Greening the Urban Fabric: Contribution of green surfaces in reducing CO_2 emissions

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Abstract: - This research focuses on the potential contribution of green surfaces [green roofs and green façades] in reducing CO_2 emissions as applied to the city core of Vancouver, Canada. This includes an analysis of their influence in reducing the energy demand by buildings and in food production, as well as in the capacity of greenery to trap air pollutants such as CO_2. It applies the Seattle Green Factor for greening the urban fabric.

The research compiles findings from previous studies on urban forest, green roofs, green walls and food production, which forms the basis of this research. From this analysis it identifies the contribution of green surfaces to the urban environment, providing specific data on the influence towards reducing CO_2.

Obtained data shows that the contribution towards reducing CO_2 emissions of the proposed green surfaces includes a 15 % reduction in CO_2 generated for cooling buildings; a 3% reduction of the energy required for transporting food by growing it on green rooftops; and another 2% via CO_2 uptake by the greenery. The research suggests that such green interventions could contribute significantly in reducing CO_2 emissions of cities, especially by reducing the energy demand by buildings and food production. This would also contribute to a reduction in cities' fossil fuel dependency.

Key-Words: - CO_2 emissions, green roofs, green façades, green walls, local food production, greenhouses, urban farms, buildings energy demand.

1 Introduction

In 2008, for the first time in history, the urban population will equal the rural population of the world and, from then on, the world population will be urban in its majority (United Nations [1]). This means that cities will keep growing in order to accommodate additional people. But at the same time this also means that more agricultural lands will be needed in order to feed this growing urban population. This research analyses the potential of growing food within existing cities through green surfaces (green roofs and façades). It then studies the contribution that such green interventions would have in reducing the CO_2 emitted by cities.

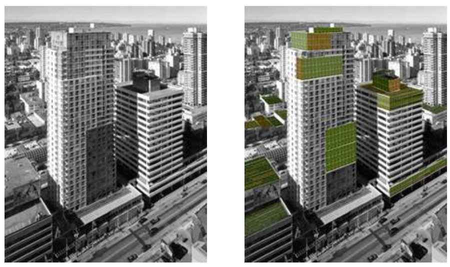

Fig1. Overall green surfaces intervention [green walls + green roofs]

What if buildings grew food in cities? Does growing food within cities make sense? What benefits would arise? This research attempts to bring clarity to these questions, analysing the contributions of green surfaces in reducing CO_2 emissions. To do so, it applies the Seattle Green Factor (Green Factor [2]) to a particular selected area in downtown Vancouver, Canada. The Seattle

Green Factor, which is based on previous European factors (BAF [3] and the Greenspace Factor [4]), suggests that "a project must plan for the equivalent of 30 per cent of the parcel area committed to urban landscaping" (Mason and GRHC, 2007 [5]. Green factors promote increased green surfaces in cities and their main objectives could be summarized as follows:

- Safeguarding and improving microclimatic and atmospheric hygiene
- Safeguarding and developing soil function and water balance
- Creating and enhancing the quality of plant and animal habitats
- Improving the urban environment by, for instance, reducing energy demand and CO_2 emissions

This research suggests an additional objective: the potential of the green surfaces to grow vegetables. It then analyses its contribution to the city in terms of reducing CO_2 emissions.

In doing so, it identifies a series of related research studies which are mainly focused on the analysis of the contribution of green roofs and green walls in reducing the energy demand by buildings. But few researchers have focused on the potential of these green surfaces to grow food within cities and the contribution to reducing CO_2 emissions. This research includes this analysis in order to develop a more holistic concept regarding the influence of green surfaces in reducing CO_2 emissions and ultimately mitigating Climate Change.

The research begins by selecting a specific site in the core of downtown Vancouver, and analysing existing green and grey surfaces. It then applies the Seattle Green Factor which requires an increase in green surfaces by 60% on flat roof areas, and 10% on façade areas in order to achieve the 0.3 value suggested by the Factor. The research argues that by greening 60% of existing flat roof areas, and assuming vegetables would be produced on them, the vegetable needs of the people living in the study area would be covered. Moreover, this would contribute to a CO_2 emissions reduction of 15percent.

