Chicago Museum of Science and Industry Smart Home – Chicago, IL
Methodology for Landscape Performance Benefits
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Environmental

Eliminates potable water usage for the production garden by using captured rainwater from rooftops and adjacent museum walkway canopies. If the Smart Home in use as an actual home, it could make use of all of the harvested rainwater, saving 68,000 gallons of potable water and an estimated $2,250 in water and sewer costs over the next 5 years.

The garden is designed to be fully integrated with the Smart Home and to maximize the capture and re-use of rainwater from horizontal roof surfaces and canopies through rainbarrels and a cistern. Because it is a display home and garden, and doesn't reflect how that captured water might be used internal to the home, we can predict the potential to fully irrigate the gardens by diverting total stormwater capture alone to this use. Because prairie and savannah gardens are designed to be drought-tolerant, they require no irrigation once established and do not get counted in the total water demand. Therefore, the methodology assumes that vegetable and herb gardens would utilize the collected rainwater, and serve as the basis for our estimation of intended use of collected rainwater.

Note: The initially the limitation of this methodology was the timing of rain events and capture from the existing system, timed against the watering schedule of the gardens. Because watering tends to be regular, and rain events are not regular, we attempted to give a range for the estimate of water usage met by rainwater collection. Ideally the rainbarrel catchment system is oversized against demand/use to both capture plenty of water for use but to also provide adequate storage to bridge dry periods or droughts thereby negating reliance on supplemental potable water use. It turned out that irrigation water demand was fairly low compared to overall capture of rainwater. However, we did find that the rain barrels because of their smaller size fill, overflow, and empty more regularly, making them less reliable as an irrigation source. The cistern served to meet this demand because of its larger size and ability to hold water longer to accommodate variations in rainfall.

Note #2: The economic value estimated assumes use of all captured water to meet demand across the home site, not just for irrigation. We wanted to provide a measure of the value of rain capture infrastructure. In Chicago, demonstrating the savings of implementing these systems seems particularly prescient, where increases in water and sewer rates are occurring rapidly.

Table 1 Runoff for 05/01/2010-10/31/2010 from the Smart Home non-green roof and the pedestrian Link roof of the Museum of Science and Industry. (See also: MSI Smart Home_2010 Rain and Green Roof Data.xlsx)

	Area (SF)	2010 Growing Season Rain (FT)*,**	Retention Rate	2010 Growing Season Runoff (FT^3)	2010 Growing Season MSI and Smart Home Runoff (Gal)

Smart Home Roof	1287	2.93	0	3773.06	28224.41
Pedestrian Link Roof	1506		0	4415.09	33027.17

Table 2 GreenGrid™ Retention Rates and Rain Event Frequency. (See also: MSI Smart Home_2010 Rain and Green Roof Data.xlsx)

From B-D066-GreenGrid.pdf				
2 hr rain event simulated over 15 minutes, where 1 in = 5 gallons	Inches	% Retention	Chicago Frequency	Occurrences in 2010
	≤1	0.722		98
	≤ 2	0.573	1-2 yr storms	9
	≤ 3	0.432	5-25 yr storms	1
	≤ 4	0.337	50-100 yr storms	0

Table 2 Runoff for 05/01/2010-10/31/2010 for the GreenGrid™ green roof at the Smart Home. (See also: MSI Smart Home_2010 Rain and Green Roof Data.xlsx)

Smart Home Green Roof Modules (861 SF GR/3 SF per module)	2010 Growing Season Runoff from 1 GreenGrid Module (FT)*	2010 Growing Season Green Roof Runoff (FT^3)	2010 Growing Season Green Roof Runoff (Gallons)
287	0.88	253.68	1897.68

Table 4 & 5 Irrigation for vegetable/herb gardens required in the Smart Home growing season. (Based on 2010 rainfall and the capacity of the 4 sixty gallon rain barrels, the rain barrels would have likely exceed capacity 36 times, and would have likely dried out 11 times (and then irrigation would have been sourced from the runoff from the Link roof, in the 2500 gal cistern). See: MSI Smart Home_2010 Rain and Green Roof Data.xlsx)

