Supplementary Material

Fig. S1 Top-view maps of nine residential zones

Fig. S1 Top-view maps of nine residential zones (continued)

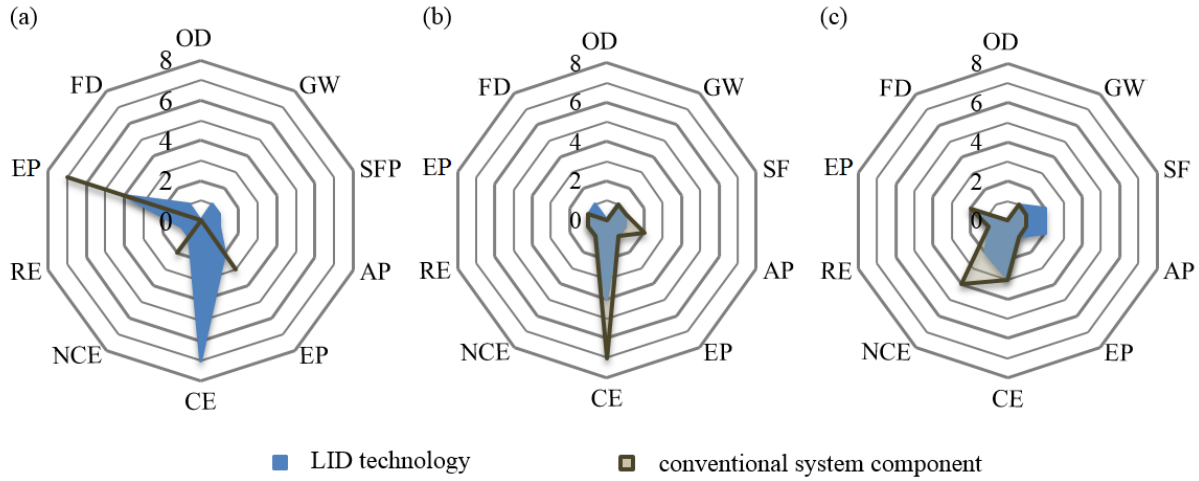

Fig. S2 Comparison of impacts normalized to the US per capita annual emissions (2008): (a) bioretention vs. stormwater collection system; (b) rainwater harvesting vs. water supply system, and; (c) xeriscaping vs. lawn

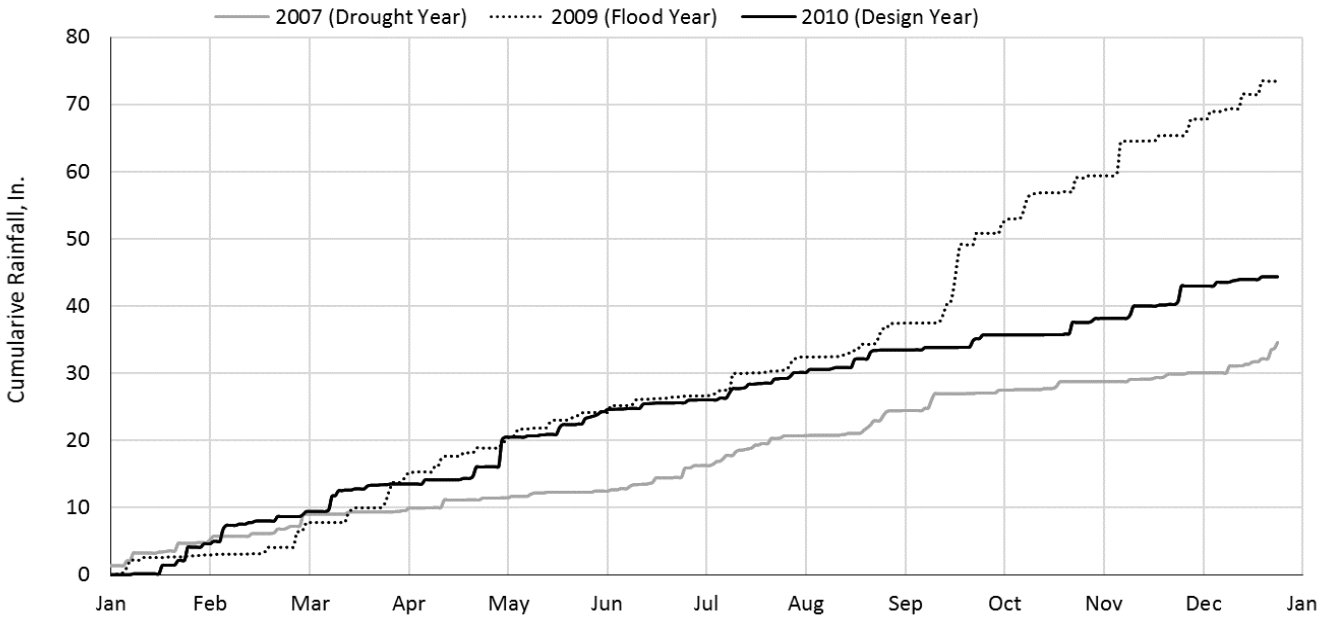

Fig. S3 Cumulative rainfall (inches) in the City of Atlanta for 2007, 2009, and 2010

Table S1 Land use design and water use profile

Residential Type	Zone	Population*		Land use				Water use	
			Lot size	House or building story	Rooftop area#	Paved area#	Landscaped open space#	Indoor (toilet flushing)	Outdoor
		persons	m^2		m^2	m^2	m^2	m^3/yr	m^3/yr
Single-family house zone (SFZ)	R-1	3.25	7,960	2	430	1,020	6,510	355 (112)	1,070
	R-2	3.25	4,830	2	351	910	3,570	355 (112)	587
	R-3	3.25	2,110	2	156	130	1,820	355 (112)	300
	R-4	3.25	945	2	144	70	731	355 (112)	120
	R-5	3.25	640	2	140	22.3	477	355 (112)	79.0
Multi-family apartment building zone (MFZ)	RG-2	45.2	8,320	2	1,500	2,000	4,820	4,940 (1560)	793
	RG-3	43.7	5,800	2	2,020	2,680	970	4,770 (1510)	160
	RG-4	18.7	1,420	2	822	382	214	2,040 (647)	35.0
	RG-5	468	7,530	31	700	4,850	1,980	51,100 (16,200)	326

*The unit numbers of multi-family apartment building zones were investigated from real estate information and the city's average household size for each zoning type was used to calculate the population.
#measured by an online tool.