Throughout history urban policies have incorporated minimum requirements for creating more liveable cities, such as minimum percentages for green spaces, [Ley Foral [6]]. This research suggests that with an increasing world urban population and scarcity of world natural resources, urban policies should begin thinking on incorporating minimum requirements of food production within urban developments, in order to ensure sufficient food supply to the population.

2 Methodology Reduction in energy demand/food production/Trapping air pollutants

In the first phase, the case study site is selected within downtown Vancouver. The selected area combines residential and commercial buildings. It is a neighbourhood from the 1960s, which hosts 8,500 people and in which new high rise buildings are still developing, promoted through the "EcoDensity" initiative (City of Vancouver [7]) launched by the City of Vancouver.

Fig2: The selected site in downtown Vancouver. It combines the residential neighbourhood – West End – and Downtown District neighbourhood.

The research analyses existing conditions of the site, in terms of green versus grey surfaces; current energy consumption by buildings based on their usage; and CO_2 emissions depending on the energy source. It also calculates current flat roof and building façade areas.

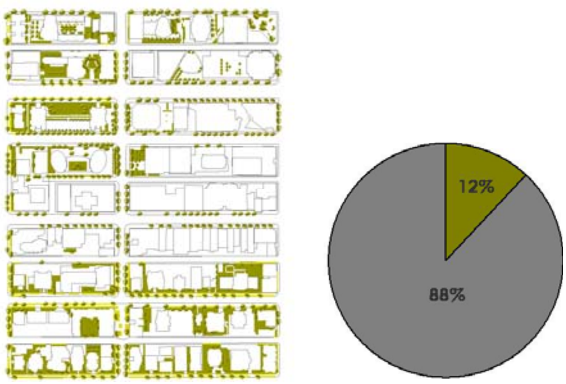

Fig3: Grey vs. Green surfaces analysis of the selected site

Table 1: Characteristics of the selected site

Building Use		Energy - CO_2	
	Area [ha]	Energy [MJ/year]*	CO_2[Tn]**
Commercial [Retail, Office, Hotel, Church, Parking lot]	28ha	327 MJ/year [235 MJ-gas 92MJ-electr]	13425 T [12402T-gas 1022T-elec]
Residential [Townhouse, Multi-family]	40ha	185 MJ/year [133 MJ-gas 52MJ-electr]	7586T [7019T-gas 566T-elec]
Green	2,3ha [12%]		
Grey	17,2ha [88%]		

*The energy consumption estimate is based on energy targets for the South East False Creek Development in downtown Vancouver (City of Vancouver [8])
** CO_2 emissions estimate assumes 1kg/1kwh gas emits 190gCO_2, and 1kwh electricity emits 40gCO_2 (Environmental Food and Rural Affairs-UK [9])

The research applies the Seattle Green Factor [3] to the case study area. In order to achieve the 0.3 value suggested by the Factor, it proposes to green 60% of existing flat roof areas, and 10% of existing building façade areas. By doing so, existing green surface areas increase from 12% to 24%.

3 Reduction in CO_2 emissions

This research analyses a series of research studies on urban forests, urban parks, green roofs, and green walls, which suggests the contribution of greenery in reducing $C0_2$. It explores three aspects by which greenery would reduce $C0_2$ by greening the urban fabric:

3.1 Contribution to reduce the energy demand by buildings

3.2 Contribution to local food production

3.3 Capacity of vegetation to trap air pollutants

3.1 Contribution to reduce the energy demand by buildings

It is worth it mentioning that some research studies focused on the influence of vegetation in reducing the air temperature of the surrounding area, which consequently reduced the energy demand by buildings. In this sense, some of these studies on urban parks suggest that for every 100m^2 of vegetation, air temperature is reduced by 1ºC, and that by increasing 10% the green to built area ratio a 0.8ºC reduction is achieved (Dimoudi & Nicolopoulou [10]). In similar terms Central Park in New York reduces its nearby temperature by 2-5ºC (Rosenzweig, Solecki & Slosberg [11]), and Shinjuku Gyoen park in Tokyo which reduces the urban heat island effect by 2ºC and decreases the temperature in adjacent areas within the range of 80-90m from the boundary. (Honjo, Narita, et. al. [12]). Vegetated courtyards reduce air temperature around 4-5ºC (Reynolds [13]), and vegetated roofs reduce air temperature between 0.5-2ºC (The City of Toronto & Ryerson University [14]).

