Measure: Mandatory Use of Green Concrete (G1)

Westmoreland Associates has determined that implementing this measure would result in emission reductions that are outside the boundary of the City's GHG Inventory. However, implementation would result in regional emissions and pollution reductions and, therefore, is worth considering.

Mandate use of "green" concrete, defined as 20% fly ash and 10% recycled aggregate, in all new commercial construction.

COT ARRA RFP Summary:

Emission reduction potential:	17,473 tCO2e over 10-years (outside of COT boundary)
Percentage of goal (2012):	NA
Percentage of goal (2020):	NA
Total annual average implementation costs:	Cost savings of $1/short-ton resulting in approximately $92K of savings
Entity that bears the costs of implementation:	Developer
Savings per tCO_2e:	$53 / tCO_2e
Net annual savings:	Cost savings of $1/short-ton
Entity that realizes the financial return:	Developer
Equitability (progressive/regressive, income/revenue neutral, etc):	Neutral
Potential unintended consequences:	Perverse incentive to increase production of fly ash, although this threat is minimal

Background information:

Concrete is a matrix of cement, course and fine aggregates, water, and air.[1] Cement production is the third largest emitter of CO_2 in the US behind fossil fuels and iron/steel production.[2] Emissions from the manufacturing of cement are "*emitted from the calcination process of limestone, from combustion of fuels in the kiln, as well as from power generation*".[3] Total emissions are nearly split 50/50 between processing and energy use. Moreover, GHG emissions also exist from the production and use of aggregate in concrete production.

Many options exist for regulating authorities to reduce emissions from concrete production. Among these options, some easily obtainable reductions can be realized from using an increased percentage of fly ash, a byproduct of coal combustion, and recycled aggregate. In many cases, these changes lead to a net cost reduction.[4]

According to Denver's Climate Action Plan (2007), "*a 20 percent mix with concrete, the use of fly ash (a by-product from coal-fired power plants) will save up to 25 percent of the carbon emissions associated with concrete, while making a highly durable, less expensive, and eco-efficient product*." Further emission reductions, on the order of 0.01 tCO_2e per short ton of concrete produced, can be realized by using recycled aggregate.[5] These measures, especially when combined, can help the City of Tucson (COT) reduce regional emissions at a net savings to the development projects.

Business as Usual:

Under a business-as-usual scenario, new commercial construction will continue to use concrete mix designs that don't utilize fly ash percentages that are deemed structurally acceptable in Denver, while accounting for project specific load designs.[6]

Description of Measure and Implementation Scenario:

This analysis assumes the COT legislates mandatory minimum use of 20% fly ash and 10% recycled aggregate in all commercial concrete design mixes. This quantification uses an annual consumption of cement totaling 8,400 metric tons for the COT concrete consumption.[7] Current mix designs call for under 3% fly ash and 0% recycled aggregate.[8] Mixes of these percentages are considered the "baseline" from which potential reductions will be quantified. Assuming that concrete is 10% cement by weight, 8,400 metric tons of cement would mean annual commercial short ton consumption of concrete in the COT would be 92,594.

Has the Measure been implemented elsewhere and with what results?:

Denver has mandated the use of "green concrete". According to their Climate Action Plan the policy covers "*concrete used in public and private projects: roads, shopping malls, homes, etc.*" Resulting emission reductions from this policy are yet to be published as the mandate is in its infancy, however Denver anticipates approximately 100,000 tCO_2e per year reduction at an immediate cost savings of $1/ton of concrete.

Energy/Emission analysis:

Description	***Input***	***Notes***
Emissions per short ton of concrete produced (w/ no fly ash)	0.111	tCO_2e/short-ton; See below for calculations
Baseline fly ash percentage	3%	
Baseline recycled aggregate percentage	0%	
Emission reduction percentage via using 20% fly ash vs. 0%	11.2%	Derived from Flower and Sanjayan[9]; See below for calculations
Emission reduction percentage via using 100% recycled aggregate (additional to fly ash)	9%	Derived from EPA modeling[10]
Projected emission reductions above baseline scenarios via using 20% fly ash and 10% recycled aggregate	17.2%	Calculated from above numbers
Projected short tons of annual commercial concrete consumption in COT	92,594	
Total potential annual emission reductions	1,747	tCO_2e per year

