INFRASTRUCTURE FOR LOW CARBON CITIES: ECONOMIC IMPLICATIONS

Christopher Kennedy
Department of Civil Engineering, University of Toronto, 35 St. George St., Ontario, Canada M5S 1A4

Abstract: This paper considers a variety of economic implications to future developments in low carbon urban infrastructure, including cost-effectiveness, potential economic returns and wider macroeconomic impacts. The GHG emissions attributable to over 40 global cities are first reviewed; while North American cities typically have high per capita GHG emissions, the Asian cities include the highest total emitters. A review of 22 infrastructure projects with reductions in GHG emissions, mainly in developed countries, shows an average cost-effectiveness around 550 t CO_2e/yr /\$millionUS, but with wide variation. Participation of the private sector in building low carbon cities depends on making sufficient economic returns; an example shows that returns from five building-scale alternative energy technologies in Toronto may vary from negative up to 23%. Development of low carbon infrastructure for cities will also give rise to deeper fundamental changes in the macro economy, potentially including changes to the patterns of investment and global trade.

1. INTRODUCTION

If the scientific prognosis of climate change is correct, then fundamental and widespread changes to infrastructure systems will be required. These changes will be driven by both mitigation of greenhouse gas (GHG) emissions and adaptation to climate change. As centers of knowledge, innovation and wealth - not to mention growing populations - cities will likely lead the way in developing low carbon infrastructure. Changes to a wide variety of infrastructure systems are required to lower urban GHG emissions. These include transportation, buildings, energy systems, waste management, and water systems, as well as integrated community design. This paper considers a variety of economic implications to future developments in such urban infrastructure, including cost-effectiveness, potential economic returns and wider macroeconomic impacts.

The carbon footprints of cities are fundamentally determined by urban infrastructure. Kennedy *et al*. (2009a) summarize the connection as follows:

"The main sources of greenhouse gas (GHG) emissions attributable to cities are transportation, energy use in buildings, electricity supply, and to a lesser extent waste. Transportation emissions per capita are inversely related to urban density; sprawling, low density cities designed around automobiles have higher emissions than more compact cities with substantial public transportation. Building energy use is primarily dependent on climate, i.e., heating degree days, but can also be impacted by the quality of building envelopes. Emissions from electricity depend to some extent on the level of consumption, but more significant is the means of power generation; nuclear and renewable sources (hydro, solar, wind, etc.) have close to zero direct emissions. Emissions from landfill waste, which are often particularly significant for cities in the developing world, are primarily dependent on the extent to which waste methane or other gases are captured. Overall, it is clear that urban GHG emissions are highly dependent on a range of infrastructure systems."

A serious effort to reduce urban GHG emissions, will essentially entail a "*long process of reconstructing the city*." This is particularly well recognized in the book *Netzstadt*, by Oswald and Baccini (2003). They recognize that the center-periphery model of cities is outdated, but the new urbanity is not sustainable. In *Netzstadt*, Oswald and Baccini begin to demonstrate how a combination of morphological and physiological tools can be used to redesign cities.

While the main examples in *Netzsatdt* perhaps fall short of fully integrating the morphological and physiological perspectives, the philosophy and approach of the book are compelling. The notion that is necessary to reconstruct cities to achieve sustainability is particularly pertinent. Oswald and Baccini write:

"Reconstruction … means launching an intelligent experiment in a democratic society in order to ensure the survival of the contemporary city. We cannot foresee the final state of this process. We are defining the quality goals of a new regionally customized urban life"

"Customization means that every society consisting of several million people must, for instance, develop concrete ideas on where they will obtain water, food, material and energy over the long term, without depleting regional or global resources; ideas on how they will renew experiential knowledge, promote creative capabilities and create symbols, without poisoning their relationship to their own origins or disrupting global communication "

This paper first frames the scope of urban reconstruction that is required by reviewing the GHG emissions attributable to over 40 global cities, including eight in Asia. The cost-effectiveness of 22 infrastructure projects which gave rise to reductions in GHG emissions, mainly in developed countries, is then presented. Cost effectiveness is, however, a limited economic measure. Participation of the private sector in building low carbon cities depends on making sufficient economic returns. An example analysis of returns from five building-scale alternative energy technologies for various audience types in Toronto is presented. Finally some of the deeper fundamental changes in the macro economy that will accompany development of low carbon infrastructure for cities are discussed. These include development of new economic sectors and changes to imports and exports.