Table S2 Materials, processes, and direct emissions of bioretention areas for 1 m^3 stormwater runoff

Material and process							
Input	Amount*	Unit	Calculation	Life span	Conversion factor	LCI dataset name	Modification for regional specification
Excavation	1.90E-02	m^3	Depth: gravel layer (6 in.), soil layer (36 in.), and ponding depth (9 in.)	N/A		Excavation, hydraulic digger/RER U	US diesel
Backfill	1.56E-02	m^3	Depth: gravel layer (6 in.) and soil layer (36 in.)	N/A		Excavation, hydraulic digger/RER U	US diesel
PVC liner	6.53E-03	kg	30 mm thickness	50 yrs	0.446 kg/m^2	Polyvinyl chloride resin, at plant/RNA Extrusion, plastic film/RER U	For extrusion, Electricity, Electricity, at Grid, US, 2008/RNA U
PVC drain pipe	7.61E-02	kg	Perforated PVC pipes of 4~6 in. diameter for two mains and one lateral every 25 ft 5m x 10m dimension	60 yrs	8.67 kg/m	Polyvinyl chloride resin, at plant/RNA Extrusion, plastic pipes/RER U	US energy for extrusion
Gravel layer	3.39	kg	Depth: 6 in.	30 yrs	1520 kg/m^3	Gravel, unspecified, at mine/CH U	
Planting soil	17.1	kg	Depth: 36 in.	30 yrs	1520 kg/m^3		
Planting	1.46E-02	m^2	Native trees, shrubs, herbaceous species	N/A		Planting/CH U	
Mulch	5.02	kg	Depth: 3 in. Frequency: every 2 years	N/A	300 kg/m^3	Wood chips, softwood, green, at sawmill, INW/kg/RNA	5.02 kg wood chip = 2.86 kg of the dataset
Mulching	0.220	m^2	Frequency: every 2 years	N/A		Mulching/CH U	US diesel
Transportation	1.70E-02	tkm*	100 km	N/A		Transport, combination truck, average fuel mix/US	

*tkm: unit of transportation measurement.

1 tkm = transporting 1tonne for 1 km or 0.5 tonne for 2 km.

Table S2 Materials, processes, and direct emissions of bioretention areas for 1 m^3 stormwater runoff (continued)

Direct emission								
Water pollutant	Concentration		Water pollutant	Concentration		Water pollutant	Concentration	
Phosphate	4.55E-01	mg/l	Aluminum	1.37E-01	mg/l	Beryllium compounds	1.18E-04	mg/l
Nitrate	6.12E-02	mg/l	Cadmium, ion	3.26E-05	mg/l	Cobalt compounds	1.10E-03	mg/l
Nitrite	2.22E-02	mg/l	Chromium, ion	3.74E-04	mg/l	Lithium, in ground	4.56E-07	mg/l
Ammonia, as N	6.12E-01	mg/l	Copper, ion	3.96E-03	mg/l	Mercury compounds	4.88E-06	mg/l
Potassium	3.56E+00	mg/l	Iron, ion	3.08E-01	mg/l	Molybdenum	1.22E-04	mg/l
Sodium, ion	6.48E+00	mg/l	Lead, ion	7.37E-04	mg/l	Strontium	3.34E-03	mg/l
Chloride	8.19E+00	mg/l	Manganese	5.06E-02	mg/l	Thallium compounds	4.06E-03	mg/l
Silicon	4.19E+00	mg/l	Nickel, ion	1.42E-03	mg/l	Vanadium	4.88E-03	mg/l
Sulfate	1.20E+01	mg/l	Silver, ion	1.21E-05	mg/l	Antimony compounds	8.12E-04	mg/l
Calcium	1.05E+01	mg/l	Zinc, ion	1.20E-02	mg/l	Arsenic compounds	3.32E-04	mg/l
Magnesium	2.32E+00	mg/l	Barium compounds	2.36E-02	mg/l	Selenium compounds	3.66E-05	mg/l

Table S3 Material and process inputs for 1 m^3 rainwater supplied from rainwater harvesting of 50-year life span

Input	Amount	Unit	Calculation	Life span	Conversion factor	LCI dataset name	Modification for regional specification
Half-rounded vinyl gutter	1.19E-02*	kg	Rooftop perimeter (See Fig. S1)	25 yrs	0.640 kg/m	Polyvinyl chloride resin, at plant/RNA Extrusion, plastic pipes/RER U	US energy for extrusion
Downspout	5.33E-03*	kg	PVC pipeline length: house or building height (10 ft/story x # of story) x # of downspout (# of storage tanks)	25 yrs	125 (D) mm: 3.42 kg/m 160 (D) mm: 4.91 kg/m		
Distribution pipelines	4.18E-03*	kg	PVC pipes for toilet flushing Vertical distance: house or building height Horizontal distance: from storage tanks to the center of a top floor (See Fig S1)	25 yrs	25 (D) mm and 4.2 (T) mm: 0.313 kg/m 90 (D) mm and 8.2 mm (T) : 1.10 kg/m		
First flush diverter	4.30E-04*	kg	for each down spout	25 yrs	1 unit: 1.81 kg		
Storage tank	0.06	kg	80% harvesting efficiency Above-ground HDPE storage tank	50 yrs	21 kg/m^3 for 10,000 gallon above-ground HDPE storage tank	High density polyethylene resin, at plant/RNA Injection molding/RER U	US energy for molding
Pumps	2.07E-02*	2002 USD	For 30 psi and for each storage tank, 1/3 HP submersible thermoplastic pump	15 yrs	1 unit: 69$ (2015 USD) → 52.5$ (2002 USD)	Pump and pumping equipment manufacturing	
Pumping energy	1.38E-01*	kWh	For 30 psi and building height uplift and 60% efficiency	N/A		GA energy mix#	
UV disinfection	0.0211	kWh/m^3		N/A			
Transportation	9.28E-03*	tkm	100 km	N/A		Transport, combination truck, average fuel mix/US	

*Average values of material inputs designed for rainwater harvesting systems of nine residential zones (See Table S4).