Total Plants, per 'MSI Smart Home Vegetable Garden Plan' by Jacobs/Ryan Associates	Total Area (SF)	Plants per 1 SF of Smart Home garden	Average Irrigation for 1 plant per week (FT)	Average Irrigation Needed for SF per week (FT)
437.00	176.00	2.48	0.13	0.31

Average Irrigation Needed Per Week (FT^3)	Average Irrigation Needed Per Week, for entire garden (Gal)	Average Irrigation Needed Per Day, for entire garden (Gal)	Weeks in Growing Season	Irrigation Required Per Growing Season (Gal)
54.63	408.62	58.37	24.00	9806.96

*On 20100724 rain exceeded 4", and data for Green Grid retention only exists up to 4" of rain, so 20100724 data was removed from this study.
**The growing season for the Smart Home is assumed from 05/01/2010-10/31/2010.
***Based on the crop types and average weekly irrigation from The Farmer's Almanac.

Square footages were derived from AutoCAD take offs by Lauren Polhamus (Jacobs/Ryan Associates) 07/2013.

See also Figures 2-6, excerpts from excel sheet, analyzing 2010 rainfall data and green roof/rain barrel retention.

WATER and SEWER $ SAVINGS CALCULATIONS, Today and projected
Total water and sewer costs are calculated based on the potential to use rainwater not just for the production gardens but for other uses internal and external to the Home. The City of Chicago water rates are increasing 15% annually and sewer rates are increasing 92% in 2013, 96% in 2014, and thereafter at 100%. Sewer charges are calculated as a % of the user's water rates.

Chicago water rates,
In 2012, $2.51/1,000 Gallons; sewer rates are 89%
In 2013, $2.89/1,000 Gallons; sewer rates are 92%
In 2014, $3.32/1,000 Gallons; sewer rates are 96%
In 2015, $3.82/1,000 Gallons; sewer rates are 100%
Water rates are not published for 2016; however assuming that they will maintain the 15% increase, the cost would be $4.39/1,000 Gallons; sewer rates will be 100%

Water capture
1,287SF rooftop x 36" seasonal rainfall = 3,861ft³ = 28,880 US gallons collected
(assumes 100% capture of average seasonal rainfall for Chicago, IL)
+
861SF Green-grid™ x 36" seasonal rainfall x 27.8% = 718.07³ =5,371 US gallons collected
(assumes 72.2% retention, 27.8% run-off for a 1" storm, majority of annual rain events)
+
1506SF pedestrian link x 36" seasonal rainfall = 4,518ft³ = 33,794 US gallons collected
= 68,045 US gallons collected annually

In 2012, water savings = $170.81 (68.05 thousand gallons x $2.51) + $152.02 (.89 x $170.81) = $322.83
In 2013, water savings = $196.66 (68.05 thousand gallons x $2.89) + $180.93 (.92 x $196.66) = $377.59
In 2014, water savings = $225.93 (68.05 thousand gallons x $3.32) + $216.89 (.96 x $227.33) = $442.82
In 2015, water savings =$259.95 (68.05 thousand gallons x $3.82) + $259.95 (1 x $259.95) = $519.90
In 2015, water savings =$298.74 (68.05 thousand gallons x $4.39) + $298.74 (1 x $298.74) = $597.48
TOTAL water and sewer savings = $2,260.62 (rounding this figure down to $2,250, listed above)

TOTAL WATER SAVINGS FOR IRRIGATION USE ALONE – not reported in figure above, since it is only a percentage of overall projected savings
Total water usage (from above) = 9806.96 Gallons
= $24.62-37.46 estimated water cost savings from use of collected rainwater for irrigation

Sources:
"B-D066-GreenGrid.pdf." GreenGrid - Truly Modular Pre-Vegetated Green Roof System. N.p., n.d. Web. <http://www.greengridroofs.com/>.

"Know My Water & Sewer Rates." City of Chicago. 12 July 2013. http://www.cityofchicago.org/city/en/depts/water/provdrs/cust_serv/svcs/know_my_water_sewerrates.html.

"Methodology_Chicago.pdf." Green Values : Natural Resources : Center for Neighborhood Technology. <http://greenvalues.cnt.org/>.

"MSI Smart Home_2010 Rain and Green Roof Data.xslx." National Climatic Data Center. <http://ncdc.noaa.gov/>. With annotations by Rachel Guinn 07/2013.