The contribution of greenery in lowering air temperature directly affects a reduced cooling energy demand of buildings by 31%, and windbreak plantings further contribute to reduced annual heating by 15% (McPherson, Nowak et. al. [15]). Similarly, according to computer simulations, green walls contribute to a reduced cooling energy use in Madrid by as much as 45%, and a 23% heating reduction (Laurenz [16]).

Considering the studies explained above, the research applies this data into the selected study area, which has proposed to green 60% of existing flat roofed areas, and 10% of existing building façade areas, in order to achieve the Green Factor. The research assumes that by greening the selected area in these terms, those buildings covered by green roofs and green façades would reduce their annual energy demand by 20%. In this sense, by these types of green interventions, the annual energy demand by buildings, including cooling and heating, would be reduced by 14% and CO_2 emissions by 15%.

3.2 Contribution to local food production

This research studies in depth the influence of the proposed green surfaces intervention to promote local food production and reduce the CO_2 emissions related to global food production. The research analyses the appropriateness of using buildings as local food producers, and its consequences. Some proposals have already been made in this direction. It is most notably through the work of Dr. Dickson Despommier, searching for alternatives to current food production (Despommier [17]). Figure 4, below, shows some projects proposed by his students from Columbia University's Department of Enviromental Health Sciences. In similar terms SOA architects have proposed the Living Tower or "La Tour Vivante" (SOA architects [18]).

Fig4. Examples of vertical farm proposals. From left to right designs by Gordon Graff, Chris Jakobs [17] and SOA architects [18].

On a larger scale, below is the Sociopolis proposal by Vicente Guallart for a new urban development in Valencia, Spain (Guallart [19])

Fig5. Sociopolis project, Valencia, Spain [19].

This research attempts to achieve specific data derived from such interventions focused on the contribution in reducing CO_2 emissions. Today, food travels farther than ever all around the world. In the United States, fruits and vegetables are travelling over 2.000 kilometers from farm to store (Pirog & Benjamin [20]). In Canada, studies show that the imports of 58 studied food items travel an average of 4.497 km in the Waterloo Region, Ontario (Xuereb [21]). In the United Kingdom, the travelling distances are 2.000 miles for vegetables (Blythman [22]).
The further food travels, the more CO_2 is emitted from food transport. Transport by air produces 1.070,4g of CO_2 per tonne-kilometre shipped, 264,7g by trucking, 53,4g by marine, and 29,2 by rail (Environment Canada, 2002 [23]). An average of 1,3 kg of GHG emissions is generated for every kilogram of food imported in Waterloo Region, Ontario (Xuereb [21]). These imports account for 51.709 tonnes of GHG emissions annually. Similarly, in Toronto, imported food items are transported 81 times further than the local items (Bentley & Barker [24]). If all the food remains local, 14.000 tonnes of GHG emissions can be reduced (Lam [25]).

As a result, local food systems can reduce "food miles" and eventually the CO_2 emissions derived from food transport. In the urban environment, rooftop area has provided large potentials for urban agriculture. In St. Petersburg, studies show that an average of 3kg/m^2 of vegetables are produced from rooftop gardens, while 8kg/m^2 are produced using plastic and greenhouses (Gavrilov [26]).

This research considers that the average fruit and vegetable production in BC is 15tonnes per hectare, per year (Statistics Canada [27]). Therefore, if 60% of existing flat roofed areas [4,6ha] within the selected site were greened and used for growing vegetables; 68,5 tonnes of fruit and vegetables would be produced annually. Considering the population of the selected area (8.478 people), and that fruit and vegetable consumption per capita in BC is about 287kg/year (BC Ministry of Agriculture and Lands [28]), this would mean that growing food on green roofs would provide 3% of the annual fruit and vegetable requirements of the people living in the area, and would consequently indicate a CO_2 reduction of 3% in transporting fruit and vegetables.