#Electricity, hard Coal, at power plant/US U 67%; Electricity, natural gas, at power plant/US U 10%; Electricity, nuclear, at power plant/US U 21%; Electricity, hydropower, at power plant/FR U 2%.

Table S4 Material inputs designed for rainwater harvesting systems of nine residential zones

Input	Unit	R-1	R-2	R-3	R-4	R-5	RG-2	RG-3	RG-4	RG-5
Half-rounded vinyl gutter	kg	1.97E-02	9.52E-03	1.42E-02	9.97E-03	1.12E-02	1.30E-02	9.50E-03	1.19E-02	7.93E-03
Downspout	kg	4.78E-03	5.85E-03	6.59E-03	7.14E-03	7.34E-03	6.89E-03	3.65E-03	3.59E-03	2.11E-03
Distribution pipelines	kg	0	2.90E-03	0	3.01E-03	3.64E-03	2.77E-03	6.71E-03	6.07E-03	4.18E-03
First flush diverter	kg	4.16E-04	5.09E-04	5.73E-04	6.21E-04	6.39E-04	4.17E-04	2.21E-04	2.18E-04	2.56E-04
Pumps	2002 USD	2.01E-02	2.46E-02	2.76E-02	3.00E-02	3.08E-02	2.01E-02	1.07E-02	1.05E-02	1.23E-02
Pumping energy	kWh	1.27E-01	1.27E-01	1.27E-01	1.08E-01	1.02E-01	1.99E-01	2.02E-01	1.19E-01	1.26E-01
Transportation	tkm	1.05E-02	8.58E-03	9.59E-03	9.11E-03	9.43E-03	9.64E-03	8.99E-03	9.41E-03	8.27E-03

Table S5 Material and process inputs for 1m^2 conventional landscaping, i.e., lawns, and xeriscaping of 10-year life span

Input	Amount	Unit	Calculation	LCI dataset name	Modification for regional specification
Lawns (maintenance)					
Mowing	27	m^2	270 times for 10 yrs	Mowing, by motor mower/CH U	US residual gasoline
Herbicides	6.30E-04	kg		Herbicides, at regional storehouse/RER U	US electricity mix
Pesticides	2.50E-04	kg		Pesticide unspecified, at regional storehouse/RER U	US electricity mix
Fertilizer	0.1	kg		Nitrogen fertilizer, production mix, at plant/US	
Irrigation	0.165	m^3	For dense landscaping for residential area	CoA's centralized water system	
Transportation	1.01E-02	tkm	100 km	Transport, combination truck, average fuel mix/US	
Xeriscaping (installation and maintenance)					
Planting	0.1	m^2		Planting/CH U	
Herbicides	4.91E-04	kg	22% reduction	Herbicides, at regional storehouse/RER U	US electricity mix
Pesticides	1.95E-04	kg	22% reduction	Pesticide unspecified, at regional storehouse/RER U	US electricity mix
Fertilizer	0.039	kg	61% reduction	Nitrogen fertilizer, production mix, at plant/US	
Irrigation	0.0823	m^3	50% reduction	CoA's water supply system	1.15m^3 water is distributed from the system for 1m^3 use
Mulch	11.4	kg	Depth: 3 in., 300 kg/m^3 Frequency: every 2 years	Wood chips, softwood, green, at sawmill, INW/kg/RNA	11.4 kg wood chip = 6.49 kg of the dataset
Mulching	0.5	m^2	Frequency: every 2 years	Mulching/CH U	US diesel
Transportation	1.15	tkm	100 km	Transport, combination truck, average fuel mix/US	

Table S6 Life cycle environmental impacts of bioretention areas as compared with stormwater collection system on the basis of 1 m^3 stormwater runoff

	Ozone depletion		**Global warming**		**Smog formation**		**Acidification**		**Eutrophication**	
	kg CFC-11 eq		**kg CO_2 eq**		**kg O_3 eq**		**kg SO_2 eq**		**kg N eq**	
	SW collection system	Bio-retention area	SW collection system	Bio-retention area	SW collection system	Bio-retention area	SW collection system	Bio-retention area	SW collection system	Bio-retention area
Bark mulch		4.59E-12		1.45E-01		3.05E-02		1.32E-03		5.92E-05
Water pollutants	0	0	0	0	0	0	0	0	3.42E-03	1.10E-03
PVC pipe		1.36E-09		1.87E-01		9.70E-03		7.07E-04		1.81E-04
Excavation and backfill		1.94E-10		1.84E-02		5.36E-03		1.81E-04		1.68E-05
PVC liner		1.34E-10		1.69E-02		8.76E-04		6.60E-05		2.75E-05
Others		1.45E-09		1.17E-02		1.98E-03		8.38E-05		3.02E-05
Total	0	3.14E-09	0	3.78E-01		4.84E-02		2.36E-03	3.42E-03	1.41E-03
Total (normalized to average impact of a US resident per year)	0%	0%	0%	0.0016%	0%	0.0035%	0%	0.0026%	0.016%	0.0065%

Table S6 LCA comparison of bioretention area with stormwater collection system on the basis of 1 m^3 stormwater runoff (continued)