"Precipitation Frequency Data Server.pdf." Hydrometeorological Design Studies Center.

"RG_CST-2058_GreenGrid_Brochure_3-10-11.pdf." GreenGrid - Truly Modular Pre-Vegetated Green Roof System. <http://www.greengridroofs.com/>.

Captures and infiltrates or reuses over 208,000 gallons of stormwater on-site through a permeable pavement system, bioswale and raingarden, preventing this volume from entering the municipal combined-sewer system.

Within the City of Chicago, green infrastructure for stormwater is among the City's most urgent stormwater design issues due to the high incidence of combined-sewer over flows in the Chicago River. Local Metropolitan Water Reclamation District of Greater Chicago, along with outreach and education organizations such as the Center for Neighborhood Technology in Chicago, encourage residential-scaled features that capture, re-use, infiltrate and or evapo-transpire rainwater. Although infiltration rates can vary across the city, the Smart Home and Garden project site is located in an area where subsurface soils are largely composed of sandy soil, thus infiltration rates are high and support and contribute to a landscape design that requires no underdrainage.

Although infiltration at the Smart Home and Garden is anticipated to take place across most of the site, two measureable features contribute to direct infiltration strategies and groundwater recharge: the permeable pavement system and the bioswale-raingarden that capture an additional lawn and garden area adjacent to the Bur Oaks. Note: calculations for each of these surface drainage areas are multiplied by average annual rainfall of 36".

4,800 SF of permeable pavement x 36" average rainfall annually = 14,400ft³ total rainfall
+
4,480 SF drainage area x 36" average rainfall annually = 13,440ft³ total rainfall
= 27,840ft³ total rainfall infiltration
(1ft³ = 7.48052 US gal lqd)
= 208,257 US gal lqd, total estimated infiltration combined across permeable pavement and bio-infiltration area

Note: This figure does not account for additional run-off from adjacent landscape areas to pavement, which could lead to a higher estimation. Any additional planters temporarily or seasonably placed on top of the pavement areas, not documented in design documents, are not subtracted in the above calculation.

Sources:
"Methodology_Chicago.pdf." Green Values : Natural Resources : Center for Neighborhood Technology. <http://greenvalues.cnt.org/>.

"Precipitation Frequency Data Server.pdf." *Hydrometeorological Design Studies Center*. NOAA, n.d. Web. <http://dipper.nws.noaa.gov/hdsc/pfds/>.

Eliminates the need for soil amendments for the native and vegetable gardens by composting waste from the gardens and yard on site.

In an interview with Madiem Kawa, Master Gardener at the Smart Home on May 23, 2013, Madiem explained that part of the education taking place within the gardens was to teach students how to compost, developing an understanding that nothing is waste, but rather is food for new soil. All students and volunteers in the gardens contributed to the regular composting process, creating enough compost to use throughout the Smart Home Garden. Madiem Kawa reported that "By 2009-2010, we produced enough compost to give away."

Figure 1. Calculation of vegetable production and value, based on www.plangarden.com

Vegetable or Herb	Space Used ft^2	Veg lb/ft^2	Vegetable Price/lb	Veg Grown lb	Total
Lettuce	2	0.9	4	1.80	7.20
Cabbage	18	0.5	0.4	9.00	3.60
Greens, Mustard	10	0.5	2.46	5.00	12.30
Kohlrabi	10	0.5	1.5	5.00	7.50
Choi, Pac/Bok	6	1.5	1.5	9.00	13.50
Kale	12	1.4	4	16.80	67.20
Radish, Red	3.25	6.2	1	20.15	20.15
Onion, Bulb	10	2.3	2.55	23.00	58.65
Potato	5	0.9	5	4.50	22.50
Chard, Swiss	16	2.2	1.49	35.20	52.45
Peas, English	3	0.5	3	1.50	4.50
Peas, Snow	2	0.6	3	1.20	3.60
Parsnips	1	4.1	5.12	4.10	20.99
Pepper, Bell	8	0.9	5	7.20	36.00
Cucumber	2	3.2	1.49	6.40	9.54
Parsley	5	1.4	2.88	7.00	20.16
Tomato, Large	8	2.6	2.67	20.80	55.54
Tomatillo	1	0.6	2	0.60	1.20
Squash, Summer, Zucchini	2	0.9	2	1.80	3.60
Okra	4	6.2	1	24.80	24.80
Eggplant	6	0.9	2.5	5.40	13.50
Cilantro	1.5	1.325	7.8	1.99	15.50
Pumpkin	81	1.5	1.8	121.50	218.70
Corn	8	1	0.66	8.00	5.28
Spinach	1.5	0.5	2	0.75	1.50
Bean, Runner	2	1.8	3	3.60	10.80
Rhubarb	3	1.7	3.66	5.10	18.67
Basil	.5	0.33	16	0.17	2.64
Dill	1	0.2	32	0.20	6.40
Tomato, Cherry	2	2	4	4.00	16.00
-- Select Vegetable --					
-- Select Vegetable --					
-- Select Vegetable --					
Add Vegetable	Recalculate				
(•) Grocery ( ) Farmers Market ( ) Organic			Grand Totals	355.56	753.97

