GREEN UP! DC CALCULATIONS

The following document describes the calculations used by the various stormwater, energy and conservation calculators. The energy and conservation calculators use formulas developed by federal agencies such as the US Department of Energy and available to the public on their web sites. The Stormwater calculators are based on formulas developed by the Center for Watershed Protection.

STORMWATER CALCULATIONS

The following outlines the data needs, calculations, and issues for the storm water runoff component of Green Up! DC. The proposed method is taken largely from the recently developed Rainfall Runoff Method, developed by the Center for Watershed Protection and the Chesapeake Stormwater Network for the VA DCR (2008). The method is largely evolved from the EPA Simple Method (Schueler, 1987).

Data Inputs

Data Needs for Stormwater Runoff Calculation, without BMPs (runoff reduction projects)

The following constants are needed, and should probably be provided in a look up table:

AR = Annual Rainfall (inches)	43
Rd = Target Rainfall Event (inches)	1.00
Pj (fraction of storms that produce runoff)	0.90

The main input will be the breakdown of land cover into 3 types (impervious, forest, and turf/disturbed soil), all of which are listed in the RFP. But the RRM goes a step further in breaking into 4 hydrologic soil groups (A, B, C, D), as follows:

Land Cover (acres)

	A soils	B Soils	C Soils	D Soils
Forest/Open Space (acres) -- undisturbed, protected forest/open space or reforested land	0.00	0.00	0.00	0.00
Managed Turf (acres) -- disturbed, graded for yards or other turf to be mowed/managed	0.00	0.00	0.00	0.00
Impervious Cover (acres)	0.00	0.00	0.00	0.00

The percent forest cover is added to the editable fields in the property characteristics. Soils data are available for DC from the NRCS' STATSGO data set: http://soils.usda.gov/survey/geography/statsgo/

It is assumed that all parcels smaller than a certain size ($1/8^{th}$ acre was suggested) have highly compacted soils, i.e. Type D, for the purposes of the runoff calculations.

Stormwater Runoff Calculation, without BMPs

The first step is to compute the runoff coefficients for Forest, Turf and Imperviousness portions of the property. The constants in the formula are the runoff coefficients for each land cover/soil type combination, e.g. 0.02 is the Rv for Forest in A soils. These values should probably be in an editable Look-Up Table (LUT), as they are subject to change.

Rv(F) = [(A(fA) x 0.02) + (A(fB) x 0.03) + (A(fC) x 0.04) + (A(fD) x 0.05)]/SA

Rv(T) = [(A(tA) x 0.15) + (A(tB) x 0.20) + (A(tC) x 0.22) + (A(tD) x 0.25)]/SA

Rv(I) = 0.95

%Forest = (A(fA) + A(fB) + A(fC) + A(fD))/SA x 100

%Turf = (A(tA) + A(tB) + A(tC) + A(tD))/SA x 100

%Impervious = (A(iA) + A(iB) + A(iC) + A(iD))/SA x 100

Where:

Rv(F) = weighted forest runoff coefficient

A(fA) = area of post-development forest and open space in A soils (acres)

A(fB) = area of post-development forest and open space in B soils (acres)

A(fC) = area of post-development forest and open space in C soils (acres)

A(fD) = area of post-development forest and open space in D soils (acres)

Rv(T) = weighted turf runoff coefficient

A(tA) = area of post-development managed turf in A soils (acres)

A(tB) = area of post-development managed turf in B soils (acres)

A(tC) = area of post-development managed turf in C soils (acres)

A(tD) = area of post-development managed turf in D soils (acres)

Rv(I) = weighted impervious cover runoff coefficient

A(iA) = area of post-development impervious cover in A soils (acres)

Site Rv:

Rv(S) = Rv(F) x %Forest + Rv(T) x %Turf +Rv(I) x %Impervious

There are three possible volume calculations:

1. The "Treatment Volume" which is the unit of measure used primarily by the RRM (see attached TM for background explanation). This amounts to the rainfall runoff from 1" of rain from the impervious surface and the managed turf.

Post Development Treatment Volume:

Tv(S) = Rd x Rv(S) x SA/12 – Rd x Rv(F) x A(f)/12

Where:

Tv(S) = post-development treatment volume for site (acre-ft)

Rd = rainfall depth for target event (1" for water quality storm)

Rv(S) = runoff coefficient for the site

SA = total site area (acres)

Rv(F) = weighted forest runoff coefficient

A(f) = total area of forest and open space

2. The total volume from the water quality storm

TRv(S) = Rd x Rv(S) x SA/12

3. The total annual volume

TARv(S) = AR x Pj x Rv(S) x SA/12

Stormwater Runoff Calculation with BMPs

The RRM has credits or runoff adjustments for the runoff reduction practices shown in Table 1. The Table lists the practices and also identifies possible additional practices applicable for non-residential property types (commercial, institutional, and multi-family residential). The additional practices are available for non-residential property types only.