2. GREENHOUSE GAS EMISSIONS FROM GLOBAL CITIES

To help gauge the magnitude of the urban infrastructure changes required, Table 1 provides calculations of GHG emissions attributable to over 40 global cities or metropolitan regions. This data set was complied for the World Bank (Kennedy *et al*., 2009b) by drawing together results from other studies, primarily those by Kennedy *et al* (2009c), Carney *et al* (2009) and Hillman and Ramaswami (2009). There are some minor differences in the methods used to calculate some inventory components, especially for waste, and in some cases components are missing (see Table 2 in Kennedy *et al*. 2009b, for specific details of each city). Overall, though the values reported are relatively comparable being based on a consistent methodological approach which is an adaptation of IPCC guidelines for national inventories.

Many of the North American cities have high per capita GHG emissions. Indeed five of the top seven emitters in Table 1 are North American: Denver; Washington DC; Minneapolis; Calgary; and Austin, all at over 15 t CO_2e /capita/yr. There are several reasons for this. The case of Denver, for example, is explored in a detailed comparison of ten global cities (Kennedy *et al*, 2009c); it has high electricity consumption from a high carbon intensity electricity supply, a low population density giving rise to high transportation emissions; and has cold winters requiring significant combustion of natural gas for heating. Similar diagnosis would likely hold for Calgary and Minneapolis.

The highest per capita emitter in Table 1 is actually a European city, but it is somewhat of an unusual case. As Europe's largest port, with a high concentration of industry – especially petrochemicals – but a relatively small population of just 600,000 people, Rotterdam has annual emissions of almost 30 t CO_2e /capita/yr. This is perhaps somewhat of an anomaly, although there is one other European city, Stuttgart (16 t CO_2e /capita), amongst the highest per capita emitters.

Amongst the cities with GHG emissions reported in Table 1 are eight in Asia. While the per capita GHG emissions of Indian cities are relatively low at ~ 1 t CO_2e /capita/yr., some other Asian cities, such as Bangkok, Beijing, Shanghai and Tianjin have per capita emissions of the same order as western cities. Beijing, London and New York City, for example, all have GHG emissions, including aviation and marine, of around 10 t CO_2 e /cap. Given the large populations of the Chinese cities, their total emissions are amongst the highest of all the cities in the table. Shanghai, Beijing and Tianjin are ranked first, second and fourth. Shanghai's total emissions of over 200 Mt CO_2 e (not including industrial process emissions) makes it the largest total polluter; comparable to the 25th ranked nation.

Table 1: GHG emissions for cities and metropolitan regions (from Kennedy *et al.* 2009b)