Figure 2 Excerpt from excel sheet, analyzing 2010 rainfall data and green roof/rain barrel retention. NOAA rainfall data for MSI 2010 (page 1 of 7).

NOAA DATA	Accessed by Rachel Guinn on 07/08/2013			
STATION_NAME	ELEVATION	LATITUDE		LONGITUDE
CHICAGO 5.5 ESE IL US	182.9		41.8008	-87.5903
DATE	PRCP	Measurement Flag		INCHES
20100101	0			0
20100102	0			0
20100103	0			0
20100104	0			0
20100105	0	T		0
20100106	0	T		0
20100107	13			0.05
20100108	124			0.49
20100109	0	T		0
20100110	0			0
20100111	0			0
20100112	5			0.02
20100113	0			0
20100114	0			0
20100115	0			0
20100116	0	T		0
20100117	0			0
20100118	0			0
20100119	0			0
20100120	0			0
20100121	5			0.02
20100122	30			0.12
20100123	0	T		0
20100124	84			0.33
20100125	20			0.08
20100126	5			0.02
20100127	0	T		0
20100128	5			0.02
20100129	0			0
20100130	0			0
20100131	0			0
20100201	0			0
20100202	13			0.05
20100203	0	T		0
20100204	0			0
20100205	0			0
20100206	13			0.05
20100207	0			0
20100208	0			0

Figure 3 Excerpt from excel sheet, analyzing 2010 rainfall data and green roof/rain barrel retention. Rain events for MSI 2010 (page 1 of 7).

	RAIN EVENTS				
DATE	1 IN	2 IN	3 IN	4 IN	5 IN or GREATER
20100101					
20100102					
20100103					
20100104					
20100105					
20100106					
20100107	1				
20100108	1				
20100109					
20100110					
20100111					
20100112	1				
20100113					
20100114					
20100115					
20100116					
20100117					
20100118					
20100119					
20100120					
20100121	1				
20100122					
20100123					
20100124	1				
20100125	1				
20100126	1				
20100127					
20100128	1				
20100129					
20100130					
20100131					
20100201					
20100202	1				
20100203					
20100204					
20100205					
20100206	1				
20100207					

Figure 4 Excerpt from excel sheet, analyzing 2010 rainfall data and green roof/rain barrel retention. Estimated Green Grid Retention and Runoff rates for MSI Smart Home installation 2010 (page 1 of 7). Retention rate based on Rain Event Type (1, 2, 3, or 4 inches of rain—from Figure 4 counts).

