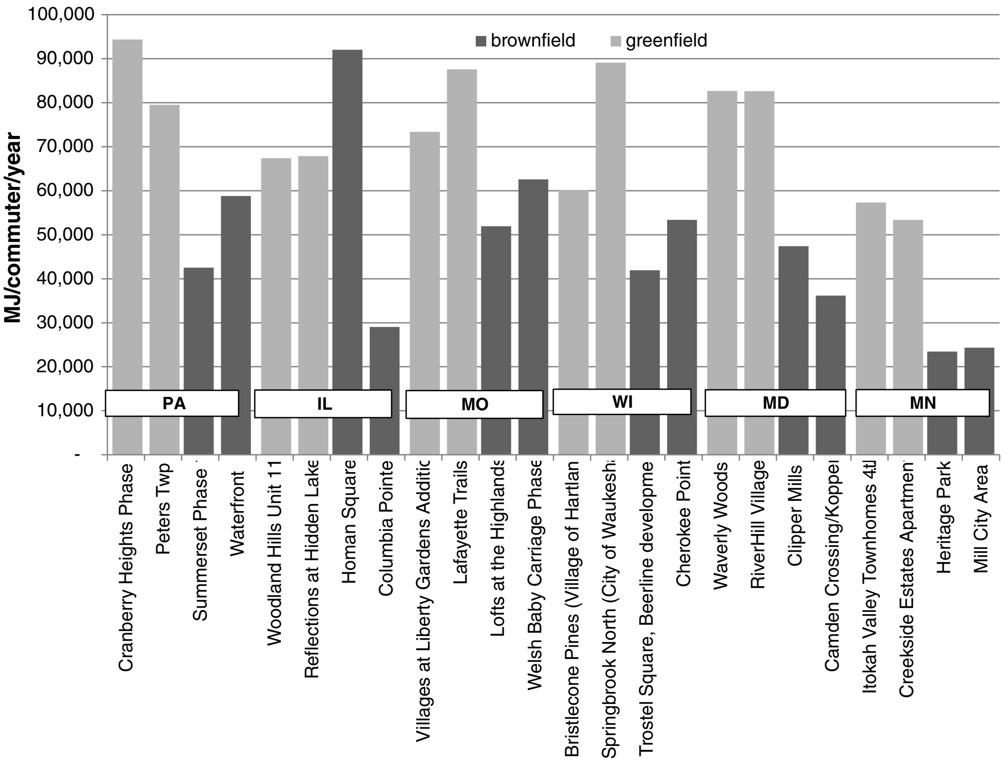

Fig. 6. Total greenfield and brownfield development energy impacts from commuting

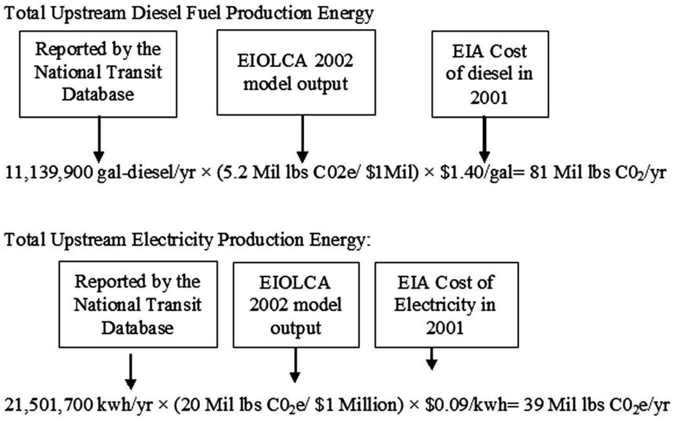

Fig. 7. Public transportation total $C0_{2e}$ upstream supply chain example calculation for Pittsburgh Transit Authority

averaged across all six studied cities is 2,000 lb $C0_2$ per bus passenger per year. Incorporating both individual automobile and public transportation travel into greenhouse gas impacts of commuting by residents, the greenfield developments average 11,000 lb $C0_2$/commuter/year, and the brownfield developments average 7,000 lb $C0_2$/commuter/year ; these results can be seen in the supplemental information.

Conclusion

This research analyzed energy consumption and greenhouse gas emissions impact differences from commuting for greenfield and brownfield developments for six cities: Baltimore, Chicago, Milwaukee, Minneapolis, Pittsburgh, and St. Louis. Greenfields are six times further from the center city, on average, than are brownfields (4 mi). On average, including both individual automobile and public transportation, the greenfield development commuters consume 75,000 MJ/commuter/year (71 MBTU/commuter/year) versus 47,000 MJ/commuter/year (45 MBTU/commuter/year) for brownfields. In terms of greenhouse gas emissions, the greenfield development emits 11,000 lb $C0_2$/commuter/year compared to 7,000 lb $C0_2$/commuter/year for the brownfield development. Thus, brownfield commuters had on average 37% lower energy and 36% lower greenhouse gas emissions for their commuting trips. These differences are from variations in modal shares (with more walking, carpooling, and public transportation for brownfield residents) and slightly shorter private automobile commuting times.