TABLE 1
Stormwater Runoff Practices in Rainfall Reduction Method, Requested in DDOE RFP, and Property Type Applicability

Runoff Reduction Practices in CWP's Runoff Reduction Method	**Corresponding Runoff Reduction Practices in DDOE's Requirements**	**Property Type Practice Applicable to**	
		Residential	**Non-Residential**
Impervious surface disconnection	Downspout Disconnection (roof area)	Yes	Yes
Rain barrels and cisterns	Downspout Disconnection (roof area), with storage	Yes	Yes
Infiltration	Drywell (roof and paved area)	Yes	Yes
Green roof	Green roof (roof area)	Yes	Yes
Bioretention (this is actually more than a rain garden)	Rain Garden (roof and paved area)	Yes	Yes

TABLE 1
Stormwater Runoff Practices in Rainfall Reduction Method, Requested in DDOE RFP, and Property Type Applicability

Runoff Reduction Practices in CWP's Runoff Reduction Method	Corresponding Runoff Reduction Practices in DDOE's Requirements	Property Type Practice Applicable to	
		Residential	Non-Residential
Impervious surface disconnection	Downspout Disconnection (roof area)	Yes	Yes
Rain barrels and cisterns	Downspout Disconnection (roof area), with storage	Yes	Yes
Infiltration	Drywell (roof and paved area)	Yes	Yes
Tree canopy is not explicitly in the RRM, but can be if a percent reduction can be assigned based on literature review. The RRM does implicitly address forest cover.	Trees (yard area)	Yes	Yes
Native Landscaping is not explicitly in the RRM, but can be if a percent reduction can be assigned based on literature review.	Native landscaping (yard area)	Yes	Yes
Permeable pavement	Porous Pavement (paved area)	Yes	Yes
Sheetflow to conservation area or filter strip		No	Yes, but not in RFP
Grass channel		No	Yes, but not in RFP
Dry swale		No	Yes, but not in RFP
Wet swale		No	Yes, but not in RFP
Extended detention pond		No	Yes, but not in RFP

These methods can be put in series, i.e., a green roof can be routed to permeable pavement, and that to a dry swale. Up to 3 practices are allowed in series.

The reduction to treatment volume is done separately for up to 5 different areas on the property.

The reduction to the treatment volume is calculated as follows (similar equation if the total volume or total annual volume are calculated):

Adjustment to Treatment Volume

Cv(x) = (Rd x Rv(land cover) x CA x 3630 + Vupstream) x CR

Where:

Cv(x) = Adjustment to treatment volume based on application of credit X (cubic feet)

Rd = rainfall depth for target event (1” for water quality storm)

Rv(land cover) = weighted runoff coefficient for land cover being treated by credit practice

(impervious or managed turf)

CA = area credit applied to (acres)

3630 = unit adjustment factor, converting acre-inches to cubic feet

Vupstream = Upstream runoff volume directed to credit practice

CR = credit (fraction of runoff eliminated by the credit practice)

The credits are determined by the values in Table 2.

TABLE 2

PERCENT RUNOFF REDUCTION BY PRACTICE IN CWP'S RUNOFF REDUCTION METHOD

Runoff Reduction Practices in CWP's Runoff Reduction Method	Corresponding Runoff Reduction Practices in DDOE's Requirements	Percent Reduction
Impervious surface disconnection	Downspout Disconnection (roof area)	25 to 50
Rain barrels and cisterns	Downspout Disconnection (roof area), with storage	40
Infiltration	Drywell (roof and paved area)	50 to 90
Green roof	Green roof (roof area)	45 to 60
Bioretention (this is actually more than a rain garden)	Rain Garden (roof and paved area)	40 to 80
Tree canopy is not explicitly in the RRM, but can be if a percent reduction can be assigned based on literature review. The RRM does implicitly address forest cover.	Trees (yard area)	TBD – forest cover is actually this addressed by changing mix of land types
Native Landscaping is not explicitly in the RRM, but can be if a percent reduction can be assigned based on literature review.	Native landscaping (yard area)	TBD
Permeable pavement	Porous Pavement (paved area)	45 to 75
Sheetflow to conservation area or filter strip		50 to 75
Grass channel		10 to 20
Dry swale		40 to 60
Wet swale		0
Extended detention pond		0 to 15

ENERGY CALCULATIONS

Energy efficiency calculations are generally based on an estimated average reduction in consumption for each project type. Typically one or more property or building-specific factors are used to customize the estimated reduction.