	Carcinogenic effects		Non-carcinogenic effects		Respiratory effects		Ecotoxicity		Fossil fuel depletion	
	CTUh*		CTUh		kg $PM_{2.5}$ eq		CTUe#		MJ surplus	
	SW collection system	Bio-retention area	SW collection system	Bio-retention area	SW collection system	Bio-retention area	SW collection system	Bio-retention area	SW collection system	Bio-retention area
Bark mulch		1.34E-09		1.42E-08		3.86E-05		2.82E-01		0.00E+00
Water pollutants	2.93E-12	5.86E-13	5.34E-08	1.09E-08	0	0	3.71E+00	8.12E-01	0.00E+00	0.00E+00
PVC pipe		1.07E-08		1.89E-08		4.67E-05		4.79E-01		1.03E-02
Excavation and backfill		1.05E-09		2.86E-09		2.21E-05		5.41E-02		2.41E-05
PVC liner		9.03E-10		1.74E-09		4.33E-06		4.73E-02		1.60E-03
Others		1.39E-09		2.99E-09		1.02E-05		2.23E-02		5.64E-05
Total	2.93E-12	1.54E-08	5.34E-08	5.16E-08	0	1.22E-04	3.71E+00	1.70E+00	0	1.20E-02
Total (normalized)	0%	0.0302%	0.0051%	0.0048%	0%	0.0005%	0.0336%	0.0153%	0%	0.0001%

*CTUh, comparative toxic unit for human toxicity: the estimated increase in morbidity in the total human population

#CTUe, comparative toxic unit for aquatic ecotoxicity: the potentially affected fraction of species (PAF) integrated over time and volume

Table S7 LCA comparison of rainwater harvesting system with water supply system (WS) for 1 m^3 water distributed to non-potable water use

	Water SS	R-1	R-2	R-3	R-4	R-5	RG-2	RG-3	RG-4	RG-5
Ozone depletion, kg CFC-11 eq										
Water SS operation	1.55E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PVC gutter and pipelines		4.43E-10	3.35E-10	3.80E-10	3.70E-10	4.06E-10	4.11E-10	3.58E-10	3.88E-10	2.58E-10
HDPE storage tank		1.34E-09	1.34E-09	1.34E-09	1.34E-09	1.34E-09	1.34E-09	1.34E-09	1.34E-09	1.34E-09
Pumping energy		1.95E-09	2.38E-09	1.95E-09	1.65E-09	1.57E-09	3.08E-09	3.08E-09	1.83E-09	1.93E-09
Pump		1.64E-08	2.00E-08	2.26E-08	2.44E-08	2.51E-08	1.64E-08	8.71E-09	8.57E-09	1.01E-08
Others		3.72E-14	2.53E-11	3.39E-14	1.73E-10	2.23E-10	2.34E-10	2.98E-10	3.14E-10	3.24E-10
Total	1.55E-08	2.01E-08	2.41E-08	2.62E-08	2.80E-08	2.87E-08	2.15E-08	1.38E-08	1.24E-08	1.39E-08
Total (normalized)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Global warming, kg CO_2 eq										
Water SS operation	5.73E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PVC gutter and pipelines		6.10E-02	4.61E-02	5.23E-02	5.09E-02	5.59E-02	5.65E-02	4.93E-02	5.34E-02	3.55E-02
HDPE storage tank		1.98E-01	1.98E-01	1.98E-01	1.98E-01	1.98E-01	1.98E-01	1.98E-01	1.98E-01	1.98E-01
Pumping energy		1.01E-01	1.25E-01	1.01E-01	9.46E-02	9.31E-02	1.72E-01	1.76E-01	1.11E-01	1.17E-01
Pump		1.24E-02	1.51E-02	1.70E-02	1.85E-02	1.90E-02	1.24E-02	6.58E-03	6.47E-03	7.60E-03
Others		9.75E-04	1.73E-02	1.79E-02	2.83E-02	3.15E-02	2.55E-02	2.29E-02	2.37E-02	2.52E-02
Total	5.73E-01	3.74E-01	4.02E-01	3.87E-01	3.91E-01	3.98E-01	4.65E-01	4.53E-01	3.93E-01	3.84E-01
Total (normalized)	0.0024%	0.0015%	0.0015%	0.0016%	0.0016%	0.0016%	0.0016%	0.0019%	0.0019%	0.0016%
Smog formation, kg O_3 eq										
Water SS operation	3.75E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PVC gutter and pipelines		3.17E-03	2.40E-03	2.72E-03	2.64E-03	2.90E-03	2.94E-03	2.56E-03	2.78E-03	1.85E-03
HDPE storage tank		1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02
Pumping energy		6.71E-03	8.17E-03	6.71E-03	5.66E-03	5.39E-03	1.06E-02	1.06E-02	6.28E-03	6.65E-03
Pump		6.41E-05	7.85E-05	8.84E-05	9.58E-05	9.85E-05	6.43E-05	3.41E-05	3.36E-05	3.94E-05
Others		1.59E-04	2.21E-04	1.45E-04	7.31E-04	9.10E-04	9.52E-04	1.16E-03	1.22E-03	1.24E-03
Total	3.75E-02	2.03E-02	2.10E-02	1.98E-02	1.93E-02	1.95E-02	2.47E-02	2.45E-02	2.05E-02	1.99E-02
Total (normalized)	0.0027%	0.0015%	0.0014%	0.0014%	0.0014%	0.0014%	0.0014%	0.0018%	0.0018%	0.0014%

Table S7 LCA comparison of rainwater harvesting system with water supply system (WS) for 1 m^3 water distributed to non-potable water use (continued)