Our results have some significant uncertainties. First, our sample was limited to 24 developments. Second, we used average metropolitan travel speeds and average impacts per public transportation passenger in our estimation. Third, there is considerable uncertainty in energy and greenhouse gas emission estimates. Fourth, the greenfield and brownfield developments include the surrounding neighborhoods as defined by the US Census tracts. Finally, we did not consider other travel, buildings, or other impacts of the developments. Nevertheless, there do appear to be substantial differences in the impacts of commuting for the two types of developments.

Acknowledgments

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Supplemental Data

The supplemental data files relating to this topic are available online in the ASCE Library (www.ascelibrary.org).

References

Carnegie Mellon University Green Design Institute. (2010). "Economic input-output life-cycle assessment (EIOLCA)." U.S. 2002 Producer Price Model. ⟨www.eiolca.net⟩ (Oct. 1, 2009).

Deakin, E. (2001). "Sustainable development and sustainable transportation: Strategies for economic prosperity, environmental quality, and equity." *Working Paper 2001-03*, Institute of Urban and Regional Development, Univ. of California, Berkeley, CA.

De Sousa, C. (2002). "Measuring the public costs and benefits of brownfield versus greenfield development in the greater Toronto area." *Environ. Plann. B, Plann. Des.*, 29(2), 251–280.

Energy Information Administration (EIA). (2002). "Voluntary reporting of greenhouse gases program—Average electricity factors by state and region." ⟨http://www.eia.doe.gov/oiaf/1605/ee-factors.html⟩ (Oct. 1, 2009).

EIA. (2008a). "Table 5.24—Retail motor gasoline and on-highway diesel fuel prices, 1949–2008." ⟨http://www.eia.doe.gov/emeu/aer/txt/ptb0524.html⟩ (Nov. 1, 2009).

EIA. (2008b). "Weekly retail on-highway diesel prices." ⟨http://tonto.eia.doe.gov/oog/info/wohdp/diesel.asp⟩ (Nov. 1, 2009).

EIA. (2008c). "Annual U.S. price of natural gas sold to commercial consumers." ⟨http://tonto.eia.doe.gov/dnav/ng/hist/n3020us3A.htm⟩ (Nov. 1, 2009).

EIA. (2008d). "Average retail price of electricity to ultimate customers by end-use sector." ⟨http://www.eia.doe.gov/cneaf/electricity/epa/epat7p4.html#_ftn1⟩ (Nov. 1, 2009).

EIA. (2009). "Voluntary reporting of greenhouse gases program—Carbon dioxide emission coefficients." ⟨http://www.eia.doe.gov/oiaf/1605/coefficients.html⟩ (Oct. 1, 2009).

Hendrickson, C. T., Lave, L. B., and Matthews, H. S. (2006). "*Environmental life-cycle assessment of goods and services: An input-output approach*." RFF Press, Washington, DC.

Lange, D., and McNeil, S. (2004). "Clean it and they will come? Defining successful brownfield development." *J. Urban Plng. and Dev. Div.*, 130(2), 101–108.

National Research Council (NRC). (2009). *Driving and the built environment: the effects of compact development on motorized travel, energy use, and* CO_2 *emissions*." TRB Special Report 298 by the NRC Committee for the Study on the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption, National Academies Press, Washington, DC.

National Transit Database (NTD). (2001). "RY 2001 data tables: Table 17." Federal Transit Administration, Washington, DC. ⟨http://www.ntdprogram.gov/ntdprogram/data.htm⟩ (Sep. 3, 2009).

Paull, E. (2009). "The environmental and energy conservation benefits of the Maryland historic tax credit program: Part 2 of an analysis of economic and environmental impacts of the Maryland historic tax credit program." ⟨http://www.preservationnation.org/issues/rehabilitation-tax-credits/additional-resources/EnvEnergyImpactsMDHistTaxCredit.pdf⟩ (Jan. 15, 2010).

Schrank, D., and Lomax, T. (2009). 2009 Annual urban mobility report, Appendix A-Exhibit A-7, Texas Transportation Institute, College Station, TX.

Shammin, M. D., Herendeen, R., Hanson, M., and Wilson, E. (2010). "A multivariate analysis of the energy intensity of sprawl versus compact living in the U.S. for 2003." *Ecol. Econ.*, 69(12), 2363–2373.

U.S. Census Bureau. (2000). "2000 decennial census." ⟨http://www.census.gov/main/www/cen2000.html⟩ (Aug. 15, 2009).

U.S. Department of Transportation (DOT)-Federal Highway Administration (FHWA). (2010). "Livability initiative." ⟨http://www.fhwa.dot.gov/livability/⟩ (Oct. 1, 2010).

U.S. EPA. (2005). "Emission facts: Greenhouse gas emissions from a typical passenger vehicle." ⟨http://www.epa.gov/OMS/climate/420f05004.htm#step2⟩ (Dec. 15, 2009).

U.S. EPA. (2009). "Brownfields and land revitalization." ⟨http://epa.gov/brownfields/⟩ (Sep. 3, 2009).

U.S. EPA. (2010). "Smart growth." ⟨http://www.epa.gov/smartgrowth/⟩ (Oct. 15, 2010).

Wernstedt, K., Meyer, P., Alberini, A., and Heberle, L. (2006). "Incentives for private residential brownfields development in U.S. urban areas." *J. Environ. Plann. Manage.*, 49(1), 101–119.