	From RG_CST-2058_GreenGrid_Brochure_3-10-11.pdf		
	For One GreenGrid module		
DATE	RETENTION RATE	RETAINED (IN)	RUNOFF (IN)
20100101	0.722	0	0
20100102	0.722	0	0
20100103	0.722	0	0
20100104	0.722	0	0
20100105	0.722	0	0
20100106	0.722	0	0
20100107	0.722	0.0361	0.0139
20100108	0.722	0.35378	0.13622
20100109	0.722	0	0
20100110	0.722	0	0
20100111	0.722	0	0
20100112	0.722	0.01444	0.00556
20100113	0.722	0	0
20100114	0.722	0	0
20100115	0.722	0	0
20100116	0.722	0	0
20100117	0.722	0	0
20100118	0.722	0	0
20100119	0.722	0	0
20100120	0.722	0	0
20100121	0.722	0.01444	0.00556
20100122	0.722	0.08664	0.03336
20100123	0.722	0	0
20100124	0.722	0.23826	0.09174
20100125	0.722	0.05776	0.02224
20100126	0.722	0.01444	0.00556
20100127	0.722	0	0
20100128	0.722	0.01444	0.00556
20100129	0.722	0	0
20100130	0.722	0	0
20100131	0.722	0	0
20100201	0.722	0	0
20100202	0.722	0.0361	0.0139
20100203	0.722	0	0
20100204	0.722	0	0
20100205	0.722	0	0
20100206	0.722	0.0361	0.0139
20100207	0.722	0	0

Figure 5 Excerpt from excel sheet, analyzing 2010 rainfall data and green roof/rain barrel retention. Estimated rain barrel usage for MSI Smart Home 2010 growing season (page 1 of 5).

2010 Growing Season Rainfall Capture and Use for Irrigation (to determine when the rainbarrels were full/empty, and when the cistern was needed to supplement rain barrel irrigation)

Bold numbers indicate when the rain barrels/cistern either reached capacity or were entirely drained for irrigation.

Numbers in frames indicate when the cistern would need to be used to supplement rain barrel irrigation.

DATE	Runoff from Green Roof (Gal)	Runoff From Roof (Gal)	Rain barrel capacity (Gal) Max 240 Gal	Water for irrigation (Gal)	Runoff from Link (Gal)	Rain in Cistern (Gal) Max 2500 Gal
20100501	12.931549	208.5943	163.16	58.37	244.0894	244.09
20100502	20.392058	328.9371	**240.00**	58.37	384.9101	629.00
20100503	0.9947345	16.04571	198.67	58.37	18.7761	647.78
20100504	0	0	140.30	58.37	0	647.78
20100505	0	0	81.93	58.37	0	647.78
20100506	0	0	23.56	58.37	0	647.78
20100507	47.249891	762.1714	**240.00**	58.37	891.8649	1539.64
20100508	15.915753	256.7314	**240.00**	58.37	300.4177	1840.06
20100509	0.9947345	16.04571	198.67	58.37	18.7761	1858.83
20100510	0	0	140.30	58.37	0	1858.83
20100511	41.778851	673.92	**240.00**	58.37	788.5964	**2500.00**
20100512	5.47104	88.25143	**240.00**	58.37	103.2686	**2500.00**
20100513	41.281484	665.8971	**240.00**	58.37	779.2083	**2500.00**
20100514	4.9736727	80.22857	**240.00**	58.37	93.88052	**2500.00**
20100516	0	0	181.63	58.37	0	2500.00
20100517	2.4868364	40.11429	165.86	58.37	46.94026	**2500.00**
20100518	4.9736727	80.22857	192.69	58.37	93.88052	**2500.00**
20100519	0	0	134.32	58.37	0	2500.00
20100520	0	0	75.95	58.37	0	2500.00
20100521	14.423651	232.6629	**240.00**	58.37	272.2535	**2500.00**
20100522	9.9473455	160.4571	**240.00**	58.37	187.761	**2500.00**
20100523	0.9947345	16.04571	198.67	58.37	18.7761	**2500.00**
20100524	0	0	140.30	58.37	0	2500.00
20100525	0	0	81.93	58.37	0	2500.00
20100526	0	0	23.56	58.37	0	2500.00
20100527	0	0	**-34.81**	58.37	0	**2465.19**
20100528	0	0	0.00	58.37	0	2406.82
20100529	0	0	0.00	58.37	0	2348.45
20100530	0	0	0.00	58.37	0	2290.08
20100531	21.88416	353.0057	**240.00**	58.37	413.0743	**2500.00**
20100601	111.53551	1171.337	**240.00**	58.37	1370.656	**2500.00**
20100602	88.617251	930.6514	**240.00**	58.37	1089.014	**2500.00**
20100605	0	0	181.63	58.37	0	2500.00
20100606	29.344669	473.3486	**240.00**	58.37	553.8951	**2500.00**
20100607	7.4605091	120.3429	**240.00**	58.37	140.8208	**2500.00**
20100608	0	0	181.63	58.37	0	2500.00
20100609	18.899956	304.8686	**240.00**	58.37	356.746	**2500.00**

Social

Provided a hands-on educational experience for 450,000 people during the 2008-2012 series of the Smart Home and Garden Exhibit.