	Water SS	R-1	R-2	R-3	R-4	R-5	RG-2	RG-3	RG-4	RG-5
Acidification, kg SO_2 eq										
Water SS operation	5.15E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PVC gutter and pipelines		2.31E-04	1.75E-04	1.98E-04	1.93E-04	2.12E-04	2.14E-04	1.87E-04	2.02E-04	1.35E-04
HDPE storage tank		1.07E-03	1.07E-03	1.07E-03	1.07E-03	1.07E-03	1.07E-03	1.07E-03	1.07E-03	1.07E-03
Pumping energy		8.76E-04	1.07E-03	8.76E-04	7.39E-04	7.04E-04	1.38E-03	1.38E-03	8.19E-04	8.67E-04
Pump		7.51E-06	9.19E-06	1.03E-05	1.12E-05	1.15E-05	7.53E-06	4.00E-06	3.93E-06	4.61E-06
Others		5.82E-06	1.62E-05	5.31E-06	8.25E-05	1.05E-04	1.11E-04	1.39E-04	1.46E-04	1.50E-04
Total	5.15E-03	2.19E-03	2.34E-03	2.16E-03	2.10E-03	2.10E-03	2.79E-03	2.78E-03	2.24E-03	2.23E-03
Total (normalized)	0.0057%	0.0024%	0.0023%	0.0024%	0.0023%	0.0023%	0.0023%	0.0031%	0.0031%	0.0024%
Eutrophication, kg N eq										
Water SS operation	3.27E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PVC gutter and pipelines		5.93E-05	4.48E-05	5.08E-05	4.94E-05	5.43E-05	5.49E-05	4.79E-05	5.19E-05	3.45E-05
HDPE storage tank		1.08E-04	1.08E-04	1.08E-04	1.08E-04	1.08E-04	1.08E-04	1.08E-04	1.08E-04	1.08E-04
Pumping energy		1.38E-05	1.68E-05	1.38E-05	1.16E-05	1.11E-05	2.18E-05	2.18E-05	1.29E-05	1.37E-05
Pump		7.56E-07	9.26E-07	1.04E-06	1.13E-06	1.16E-06	7.59E-07	4.03E-07	3.96E-07	4.65E-07
Others		3.25E-07	4.52E-07	2.96E-07	1.50E-06	1.87E-06	1.95E-06	2.38E-06	2.51E-06	2.54E-06
Total	3.27E-04	1.82E-04	1.71E-04	1.74E-04	1.72E-04	1.77E-04	1.88E-04	1.81E-04	1.76E-04	1.59E-04
Total (normalized)	0.0015%	0.0008%	0.0007%	0.0008%	0.0008%	0.0008%	0.0008%	0.0008%	0.0009%	0.0007%
Carcinogenic effects, CTUh										
Water SS operation	1.53E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PVC gutter and pipelines		3.49E-09	2.63E-09	2.99E-09	2.91E-09	3.19E-09	3.23E-09	2.82E-09	3.05E-09	2.03E-09
HDPE storage tank		4.56E-09	4.56E-09	4.56E-09	4.56E-09	4.56E-09	4.56E-09	4.56E-09	4.56E-09	4.56E-09
Pumping energy		1.62E-10	1.97E-10	1.62E-10	1.36E-10	1.30E-10	2.55E-10	2.55E-10	1.51E-10	1.60E-10
Pump		6.05E-10	7.41E-10	8.34E-10	9.04E-10	9.30E-10	6.07E-10	3.22E-10	3.17E-10	3.72E-10
Others		1.23E-11	1.25E-11	1.13E-11	2.50E-11	2.96E-11	3.07E-11	3.53E-11	3.71E-11	3.66E-11
Total	1.53E-08	8.83E-09	8.15E-09	8.56E-09	8.53E-09	8.84E-09	8.68E-09	7.99E-09	8.12E-09	7.16E-09
Total (normalized)	0.0301%	0.0174%	0.0152%	0.0169%	0.0168%	0.0174%	0.0169%	0.0157%	0.0162%	0.0141%

Table S7 LCA comparison of rainwater harvesting system with water supply system (WS) for 1 m^3 water distributed to non-potable water use (continued)

	Water SS	R-1	R-2	R-3	R-4	R-5	RG-2	RG-3	RG-4	RG-5
Non-carcinogenic effects, CTUh										
Water SS operation	2.68E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PVC gutter and pipelines		6.16E-09	4.66E-09	5.28E-09	5.14E-09	5.65E-09	5.71E-09	4.98E-09	5.40E-09	3.59E-09
HDPE storage tank		7.77E-09	7.77E-09	7.77E-09	7.77E-09	7.77E-09	7.77E-09	7.77E-09	7.77E-09	7.77E-09
Pumping energy		2.63E-09	3.21E-09	2.63E-09	2.22E-09	2.11E-09	4.15E-09	4.15E-09	2.46E-09	2.61E-09
Pump		1.31E-08	1.61E-08	1.81E-08	1.96E-08	2.02E-08	1.32E-08	6.98E-09	6.86E-09	8.06E-09
Others		1.21E-10	1.36E-10	1.10E-10	3.38E-10	4.09E-10	4.27E-10	5.05E-10	5.32E-10	5.32E-10
Total	2.68E-08	2.98E-08	3.18E-08	3.39E-08	3.51E-08	3.61E-08	3.12E-08	2.44E-08	2.30E-08	2.26E-08
Total (normalized)	0.0026%	0.0028%	0.0029%	0.0032%	0.0033%	0.0034%	0.0028%	0.0023%	0.0024%	0.0021%
Respiratory effects, kg $PM_{2.5}$ eq										
Water SS operation	2.89E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PVC gutter and pipelines		1.53E-05	1.15E-05	1.31E-05	1.27E-05	1.40E-05	1.41E-05	1.23E-05	1.34E-05	8.89E-06
HDPE storage tank		7.29E-05	7.29E-05	7.29E-05	7.29E-05	7.29E-05	7.29E-05	7.29E-05	7.29E-05	7.29E-05
Pumping energy		4.42E-05	5.38E-05	4.42E-05	3.73E-05	3.55E-05	6.97E-05	6.97E-05	4.13E-05	4.38E-05
Pump		3.30E-07	4.04E-07	4.55E-07	4.93E-07	5.07E-07	3.31E-07	1.76E-07	1.73E-07	2.03E-07
Others		1.01E-07	6.57E-07	9.25E-08	4.00E-06	5.14E-06	5.40E-06	6.83E-06	7.20E-06	7.41E-06
Total	2.89E-04	1.33E-04	1.39E-04	1.31E-04	1.27E-04	1.28E-04	1.62E-04	1.62E-04	1.35E-04	1.33E-04
Total (normalized)	0.0012%	0.0005%	0.0005%	0.0005%	0.0005%	0.0005%	0.0005%	0.0007%	0.0007%	0.0005%
Ecotoxicity, CTUe										
Water SS operation	2.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PVC gutter and pipelines		1.56E-01	1.18E-01	1.34E-01	1.30E-01	1.43E-01	1.45E-01	1.26E-01	1.37E-01	9.11E-02
HDPE storage tank		2.82E-01	2.82E-01	2.82E-01	2.82E-01	2.82E-01	2.82E-01	2.82E-01	2.82E-01	2.82E-01
Pumping energy		2.04E-02	2.48E-02	2.04E-02	1.72E-02	1.64E-02	3.21E-02	3.21E-02	1.91E-02	2.02E-02
Pump		7.78E-02	9.53E-02	1.07E-01	1.16E-01	1.20E-01	7.81E-02	4.14E-02	4.07E-02	4.78E-02
Others		2.45E-03	2.33E-03	2.24E-03	3.92E-03	4.53E-03	4.70E-03	5.21E-03	5.47E-03	5.31E-03
Total	2.78E-01	5.39E-01	5.22E-01	5.46E-01	5.50E-01	5.66E-01	5.42E-01	4.87E-01	4.84E-01	4.46E-01
Total (normalized)	0.0025%	0.0049%	0.0045%	0.0049%	0.0050%	0.0051%	0.0048%	0.0044%	0.0045%	0.0040%