City or Metropolitan Region	Definition	Year	Population	Total Emissions Million t CO_2 e	Per capita emissions t CO_2 e
Athens	Metropolitan Region	2005	3,989,000	41.57	10.4
Barcelona	City	2006	1,605,602	6.74	4.2
Bologna	Province	2005	899,996	9.97	11.1
Brussels	Capital region	2005	1,006,749	7.55	7.5
Frankfurt	Frankfurt/Rhein Main	2005	3,778,124	51.61	13.7
Geneva	Canton	2005	432,058	3.35	7.8
Glasgow	Glasgow and the Clyde Valley	2004	1,747,040	15.30	8.8
Hamburg	Metropolitan Region	2005	4,259,670	41.52	9.7
Helsinki	Capital Region	2005	988,526	6.94	7.0
London	Greater London	2003	7,364,100	70.84	9.6
Ljubljana	Osrednjeslovenska Region	2005	500,021	4.77	9.5
Madrid	Comunidad de Madrid	2005	5,964,143	40.98	6.9
Naples	Province	2005	3,086,622	12.49	4.0
Oslo	Metropolitan Region	2005	1,039,536	3.63	3.5
Paris	Ile de France	2005	11,532,398	59.64	5.2
Porto	Metropolitan Region	2005	1,666,821	12.14	7.3
Prague	Greater Prague	2005	1,181,610	11.03	9.3
Rotterdam	City	2005	592,552	17.64	29.8
Stockholm	Metropolitan Region	2005	1,889,945	6.88	3.6
Stuttgart	Metropolitan Region	2005	2,667,766	42.57	16.0
Torino	Metropolitan Region	2005	2,243,000	21.86	9.7
Veneto	Province	2005	4,738,313	47.29	10.0
Austin	City	2005	672,011	10.48*	15.6*
Calgary	City	2003	922,315	16.37*	17.7*
Denver	City and County	2005	579,744	11.08	19.4
Los Angeles	County	2000	9,519,338	124.04	13.0
Minneapolis	City	2005	387,711	7.03*	18.3*
New York	City	2005	8,170,000	85.87	10.5
Portland	City	2005	682,835	8.47*	12.4*
Seattle	City	2005	575,732	7.82*	13.7*
Toronto	Greater Toronto Area	2005	5,555,912	64.22	11.6
Washington D	District of Columbia	2000	571,723	11.04*	19.3*
Mexico City	City	2000	8,669,594	35.27*	4.1*
Rio de Janeiro	City	1998	5,633,407	12.11	2.1
Sao Paulo	City	2000	10,434,252	14.22	1.4
Bangkok	City	2005	5,658,953	60.44	10.7
Beijing	Beijing Government Administered Area	2006	15,810,000	159.00	10.1
Delhi	Metropolitan Area	2000	15,700,000	20.65*	1.6*
Kolkata	National capital territory	2000	13,200,000	17.80*	1.1*
Shanghai	Shanghai Government Administered Area	2006	18,150,000	211.98	11.7
Seoul	Seoul City	1998	10,321,496	42.03*	4.1*
Tianjin	Tianjin Government Administered Area	2006	10,750,000	119.25	11.1
Tokyo	Tokyo Metropolitan Government Admin. Area	2006	12,677,921	62.02	4.9
Cape Town	City	2006	3,497,097	40.43	11.6

3. COST EFFECTIVENESS OF INFRASTRUCTURE STRATEGIES FOR GHG REDUCTION

As part of the Toronto Region's Living City initiative, the Sustainable Infrastructure Group at the University of Toronto has produced a guidebook to assist medium to large Canadian municipalities down the path to becoming carbon neutral (Kennedy, 2009). The guidebook contains:

- Over 70 case studies of best practices in sustainable urban design and planning worldwide.
- Guidelines for estimating the GHG emission reductions from a wide range of infrastructure strategies.
- An example of how integration of these strategies can be used to reduce Toronto's per capita GHG emissions by over 70%.

Amongst the case studies are 22 examples of infrastructure projects that reduce GHGs, for which sufficient data were available to calculate cost effectiveness (Table 2). Cost effectiveness is defined as follows:

$$\text{Cost effectiveness} = \frac{\text{Annual GHG emissions saved}}{\text{Capital investment}} \tag{1}$$

This measure only considers initial capital costs; it excludes recurring costs, user fees, financial benefits, low-cost financing and/or government subsidies. As cost effectiveness gives no indication of financial returns it may be considered a limited economic measure. It is useful, however, from the perspective of capital budgeting to reduce GHG emissions.

For the 22 case studies where the capital costs and GHG emissions are both known there is a relatively consistent fit of increased emissions savings with higher investments (Fig. 1). The data is, however, plotted on a log-log basis, which disguises very large deviations in the data set. For example, a solar air heating system in Montreal costing US$1.96 million has reported GHG savings of 1,342 t CO_2e/yr, while a bike campaign in Whitehorse costing US$1.51 million is estimated to save only 45 t CO_2e/yr (Table 2). Moreover, comparison of the 22 studies with projects from the United Nations Clean Development Mechanism database, found that the developing world GHG reduction projects were generally far more cost-effective (by orders of magnitude). The average cost-effectiveness of the projects in Table 2 is 550 t CO_2e/yr /$million US, but clearly there are significant differences in cost-effectiveness between the case studies, with respect to reducing GHG emissions.