Anne Rashford, MSI program manager for the Smart Home exhibit, stated that between 2008-2012 “more than 450,000 guests had seen the exhibit”. The Smart Home exhibit charged a $3 additional fee on top of base museum entry fee.

Provided a training and volunteer opportunity for 40-50 Master Gardeners annually, who, between 2008-2010, contributed over 5,500 hours, which is valued at over $119,000.

From an interview with Madiem Kawa (May 23, 2013 and June 21, 2013) and a document prepared for the University of Illinois Extension by Madiem Kawa.

In 2008, Master Gardeners from the University of Illinois Extension volunteered 1,356 hours at the Smart Home; in 2009, 46 Master Gardeners volunteered 1,733 hours; in 2010, 52 Master Gardeners volunteered 2,605 hours. The value of this volunteer time, taken from the national averages from the respective years is over $119,000.

Table 3 Master Gardener volunteer hours and the value of volunteer hours, 2008-2010.

Years	**2008**	**2009**	**2010**	
Volunteer Hours	1356	1733	2605	
Rate of Volunteer Hours	20.25	20.85	21.36	**Total:**
Value of Volunteer Hours	$27459	$36133.05	$55642.8	$119234.85

Master Gardeners operated under three functions: groomers (performing gardens and yard maintenance), docents (providing tours and information over any aspect of the gardens), and historians (who documented conversations with visitors and the gardens themselves). The Smart Home’s native garden provided a particularly unique training opportunity for the Master Gardeners, who usually do not get to work in garden dedicated to native species. In 2010, the Master Gardeners presented a lecture series on topics ranging from Square Foot Gardening to Plant Propagation, which were attended by visitors as well as other Master Gardeners and Museum employees.

Sources:
"Value of Volunteer Time." Independent Sector. <http://www.independentsector.org/volunteer_time>.

Provides a venue for educational programming for children that focuses on healthy eating, the importance of biodiversity, and the cycle of gardening-harvesting-composting, such as the 2009 program for 25 local Chicago elementary students.

In a document prepared for the University of Illinois Extension by Madiem Kawa, Master Gardener at the Smart Home, detailed the children’s program, a partnership with the University of Illinois Extension, at the Smart Home. From May to October in 2009, 25 Bret Harte elementary schoolchildren worked with Master Gardeners at the Smart Home 1-3 days per week, during which they had hands-on experience learning about gardening, harvesting, composting, and plant/insect/bird identification. The program encouraged

the children, aged 8-11 years old, who come from an urban Chicago neighborhood, to eat fresh vegetables and become involved in outdoor physical activities. Under the Junior Docents program, children who excelled at certain activities in the garden were also allowed to give tours, under the guidance of the Master Gardeners, to other visiting children about the activities they were performing.

Economic

Produces an estimated 300 lbs of honey and more than 350 lbs of vegetables and herbs annually (which alone is valued at over $750).

In a document prepared for the University of Illinois Extension by Madiem Kawa, Master Gardener at the Smart Home from 2008-2010, 150lbs of honey was extracted from two of the four hives at the Smart Home. Because vegetables and herbs were harvested 5-6 times per year by Master Gardeners/children's education program, as well as weekly harvests that were donated to a local church soup kitchen, and were not weighed in the process, we have utilized a calculator to estimate the average yield of the garden based on SF and plant type.

PlanGarden.com (http://www.plangarden.com/app/vegetable_value/) was used to estimate the amount of fruits and vegetables produced over a one-year period. The calculator produces an average annual potential yield for the productive area based on crop variety. It does not account for environmental conditions that may improve or reduce crop yields annually.
The value of the productive yield was generated based on the PlanGarden calculator, totaling over $750 (using the 'Grocery' standard, which is the least expensive option). See also Figure 1.

Sources:
Stahl, Roy. "Plangarden Vegetable Calculator." Plangarden Vegetable Garden Plan - Design Software. <http://www.plangarden.com/?pgref=27639>.