Energy Production Calculations

Energy Source calculations are based on the best data (e.g., US Department of Energy) we can obtain for the production and cost of the system. As a rule, costs are calculated as a cost/unit (unit=kW, gallons, etc).

- **Solar Electric (Photovoltaic)**

  The user draw a shape on their roof. The area in square feet (*A*) of that shape will be used to estimate a PV panel capacity in kW at 18% efficiency. Using Standard Test Conditions STC, the output is 16.7 W/ft^2. The following assumptions will be used:

  - Panels are oriented due South
  - Panel tilt angle is 38.773° (equivalent to latitude)
  - The system has a derate factor of 0.77.

  Under these assumptions, PVWatts estimates annual production (*ap*) of 1,206 kWh/kW based on a representative location within the district. The District will provide an average cost of electricity (*e*) in $/kWh, resulting in the following equation to derive the value, in dollars, of the energy produced.

  $$\text{Value} = A * 16.7\ W/ft^2 * 1.206\ kWh/W * e$$

  $$\text{Installed Cost} = A * 16.7\ W/ft^2 * (\$/W) - (\text{incentive amount})$$

  $$\text{Greenhouse gas emissions} = A * 16.7\ W/ft^2 * 1.206\ kWh/W * 6.8956 \times 10\text{-}4 \text{ metric tons } CO_2 / kWh$$[1]

  Photovoltaic incentives are based on the combined system rating in kilowatts of Direct-Current (DC) rated output.
  $1.50 for each of the first 3,000 installed watts of capacity
  $1.00 for each of the next 7,000 installed watts of capacity
  $0.50 for each of the next 10,000 installed watts of capacity "
  A value of $5.50 is used for the installation cost per watt ($/W) based on information provided by the DDOE.

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[1] http://www.epa.gov/greenpower/pubs/calcmeth.htm

- **Solar Hot Water (Domestic)**

  Due to the variability of solar hot water applications, a number of assumptions must be made in calculating both the cost of a solar hot water system and the energy produced. For this calculator we assumed that the system would be for a household potable hot water system with an auxiliary backup tank. This calculator relies on formulas provided by the DDOE and other organizations. With this calculator the installation cost of the system is determined by the number of users and the efficiency is determined by the Energy Factor of the Solar System versus a conventional hot water heater.

  The surface area of the collector (A) is based on the number of people in the home, where n_1 is the first two people in the home and n_2 is the number of people in the home greater than 2.

  $$A = (n_1 * 20) + (n_2 * 8)$$

  The cost of the unit (C), including auxiliary tank is based on the collector area and a national average installation cost of $190 per square feet:

  $$C = A * \$190/ft^2$$

  The cost savings for a solar hot water system is based on the difference in annual operating costs between the solar collector's auxiliary tank and the home's existing hot water heater.

  The annual operating cost of the solar hot water system (C_s) with an auxiliary tank is calculated as follows:

  $$C_s = 365 * 0.4105/SEF * \text{fuel cost per therm for gas or oil}$$

  $$C_s = 365 * 12.03/SEF * \text{fuel cost per kilowatt for electricity}$$

  where SEF is the system's Solar Energy Factor. According to the Department of Energy, SEFs range from 1.0 to 11 with solar energy factors of 2 or 3 being the most common.

  For our calculations we are using the average value of 2.5 for the SEF:

  $$C_s = 365 * 0.4105/2.5 * \text{fuel cost per therm for gas or oil}$$

  $$C_s = 365 * 12.03/2.5 * \text{fuel cost per kilowatt for electricity}$$

  The annual operating cost of the existing conventional hot water heater (C_c) is calculated using the same formula, but using an energy factor (EF) instead of the SEF as follows:

  $$C_c = 365 * 0.4105/EF * \text{fuel cost per therm for gas or oil}$$

  $$C_c = 365 * 12.03/EF * \text{fuel cost per kilowatt for electricity}$$

where EF is the system's Energy Factor. According to the California Department of Energy's Consumer Energy Center, EFs range from 0.5 to 0.7 for gas water heaters, and 0.75 to 0.95 for electric water heaters. Average EFs for oil water heaters could not be obtained.

For our calculations we use an average value of 0.7 for the EF:

$$C_c = 365 * 0.4105/0.7 * \text{fuel cost per therm for gas or oil}$$

$$C_c = 365 * 12.03/0.7 * \text{fuel cost per kilowatt for electricity}$$

Using these costs the difference in cost (cost savings) and efficiency (energy savings) can be determined:

$$\text{Cost Savings} = C_c - C_s$$

$$\text{Energy Savings} = C_c\ /\text{fuel cost} - C_s\ /\text{fuel cost}$$

The CO_2 generated for **solar hot water** is based on the CO_2 generated for electricity usage for an electric hot water heater or an average CO_2 generated for gas and oil usage:

0.005304 Metric Tons CO_2/Dollar (electric)
0.003744 Metric Tons CO_2/Dollar (gas/oil)

Energy Conservation Calculations

To obtain baseline estimates of energy consumption attributable to various uses, basic information is obtained from the user and combined with information obtained from local jurisdiction data.