Five cases at the top end of Figure 1 are particularly noteworthy. These are cases which lie above the line of best fit, and exceed GHG savings of 100,000 t CO_2e per year:

- **Seville's Solar Central Receiver Station** with a peak power capacity of 11MW is the first commercial grid connected version of its type. The project cost $55 million and has estimated savings of 110,000 t CO_2e per year. There are plans to expand the system to 300MW by 2013, which would be enough to power 180,000 homes (approximately the size of Seville).
- **London's Congestion Charging Scheme** is estimated to reduce emissions by 120,000 t CO_2e per year; it cost about $324 million to implement including traffic management measures, communications / public information, systems set-up and management. In 2007/08, the congestion charging generated net revenue of £137m.

Table 2. Capital costs and annual greenhouse gas savings for the case studies (v = verified; * = GHG calculation undertaken by the project team; adapted from Table 4 of Kennedy *et al*., 2009a)

PROJECT	LOCATION	CAPITAL COST ($ million US)	ANNUAL GHG SAVING (kt CO_2 e)
TRANSPORTATION / LAND USE			
Light Rail Transit	Calgary	447	591(v)
Bus Rapid Transit	Vancouver, BC	39.2	1.8
Metrolink: Express Bus	Halifax, NS.	9.3(v)	1.125(*)
Heavy-Duty HCNG Transit Buses-Hydrogen Highway	Port Coquitlam, BC.	2.3(v)	0.12(v)
Congestion Charging	London	244(v)	120(v)
Bike Share	Paris	132(v)	18(*)
Bike Campaign	Whitehorse	1.5(v)	0.0045(v)
BUILDINGS			
Solar Air Heating	Montreal	1.96	1.342
Solar Hot Water Heating	Paris	0.91 (v)	0.214 (v)
Heat Recovery from Restaurant Exhaust	Toronto	0.015	0.0075
ENERGY			
Solar Central Receiver Station	Seville	41	110(*)
Tidal Stream System	N. Ireland	5.4 (v)	2(v)
Solar Power and Borehole Thermal Storage	Okotoks, Alberta	3.8 (v)	0.26 (v)
Photovoltaic Plant	Olmedilla de Alarcon, Spain	460	29(*)
Wave Power Plant	Portugal	10.6	1.8(*)
Small Hydro	Cordova Mines, Ontario	1.36	0.06(*)
Urban Wind Power	Toronto	1.21	0.38
Vertical Axis Wind	Liverpool	0.46 (v)	0.0014(*)
SOLID WASTE			
Source-Separation & Methane Production	Sydney	75 (v)	210 (v)
Incineration-Based CHP	Gothenburg	453 (v)	205 (v)
WATER / WASTEWATER			
Biogas from sewage	Stockholm	15	14
SUSTAINABLE COMMUNITY			
Dockside Green	Victoria, B.C.	4.5 (v)	5.2 (v)