Table S7 LCA comparison of rainwater harvesting system with water supply system (WS) for 1 m^3 water distributed to non-potable water use (continued)

	Water SS	R-1	R-2	R-3	R-4	R-5	RG-2	RG-3	RG-4	RG-5
Fossil fuel depletion, MJ surplus										
Water SS operation	5.53E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PVC gutter and pipelines		3.37E-03	2.54E-03	2.89E-03	2.81E-03	3.08E-03	3.12E-03	2.72E-03	2.95E-03	1.96E-03
HDPE storage tank		3.03E-02	3.03E-02	3.03E-02	3.03E-02	3.03E-02	3.03E-02	3.03E-02	3.03E-02	3.03E-02
Pumping energy		4.13E-06	5.03E-06	4.13E-06	3.48E-06	3.32E-06	6.52E-06	6.52E-06	3.86E-06	4.09E-06
Pump		1.50E-02	1.83E-02	2.06E-02	2.24E-02	2.30E-02	1.50E-02	7.97E-03	7.84E-03	9.20E-03
Others		0.00E+00	5.34E-08	0.00E+00	3.65E-07	4.72E-07	4.96E-07	6.31E-07	6.64E-07	6.85E-07
Total	5.53E-04	4.87E-02	5.12E-02	5.38E-02	5.55E-02	5.64E-02	4.85E-02	4.10E-02	4.11E-02	4.15E-02
Total (normalized)	0%	0.0003%	0.0003%	0.0003%	0.0003%	0.0003%	0.0003%	0.0002%	0.0002%	0.0002%

Table S8 LCA comparison of xeriscaping (construction-maintenance) with lawn (maintenance) for 1 m^2 landscaped open space

	Ozone depletion kg CFC-11 eq		**Global warming** kg CO_2 eq		**Smog** kg O_3 eq		**Acidification** kg SO_2 eq		**Eutrophication** kg N eq	
	Lawn	Xeriscaping	Lawn	Xeriscaping	Lawn	Xeriscaping	Lawn	Xeriscaping	Lawn	Xeriscaping
Mowing	2.33E-09	0.00E+00	4.11E-02	0.00E+00	5.49E-03	0.00E+00	2.36E-04	0.00E+00	8.06E-05	0.00E+00
Mulch	0.00E+00	1.05E-11	0.00E+00	3.29E-01	0.00E+00	6.95E-02	0.00E+00	3.01E-03	0.00E+00	1.35E-04
Herbicides and pesticides	2.39E-08	1.86E-08	9.20E-03	7.18E-03	7.24E-04	5.65E-04	9.98E-05	7.78E-05	4.91E-05	3.83E-05
Fertilizer	7.73E-11	3.01E-11	1.96E-01	7.63E-02	2.62E-03	1.02E-03	2.00E-03	7.79E-04	1.98E-05	7.74E-06
Irrigation	2.55E-09	1.28E-09	9.44E-02	4.72E-02	6.18E-03	3.09E-03	8.47E-04	4.24E-04	5.39E-05	2.69E-05
Transportation	3.57E-14	4.06E-12	9.35E-04	1.06E-01	1.53E-04	1.74E-02	5.59E-06	6.35E-04	3.11E-07	3.54E-05
Others	0.00E+00	2.21E-10	0.00E+00	9.83E-04	0.00E+00	2.14E-04	0.00E+00	7.62E-06	0.00E+00	2.13E-06
Total	2.89E-08	2.02E-08	3.41E-01	5.67E-01	1.52E-02	9.18E-02	3.19E-03	4.94E-03	2.04E-04	2.45E-04
Total (normalized)	0%	0%	0.0014%	0.0023%	0.0011%	0.0066%	0.0035%	0.0054%	0.0009%	0.0011%
	Carcinogenic effects CTUh		**Non-carcinogenic effects** CTUh		**Respiratory effects** kg $PM_{2.5}$ eq		**Ecotoxicity** CTUe		**Fossil fuel depletion** MJ surplus	
	Lawn	Xeriscaping	Lawn	Xeriscaping	Lawn	Xeriscaping	Lawn	Xeriscaping	Lawn	Xeriscaping
Mowing	3.14E-09	0.00E+00	1.51E-07	0.00E+00	3.74E-05	0.00E+00	1.85E-01	0.00E+00	1.72E-04	0.00E+00
Mulch	0.00E+00	3.06E-09	0.00E+00	3.24E-08	0.00E+00	8.79E-05	0.00E+00	6.43E-01	0.00E+00	0.00E+00
Herbicides and pesticides	4.62E-10	3.60E-10	1.47E-09	1.15E-09	6.75E-06	5.27E-06	5.56E-02	4.34E-02	4.74E-05	3.69E-05
Fertilizer	6.84E-11	2.67E-11	1.15E-08	4.50E-09	1.17E-04	4.57E-05	2.96E-01	1.16E-01	0.00E+00	0.00E+00
Irrigation	2.51E-09	1.26E-09	4.42E-09	2.21E-09	4.75E-05	2.38E-05	4.58E-02	2.29E-02	9.10E-05	4.55E-05
Transportation	1.18E-11	1.35E-09	1.16E-10	1.32E-08	9.73E-08	1.11E-05	2.35E-03	2.67E-01	0.00E+00	0.00E+00
Others	0.00E+00	6.36E-11	0.00E+00	2.68E-09	0.00E+00	4.79E-07	0.00E+00	2.18E-03	0.00E+00	4.28E-06
Total	6.20E-09	6.11E-09	1.69E-07	5.62E-08	2.09E-04	1.74E-04	5.85E-01	1.09E+00	3.10E-04	8.67E-05
Total (normalized)	0.0122%	0.0120%	0.0160%	0.0054%	0.0009%	0.0007%	0.0053%	0.0099%	0%	0%