3.3 Capacity of vegetation to trap air pollutants

During the photosynthesis process, plants uptake CO_2 converting it into glucose by the use of light. The amount of CO_2 trapped by plants is closely related to their biomass and depends on different factors such as temperature, light, and plants' growth curves (Taiz & Zeiger [29]). However, little research has been done focused on calculating the biomass of different plant species. A few references on this topic provide some general information, such as for the Chicago urban forest, which stores 942.000 tonnes of carbon/year (McPherson, Nowak et. al. [14]). This research assumes that the capacity of plants to sequester CO_2 is the following: grassy plants would trap 4.38kg/m² per year; shrubby plants (on green roofs) would trap 8.76 kg/m²; and climber plants (on green walls) would trap 6.57 kg/m² (Schaefer [30]).

Considering these numbers and applying them to the proposed green intervention for the selected area, the research concludes that the capacity of vegetation to trap CO_2, contributes to a 2% CO_2 emissions reduction derived from energy consumed by buildings.

4 Conclusion / Discussion

This research demonstrates the potential of green surface interventions in reducing CO_2 emissions. Results demonstrate that by greening a certain area of a city, in order to achieve the requirements indicated in the Seattle Green Factor, the CO_2 emissions of the selected area would be reduced by 15% by reducing the energy demand by buildings; by 3% in avoiding the transportation of fruit and vegetables; and by 2% by sequestering CO_2 emitted by buildings.

This research acknowledges the complexity in providing these types of findings, however, since the results are based on related research, and transferred to an overall green intervention. This means that some important factors have been left out, such as local climate conditions, which results in a lack of accuracy. In order to achieve more precise data, the research suggests that it would be more accurate to analyse such research within a real building using the local climate and employing computerized test rooms. Nonetheless, this research considers that the demonstrated results thus far adequately illustrate the influence of such a green intervention in cities, in order to encourage urban decision makers to seriously consider these interventions as viable methods for reducing CO_2 emissions.

5 References

[1] United Nations, *World Urbanization Prospects. The 2007 Revision*. http://www.un.org/esa/population/publications/wup2007/2007WUP_Highlights_web.pdf. New York, 2008 [accessed 28 February 2008]

[2] The Seattle Department of Planning & Development, Green Factor, http://www.seattle.gov/dpd/Permits/GreenFactor/, Seattle, US 2007 [accessed Oct. 2007]

[3] Biotope Area Factor (BAF), http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/index_en.shtml, Berlin, Germany 1994 [accessed Oct. 2007]

[4] Greenspace Factor, http://www.map21ltd.com/scan-green/bo01.htm, Malmö, Sweden, 2001 [accessed Oct. 2007]

[5] Mason, L., "Seattle's Green Factor". Living Architecture Monitor Magazine. Green Roofs for Healthy Cities, p. 34-35.Toronto, Ontario, 2007.

[6] Navarre Government, *Ley Foral de Navarra 35/2002*, Navarre, 2002.

[7] City of Vancouver. Eco-Density initiative, http://www.vancouver-ecodensity.ca/, Vancouver, Canada, 2006 [accessed January 2008]

[8] City of Vancouver. Sustainability Indicators, Targets, Stewardship & Monitoring for South East False Creek. http://www.city.vancouver.bc.ca/ctyclerk/cclerk/20050301/ph2.htm. pp. 5, 2005 [accessed April 2007].

[9] Department for environmental food and rural affairs – UK. http://www.defra.gov.uk/, 2007 [accessed April 2007].

[10] Dimoudi, A. & Nicolopoulou, M., *Vegetation in urban environment. Microclimatic analysis and benefits*, Elsevier, Energy and Buildings volume 35, pp. 69-76, 2003.

[11] Rosenzweig, C., Solecki, W. D. & Slosberg R.B., *New York city's heat island with urban forestry, living roofs and light surfaces*, New York State Energy Research and Development Authority, NY, 2006.