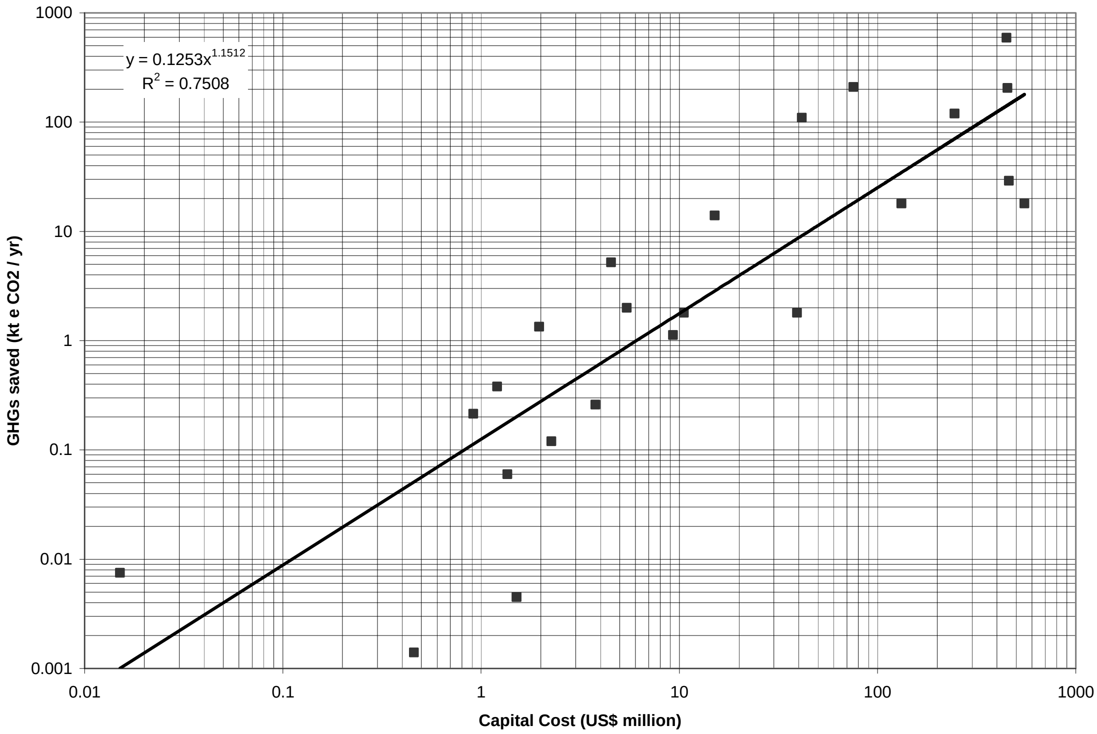

Figure 1 Log-log plot of annual GHG savings versus capital costs for infrastructure case studies in the *Getting to Carbon Neutral* project. (Figure 2 from Kennedy et al. 2009a).

- **Gothenburg's Combined Heat and Power (CHP) System** fuelled by waste incineration reduces municipal solid waste disposal needs and displaces fossil fuel generated heat and electricity. The system cost $600 million; and saves about 205,000 t CO_2 e per year.
- **Sydney's Source Separation and Energy Recovery Facility** achieves a 70% diversion of municipal solid waste from landfill. An anaerobic digestion process produces methane, which is combusted to produce electricity to power the separation facility. The estimated GHG savings are 210,000 t CO_2e per year, following a capital cost of $100 million.
- **Calgary's Light Rail Transit System** is essentially emissions-free as the train fleet is powered by wind-generated electricity. Following capital investment of $447 million (in the transit system and wind turbines), Calgary's C-train saves around 590,000 t CO_2e per year.

Further to these five cases, the data set included four other projects with annual GHG savings over 100,000 t CO_2e, but for which the capital costs were unknown (Kennedy et al, 2009a). These were: a solar thermal electricity plant in the Mojave desert (270,000 t CO_2e per year); a series of over twenty geothermal power plants in Northern California (950,000 t CO_2e per year); Chicago's plan to double its tree canopy (170,000 t CO_2e per year); and the (now postponed) Dongtan sustainable community development near Shanghai (750,000 t CO_2e per year). These nine cases with savings over 100,000 t CO_2e per year cover several sectors: transportation, solid waste, energy supply and even urban forestry. This is encouraging, as it shows that a diverse range of strategies can be taken to reduce GHG emissions.

4. PRIVATE SECTOR RETURNS ON INVESTMENT IN SUSTAINABLE INFRASTRUCTURE: BUILDING SCALE ALTERNATIVE ENERGY IN ONTARIO

While the public sector will have to cover some of the costs of developing sustainable urban infrastructure, substantial participation from the public sector will also be required. When considering some of the greatest cases of urban transformation in history – such as Paris under Haussmann, or New York at the turn of the 19th century – the challenge, as Hall (1998) observes, has always been to "*gear urban finances so that the public sector triggers private development and in turn is financed by it.*" Developments ranging from the model socialist city of Stockholm in the 1950s and 1960s to London under Thatcher have all relied upon some form of public and private collaboration. Hence it is key that the public sector finds ways to leverage private sector investments as cities embark on Oswald and Baccini's long process of reconstruction in order to combat climate change.