Table S9 Data uncertainty of materials, processes, direct emissions, and transportation for system operation

Alternatives	Input	Basic uncertainty, GSD^{2*}	Data quality indicators	Data uncertainty, GSD^2
Bioretention area	Excavation	2.00	4, 1, 1, 1, 1, na	2.05
	Backfill	2.00	4, 1, 1, 1, 1, na	2.05
	PVC liner	1.05	4, 1, 1, 1, 1, na	1.21
	PVC drain pipe	1.05	4, 1, 1, 1, 1, na	1.21
	Gravel layer	1.05	4, 1, 1, 1, 1, na	1.21
	Planting	1.05	4, 1, 1, 1, 1, na	1.21
	Mulch	1.05	4, 1, 1, 1, 1, na	1.21
	Mulching	1.05	4, 1, 1, 1, 1, na	1.21
	Transportation	2.00	5, na, na, na, na, na	2.23
	Water pollutants	1.50	2, 1, 1, 1, 1, na	1.50
Rainwater harvesting system	Half-rounded vinyl gutter	1.05	4, 1, 1, 1, 1, na	1.21
	Downspout	1.05	4, 1, 1, 1, 1, na	1.21
	Distribution pipelines	1.05	4, 1, 1, 1, 1, na	1.21
	First flush diverter	1.05	4, 1, 1, 1, 1, na	1.21
	Storage tank	1.05	4, 1, 1, 1, 1, na	1.21
	Pumps	1.05	4, 1, 1, 1, 1, na	1.21
	Pumping energy	1.05	4, 1, 1, 1, 1, na	1.21
	UV disinfection	1.05	4, 1, 1, 1, 1, na	1.21
	Transportation	2.00	5, na, na, na, na, na	2.23
Lawn	Mowing	1.05	2, 3, 1, 3, 1, na	1.09
	Herbicides	1.05	2, 3, 4, 3, 1, na	1.22
	Pesticides	1.05	2, 3, 4, 3, 1, na	1.22
	Fertilizer	1.05	2, 3, 4, 3, 1, na	1.22
	Irrigation	1.05	2, 1, 2, 1, 1, na	1.08
	Transportation	2.00	5, na, na, na, na, na	2.23
Xeriscaping	Planting	1.05	1, 1, 1, 1, 1, na	1.05
	Herbicides	1.05	2, 3, 4, 3, 1, na	1.22
	Pesticides	1.05	2, 3, 4, 3, 1, na	1.22
	Fertilizer	1.05	2, 3, 4, 3, 1, na	1.22
	Irrigation	1.05	2, 1, 2, 1, 1, na	1.08
	Mulch	1.05	4, 1, 1, 1, 1, na	1.21
	Mulching	1.05	4, 1, 1, 1, 1, na	1.21
	Transportation	2.00	5, na, na, na, na, na	2.23

*GSD^2: the square of geometric standard deviation

Table S10 Impact reduction probability of a technology against a conventional system component

Impact	Bioretention area vs. Stormwater	Rainwater harvesting vs. Water Supply System	Xeriscaping vs. Lawns
Ozone depletion	0%	1%	100%
Global warming	0%	100%	0%
Smog	0%	100%	5%
Acidification	0%	100%	0%
Eutrophication	100%	96%	0%
Carcinogenics	0%	70%	2%
Non carcinogenics	51%	48%	100%
Respiratory effects	0%	100%	2%
Ecotoxicity	100%	31%	0%
Fossil fuel depletion	0%	0%	100%

Table S11 Contributions of water pollutants to major impacts of stormwater runoff filtered using bioretention areas

Impact			Phosphate, 0.455 mg/l	Thallium compounds, 4.06 µg/l	Vanadium compounds, 4.88 µg/l
Eutrophication	1.41E-03	kg N eq	76%	-	-
Non-carcinogenic effects	5.16E-08	CTUh	-	14%	-
Ecotoxicity	8.12E-01	CTUe	-	-	68%

Table S12 Conventional system water use and LID technology design for 1,000 m^2 land use