[12] Honjo, T., Narita, K., et. al., *Observation of thermal effect of Shinjuku Gyoen Park*, AMS Fourth Symposium on the Urban Environment, pp. 84-85, Norfolk, VA, 2002.

[13] Reynolds, J.S., *Courtyards. Aesthetic, social and thermal delight*, John Wiley & sons Inc., NY, 2002.

[14] The city of Toronto & Ryerson University, *Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto*, http://www.toronto.ca/greenroofs/pdf/fullreport 103105.pdf, Toronto, 2005 [accessed Sept 2007].

[15] McPherson, E. G., Nowak, D. J., et. al. 1993. "*Chicago's Evolving Urban Forest: Initial report of the Chicago Urban Forest Climate Project*". North-eastern Forest Experiment Station, pp 40-41. Radnor, Pennsylvania, 1993.

[16] Laurenz, J. 2005. "*Natural Envelope: The green element as a boundary limit*". The 2005 World Sustainable Building Conference. Tokyo, 2005.

[17] Despommier, D., Vertical farm, http://www.verticalfarm.com/, NY [accessed February 2008]

[18] Sartoux, P., La Tour Vivante, http://www.ateliersoa.fr/activites/index.htm, Paris [accessed Feb 2008]

[19] Guallart, V., Sociópolis, http://www.sociopolis.net/web/sociopolis.php, Valencia, Spain [accessed Feb 2008]

[20] Pirog, R. and Benjamin,A., *"Checking the food odometer: Comparing food miles for local versus conventional produce sales to Iowa institutions"* Leopold Center for Sustainable Agriculture, Ames, Iowa, 2003. www.leopold.iastate.edu/pubs/staff/files/food_travel072103.pdf [accessed Feb 08]

[21] Xuereb, M.,*"Food Miles: Environmental Implications of Food Imports to Waterloo Region*" Region of Waterloo Public Health, Waterloo, Ontario, 2005 http://chd.region.waterloo.on.ca/web/health.nsf/4f4813c75e78d71385256e5a0057f5e1/54ED787F44ACA44C852571410056AEB0/$file/FOOD_MILES_REPORT.pdf [accessed Feb 2008]

[22] Blythman, J., *"Shopped: The shocking Power of British Supermarkets"* Harper Perennial, New York, 2005.

[23] Environment Canada,*"Factsheet 3: Canada's Greenhouse Gas Inventory 1990-2000",* http://www.ec.gc.ca/pdb/ghg/inventory_report/1990_00_factsheet/ transp_e.pdf, 2002 [accessed Feb 2008]

[24] Bentley, S. & Barker, R., *"Fighting Global Warming at the Farmer's Market:The Role of Local Food Systems In Reducing Greenhouse Gas Emissions"* A FoodShare Research in Action Report, Second Edition,Foodshare Toronto, Toronto, Ontario, 2005.

[25] Lam, S. O., *"Urban Agriculture in Kingston: Present and Future Potential for Re-Localization and Sustainability"* Queen's University, Ontario, 2007.

[26] Gavrilov, A., *"Urban agriculture in St Petersburg, Russian Federation."* Series on Urban Food Security - Case Study 1, p. 1-24. Copenhagen, World Health Organization, Regional Office for Europe, 2000. http://www.euro.who.int/document/e70095.pdf [accessed Feb 2008]

[27] Statistics Canada, "Fruit and Vegetable Production", 2008 http://www.statcan.ca/english/freepub/22-003-XIE/22-003-XIE2007002.pdf [accessed Feb 2008]

[28] BC Ministry of Agriculture, "*Food self reliance in British Columbia*" http://datafind.gov.bc.ca/query.html?qp=&style=al&qt=food+consumption+per+capita&Submit.x=0&Submit.y=0, [accessed March 2008] .

[29] Taiz L., Zeiger, E., “*Plant Physiology*“ Sinauer Associates, Inc, Sunderland, MA, 2006.

[30] Schaefer, V., Rudd, H., Vala, J., “*Urban Biodiversity*“. Captus Press, Ontario, 2004.