Participation of the private sector in reconstructing the city will only occur if there are suitable rates of return. An example of how such returns have been fostered is illustrated by the alternative energy sector in Ontario, Canada. In recent years, the Ontario and Canadian governments have enacted several policies to encourage an uptake of alternative energy technologies. These include grants for solar water heaters (SWH), solar air heaters (SAH), and ground-source heat pumps (GSHP); and rebates for electricity generated by renewable sources such as solar and wind, first through a Standard Offer Program (SOP) and more recently through Feed in Tariffs (FIT).

Table 3 Average expected rates of return for building-scale alternative energy systems in Ontario (Table 1 from Bristow and Kennedy, 2009)

		Incentive Used**			
Audience	Technology	None	SOP	FIT	Grants
Homeowner	PV	-14%	-3.0%	3.7%	
	SAH	1.7%			
	SWH	-3.8%			
	Wind	DNE	-20.3%	-12%	
	GSHP*	6.4%			23%
Small Business	PV	-12%	-0.4%	5.7%	
	SAH*	1.7%			10%
	SWH*	-1.4%			5.8%
	Wind	DNE	DNE	-17%	
	GSHP	14.7%			
Commercial /Institution	PV	-11%	1.5%	8.1%	
	SAH*	2.2%			11%
	SWH*	-1.3%			5.9%
	Wind	0.9%	3.6%	7.6%	
	GSHP	12%			

** In all small business and commercial/institution cases the capital cost allowance is included; * The GSHP-Homeowner grants are 61% of the capital costs, while the SAH and SWH grants are 50% of the capital costs of these systems.
SAH = solar air heating; SWH = solar water heating; GSHP = ground source heat pump
DNE = does not exist (cumulative cash flows are negative throughout project life)
Blank cells = incentive not applicable for given technology
SOP = standard offer program; FIT = feed in tariff

Table 3 shows the average expected return for different audiences (residential, small business, commercial/institutional) for five different building scale alternative energy technologies. In the absence of government incentives, only GSHP installations offer potentially attractive returns, from 6% for homeowners up to 14% for small businesses; SAH and larger scale wind power can make small positive returns. With government grants, however, SAH and SWH installations can offer returns of 10-11% and close to 6% respectively. While under the FIT, PV installations can provide returns of varying from 3.7% for homeowners to 8.1% for commercial/institutional. In all these cases, the returns quoted are average expected returns for typical installations in or around Toronto (Bristow and Kennedy, 2009). Profits can be made from these alternative energy systems by selling electricity to the grid and/or avoiding future costs of purchasing energy from conventional sources.

There is clearly uncertainty in the returns, however, due to the unknown future price of energy. To incorporate such financial risk into the analysis Bristow and Kennedy (2009) examined a wide range of predictions of future energy prices. Figure 2, for example, shows a range of forecasts for North American natural gas prices. Expected prices vary from around 0.2 CAD/m^3 to over 0.5 CAD/m^3. The risk can be incorporated into the financial analysis, however, by means of a plot of average return versus the coefficient of variation of returns. Simulation of the investments using the Monte Carlo technique shows that many of the alternative energy investments perform better than investments in government bonds or the stock market. Several of the alternative energy investments offer suitably high returns at relatively low risk (Fig. 3).