- Gas bill
  - Representative summer bill amount
  - Representative winter bill amount
- Electric bill
  - Representative summer bill amount
  - Representative winter bill amount
- Heating source (i.e., gas or electric) and installation year
- Space cooling system (i.e., heat pump, central electric or window electric) and installation year
- Water heating source (i.e., gas or electric) and installation year

Based on the above, we estimate the average annual dollars spent on:

- space heating (*SHD*),
- space cooling (*SCD*),

- water heating (*WHD*), and
- ‘general use’ (*GUD*).

These estimates account for the expected efficiency of each system based on their installation year to assign and efficiency % or SEER to the system.

The following sections describe the specific methods used to calculate energy savings for each project type. Cost of each system will be calculated either as a flat cost or as a multiple of the square footage of the building.

- **Air sealing & Insulation**

  Dollars saved = (SHD + SCD) * (.20)

  A 20% typical reduction is conservatively estimated by the U.S. EPA for quality home air sealing and insulation projects. (see http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_methodology)

- **Hot Water Conservation**

  Dollars saved = *WHD* * (.05)

  Energy Star program indicates that typical water conservation measures reduce home water heating demand by 5% on average.

- **Duct Sealing & Repair**

  Dollars saved = (*SCD* + *SHD*) * (.15)

  Energy Star program indicates that typical water conservation measures reduce home water heating demand by 5% on average.

- **Carbon Calculations for Air Sealing and Insulation, Duct Sealing and Repair, and Hot Water Conservation**

  The calculations for these three energy conservation measures use an input of dollars spent on heating or cooling. Dollars are converted to tons of CO_2 using formulas for the amount of CO_2 generated per energy unit, and average energy price per unit of energy.

  Natural gas:

  0.005 metric tons CO_2/therm[2]

  2011 Average natural gas price: $1.135/therm[3]

[2] US Environmental Protection Agency (http://www.epa.gov/greenpower/pubs/calcmeth.htm)

[3] US Department of Labor Bureau of Labor Statistics (http://www.bls.gov/ro3/apwb.htm)

Metric Tons CO_2/ Dollar: 0.004405

Electricity:

0.00068956 metric tons CO_2 / kWh[4]
2011 Average electricity price: $0.130/ kWh[5]
Metric Tons CO_2/Dollar 0.005304

Propane:

5.74 kg CO_2 / gallon[6] = 0.00574 metric tons CO_2 / gallon
Average propane price: $3.23/gallon[7]
Metric Tons CO_2 / Dollar: 0.00178

Heating Oil:

0.43 metric tons CO_2/barrel [8]
2011 Average heating oil price: $3.321/gallon[9] x 42 gallons/barrel = $139.482/barrel
Metric Tons CO_2/Dollar: 0.003083

Percentage of homes using each of the following home heating sources:[10]

Residents using natural gas: 54%
Residents using electricity: 36%
Residents using propane: 2%
Residents using heating oil: 6%

The CO_2 generated for **cooling** is based on the CO_2 generated for electricity usage:

0.005304 Metric Tons CO_2/Dollar

The CO_2 generated for **heating** is based on the weighted average CO_2 generated the four primary heating energy types (Natural Gas, Electricity, Propane and Heating Oil):

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[4] US Environmental Protection Agency (http://www.epa.gov/greenpower/pubs/calcmeth.htm)
[5] US Department of Labor Bureau of Labor Statistics (http://www.bls.gov/ro3/apwb.htm)
[6] US Energy Information Administration (http://www.eia.gov/oiaf/1605/coefficients.html)
[7] US Energy Information Administration (http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=W_EPLLPA_PRS_SMD_DPG&f=W)
[8] US Environmental Protection Agency (http://www.epa.gov/greenpower/pubs/calcmeth.htm)
[9] US Energy Information Administration (http://www.eia.gov/oog/info/hopu/hopu.asp)
[10] Forbes (http://www.forbes.com/2008/10/03/home-heating-expensive-forbeslife-cx_mw_1003realestate.html)

$$(0.004405)(0.54)+(0.005304)(0.36)+(0.00178)(0.02)+(0.003083)(0.06) = 0.00451 \text{ Metric Tons } CO_2\text{/Dollar}$$