Contribution analysis:		
COT 1990 Citywide GHG emissions (baseline):[11]	5,461,020	tCO_2e
MCPA 7% reduction target for COT:	5,078,749	
2012 BAU GHG emissions projection:	7,000,000	

2020 BAU GHG emissions projection:	7,343,141	
GHG emissions reduction to meet 7% goal (2012):	1,921,251	
GHG emissions reduction to meet 7% goal (2020):	2,264,392	
Mandatory use of green concrete in commercial construction		
Contribution of G1 Green Concrete (over 10-yrs):	17,473	tCO_2e
% Contribution of G1 Green Concrete (over 10-yrs):	NA	

Economic analysis:

The Denver Climate Action Plan calls for, approximately, a savings of $1 per short ton of concrete for use of these measures. Cost savings are estimated to be $1/(0.111 * 17.2%) (derived from above). This equals a ***savings of $53/tCO₂e*** with an overall annual savings of approximately $92,000.

Co-benefits:

Diversion of waste from landfills is the most noticeable attribute of both fly ash and recycled aggregate. Also, given the structural properties of fly ash, its use in concrete mixtures makes the product easier to work with.[12]

Equitability:

Neutral.

Potential unintended consequences:

A possible negative unintended consequence of mandating the use of any specific material is that the resulting demand may drive up the costs. Per Denver's CAP: "*Using fly ash to substitute for a portion of cement in concrete is currently economically beneficial, as fly ash typically costs less or the same as cement. Future supplies and costs of fly ash are likely to change as more cities institute fly ash concrete policies, with the potential to drive up demand*." Also, the toxicity levels of fly ash, and the products that contain it, are currently of serious concern.[13] Lastly, it is argued that aiming to increase the use of coal combustion waste products creates a perverse incentive to continue the use of coal.[14]

Calculations:

Calculation of emissions per short ton of concrete produced (based on Flower and Sanjayan[9]):

- (0.29 tCO_2e/m^3) x (2371 kg of concrete / m^3)$^{-1}$ (Note 15) x (907.2 kg / short ton)

Derivation of 11.2% reduction from 20% fly ash (assumes linear interpolation of Flower and Sanjayan[9]):

- (25% fly ash /14% reduction (AVG)) = (20% fly ash / ***X*** %); where ***X*** = 11.2%

General Note: All references retrieved October through December of 2010 unless otherwise noted.

Endnotes:

[1] http://www.epa.gov/osw/conserve/tools/cpg/pdf/rtc/app-a.pdf
[2] http://www.epa.gov/climatechange/emissions/co2_human.html
[3] Worrell, E., L. Price, N. Martin, C. Hendriks, and L.O. Meida, (2001). Carbon Dioxide Emissions from the Global Cement Industry. Annual Review of Energy and the Environment 26: 303-329.
[4] http://www.toolbase.org/Construction-Methods/Concrete-Construction/concrete-aggregate-substitutes#benefits
[5] http://epa.gov/climatechange/wycd/waste/downloads/concrete-chapter10-28-10.pdf
[6] Denver Climate Action Plan available at: http://www.greenprintdenver.org/docs/DenverClimateActionPlan.pdf
[7] This analysis assumes that annual commercial cement consumption over the coming decade is equal to 30% of the 2006 consumption, which can be found at: http://www.cement.org/.
[8] Per email communication with Greg Martin, Project Manager for general contractor The Weitz Company (TWC). TWC self-performs concrete work and has working knowledge of current mix designs.
[9] Flower DJM, Sanjayan JG (2007): Green House Gas Emissions due to Concrete Manufacture. Int J LCA 12 (5) 282–288
[10] http://epa.gov/climatechange/wycd/waste/downloads/concrete-chapter10-28-10.pdf
[11] PAG Regional Greenhouse Gas Inventory- 2010
[12] http://www.flyash.com/flyashenvironment.asp
[13] http://www.psr.org/resources/coal-ash-the-toxic-threat-to-our-health-and-environment.html
[14]http://www.peer.org/docs/epa/8_2_10_PEER_comments_GHG_procurement.pdf
[15] http://www.simetric.co.uk/si_materials.htm