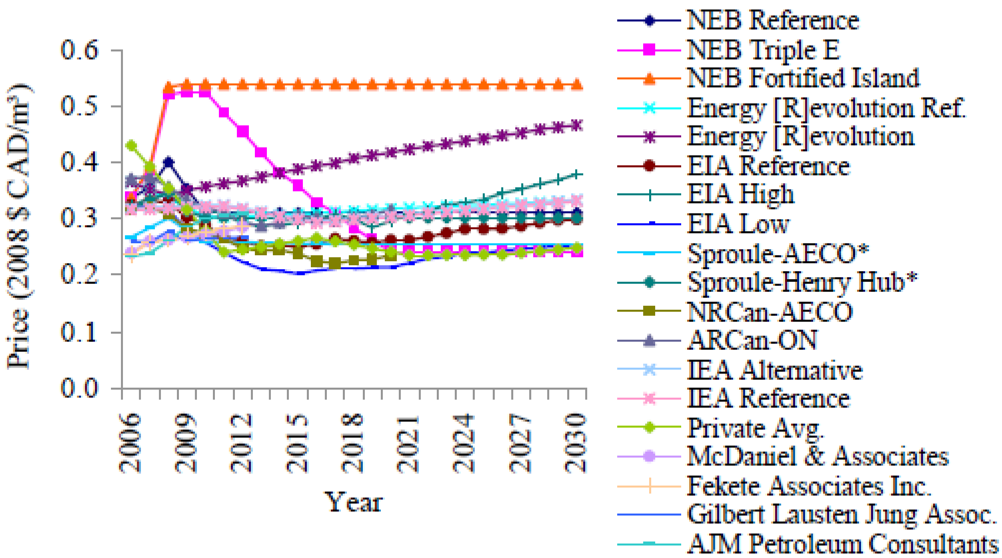

Figure 2 North American natural gas price forecasts - adjusted to US Wellhead. (Fig 1 from Bristow and Kennedy, 2009)

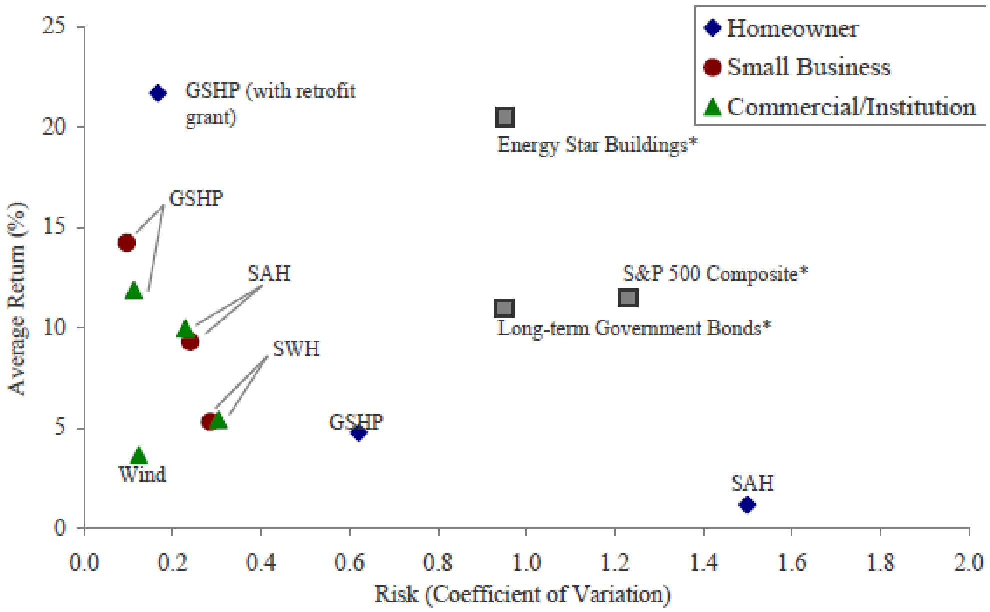

Figure 3. Risk versus expected return for building scale alternative energy systems in or around Toronto, Canada. (Fig. 2 from Bristow and Kennedy, 2009) *Data from Rickard et al. (1998); SAH = solar air heating, SWH = solar water heating, GSHP = ground source heat pump

5. WIDER ECONOMIC EFFECTS

Public sector incentives to encourage private sector investments in low carbon infrastructure have potentially substantial effects on the wider economy. Continuing with the Ontario example above, the government may be able to justify the high feed in tariff rates to investors, as they offset the cost of installing other larger scale generating capacity. More important, however, is that the strategy attracts manufactures of renewable energy technology to the province, providing capital investment and employment.

Expanding beyond the alternative energy sector, the path to developing low carbon cities will also require large scale investments in other types of infrastructure, in particular transportation. In a report for the Ontario government, the author proposed that widespread electrification of many infrastructure systems would be a desirable strategy for substantially reducing the province's GHG emissions, one that is consistent with the greening of the province's electricity grid (Kennedy *et al*, 2008). With regard to transportation in the Greater Toronto region this would mean developing high speed electric rail and providing incentives to households for purchasing electric vehicles.

If played out to its full extent, the elimination of fossil fuel combustion in Ontario – through electrification – would have significant impacts on trade. Ontario's main export sector is automobiles (with net exports of $37.768 billion CAN in 2004), so being an early adopter of electric vehicles is key to maintaining its auto manufacturing sector. Perhaps more dramatic though is the impacts on imports. Ontario's primary import sector is mineral fuels – including coal, oil and natural gas (with net imports of $17.856 billion CAN in 2004). Under the emerging green economy – in a low carbon world – these imports of fossils fuels have to essentially cease – likely to be replaced with other (undetermined) imports.

Considering the implications of low carbon infrastructure development on a global scale, it is clear that profound changes to local – and indeed national – economies will occur. The green economy will potentially involve major changes to the patterns of investment and trade that occur around the globe. Overcoming society's addiction to fossil fuels will involve a wave of creative destruction - as Schumpeter might put it – comparable to the industrial revolution. Cities that can catch and ride the wave will prosper.

6. CONCLUSION

In reviewing urban infrastructure projects that reduce GHG emissions, five projects were singled out for having savings of over 100,000 t CO_2e / yr. while achieving above the average cost effectiveness (550 t CO_2e /yr /$million US). Compared to the magnitude of emissions from global cities (Table 1), however, the GHG reductions from these multi-million dollar projects are still a drop in the bucket. Western cities (and some Eastern) of 1 million persons typically have GHG emissions of the order 10 million t CO_2e/yr., while megacities of 10 million person have emissions of the order 100 million t CO_2e/yr.

The long process of reconstructing cities to substantially reduce GHG emissions will require public sector incentives to leverage private sector investment. An example of how such incentives provide suitable rates of return for building-scale alternative energy systems in Ontario has been demonstrated. Similar strategies will have to be developed for other sectors, especially transportation. Such development of sustainable urban infrastructure will likely involve major changes to global patterns of investment and trade.

7. REFERENCES

Bristow, D. and Kennedy, C.A. (2009). Potential of Building-Scale Alternative Energy to Alleviate Risk from the Future Price of Energy, accepted for publication in *Energy Policy*.

Carney, S., N. Green, R. Wood, R. Read (2009) Greenhouse Gas Emissions Inventories for Eighteen European Regions, EU CO_2 80/50 Project Stage 1: Inventory Formation. The Greenhouse Gas Regional Inventory Protocol (GRIP)

Hall, P. (1998) *Cities in Civilization.* Pantheon.

Hillman, T. and Ramaswami, A. (2009) Greenhouse Gas Footprints and Energy Use Benchmarks for Eight US Cities, submitted to *Environmental Science & Technology.*

Kennedy, C.A., ed. (2009) Getting to Carbon Neutral: A Guide for Canadian Municipalities, prepared for the Toronto and Region Conservation Authority, pp. 137.

Kennedy, C.A., Karney, B., Miller, E., and Hatzopoulou, M. (2008) Infrastructure and the Economy: Future Directions for Ontario, report for the Martin Prosperity Institute, pp. 26.

Kennedy, C., D. Bristow, S. Derrible, E. Mohareb, S. Saneinejad, R. Stupka, L. Sugar, R. Zizzo, and B. McIntyre (2009a), Getting to Carbon Neutral: A Review of Best Practices in Infrastructure Strategy. Paper presented at the World Bank's Fifth Urban Research Symposium, Marseille, France, June 28 – 30, 2009.

Kennedy, C.A., Ramaswami, A., Carney, S., and Dhakal, S (2009b). Greenhouse Gas Emission Baselines for Global Cities and Metropolitan Regions. Plenary paper presented at the World Bank's Fifth Urban Research Symposium, Marseille, France ,June 28 – 30, 2009.

Kennedy, C., J. Steinberger, B. Gasson, T. Hillman, M. Havránek, Y. Hansen, D. Pataki, A. Phdungsilp, A. Ramaswami, G. Villalba Mendez (2009c) Greenhouse Gas Emissions from Global Cities, *Environmental Science and Technology,* 43, 7297–7302.

Oswald, F., and Baccini, P. (2003) *Netzstadt: Designing the Urban*, Birkhäuser.