				Single-family house zone (SFZ)					Multi-family apartment building zone (MFZ)			
				R-1	R-2	R-3	R-4	R-5	RG-2	RG-3	RG-4	RG-5
Population density		Person		0.4	0.7	1.5	3.4	5.1	5.4	7.5	13.2	62.2
Impervious land surface area		%		18	26	14	23	25	42	82	85	74
Landscaped area		%		82	74	86	77	75	58	18	15	26
Conventional system	Annual stormwater runoff	$m^3\ yr^{-1}$		173	174	172	173	173	259	474	474	375
	Water supply	$m^3\ yr^{-1}$	Indoor (toilet flushing)	30.4 (14.1)	50.2 (23.2)	115 (53.1)	257 (119)	379 (175)	406 (188)	562 (260)	985 (455)	4637 (2144)
			Outdoor irrigation	134	122	142	128	123	95.6	27.8	25.3	45.6
	lawn	m^2		818	739	864	774	746	579	167	151	263
Hybrid system	Annual stormwater runoff (infiltrated)	$m^3\ yr^{-1}$		164	162	151	138	128	154	276	155	368
	Bioretention areas	m^2		73.5	77.9	70.1	72.3	74.3	88.5	162	146	163
	Water supply	$m^3\ yr^{-1}$	Indoor (toilet flushing)	44.5 (14.1)	68.8 (18.6)	168 (53.1)	309 (52.8)	432 (53.0)	487 (81.7)	787 (225)	1,406 (421)	6,714 (2,077)
			Outdoor irrigation	17.4	0	5.36	0	0	0	0	0	0
	Rainwater harvesting	$m^3\ yr^{-1}$	Toilet flushing	0	4.60	0	65.9	122	106	34.5	34.5	67.2
			Outdoor irrigation	43.8	54.4	60.0	57.7	55.3	40.4	0.455	0.422	8.25
	Xeriscaping	m^2		744	661	794	702	672	491	6	5	100

Table S13 Rainwater harvesting potential within each zone for the design year (2010), a drought year (2007), and a flood year (2009)

Zoning Code		**R-1**	**R-2**	**R-3**	**R-4**	**R-5**	**RG-2**	**RG-3**	**RG-4**	**RG-5**
Population Density, people/1,000 m^2		0.4	0.7	1.5	3.4	5.1	5.4	7.5	13.2	62.2
Rooftop Area, m^2		430.0	351.2	156.1	144.0	140.0	1,500.0	2,020.0	821.9	700.0
	L/m^2 rooftop	Storage Tank Volume for 2010 Precipitation Pattern, m^3								
	116	49.9	40.7	18.1	16.7	16.2	174.0	234.3	95.3	81.2
Year	$L/d\text{-}m^2$ rooftop	Rainwater Harvesting Potential, m^3/yr								
2007	1.67	262.7	214.6	95.4	88.0	85.5	916.5	1234.2	502.2	427.7
2010	2.22	348.9	284.9	126.6	116.8	113.6	1217.1	1639.0	666.9	568.0
2009	2.32	364.1	297.4	132.2	121.9	118.6	1270.2	1710.5	696.0	592.8
Year	L/m^2 rooftop	Optimum Tank Size for each Precipitation Pattern, m^3								
2007	117	50.3	41.1	18.3	16.8	16.4	175.5	236.3	96.2	81.9
2010	116	49.9	40.7	18.1	16.7	16.2	174.0	234.3	95.3	81.2
2009	212	91.2	74.5	33.1	30.6	29.7	318.3	428.6	174.4	148.5
Year	$L/d\text{-}m^2$ rooftop	Optimum Rainwater Harvesting Potential, m^3/yr								
2007	1.89	296.6	242.2	107.7	99.3	96.6	1034.8	1393.5	567.0	482.9
2010	2.22	348.9	284.9	126.6	116.8	113.6	1217.1	1639.0	666.9	568.0
2009	3.78	593.3	484.5	215.3	198.7	193.2	2069.6	2787.0	1134.0	965.8

Table S14 Stormwater runoff generated (in.) within each zone during various rainfall events for a conventional system (CS) and a hybrid system (HS)

Zone				R-1	R-2	R-3	R-4	R-5	RG-2	RG-3	RG-4	RG-5
Population Density, people/1000 m^2				0.4	0.7	1.5	3.4	5.1	5.4	7.5	13.2	62.2
Imperviousness, %				18%	26%	14%	23%	25%	42%	83%	85%	74%
CN				72	73	71	72	72	81	93	94	90
S				3.9	3.7	4.1	3.9	3.9	2.3	0.8	0.6	1.1
System	Return Period	in./hr for 24-hr event	in./day	Stormwater Runoff Generated, in.								
CS	1 yr	0.14	3.36	1.03	1.09	0.98	1.03	1.03	1.60	2.60	2.70	2.32
	2yr	0.17	4.08	1.52	1.59	1.45	1.52	1.52	2.19	3.30	3.40	3.00
	5yr	0.2	4.8	2.05	2.12	1.97	2.05	2.05	2.81	4.00	4.11	3.68
	10 yr	0.23	5.52	2.61	2.70	2.52	2.61	2.61	3.45	4.71	4.82	4.38
	25 yr	0.27	6.48	3.39	3.49	3.29	3.39	3.39	4.32	5.66	5.77	5.31
	50 yr	0.3	7.2	4.00	4.11	3.89	4.00	4.00	4.99	6.37	6.49	6.02
	100 yr	0.33	7.92	4.62	4.74	4.51	4.62	4.62	5.67	7.08	7.20	6.73
HS	1 yr	0.14	3.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2yr	0.17	4.08	0.49	0.50	0.47	0.49	0.49	0.59	0.70	0.70	0.68
	5yr	0.2	4.8	1.01	1.04	0.99	1.01	1.01	1.21	1.40	1.41	1.37
	10 yr	0.23	5.52	1.58	1.61	1.54	1.58	1.58	1.85	2.11	2.12	2.06
	25 yr	0.27	6.48	2.36	2.40	2.31	2.36	2.36	2.73	3.06	3.07	3.00
	50 yr	0.3	7.2	2.97	3.02	2.92	2.97	2.97	3.40	3.77	3.79	3.70
	100 yr	0.33	7.92	3.59	3.65	3.53	3.59	3.59	4.07	4.48	4.50	4.41

Table S15 Water consumption for outdoor irrigation and FEI of CS and HS for nine residential zones

Zone	CS		HS	
	Outdoor irrigation	FEI	Outdoor irrigation	FEI
	m^3	m^3 ecosystem equivalent	m^3	m^3 ecosystem equivalent
R-1	135	33.4	61.3	15.19
R-2	122	30.2	54.4	13.49
R-3	142	35.3	65.4	16.21
R-4	127	31.6	57.8	14.32
R-5	123	30.5	55.3	13.72
RG-2	95.4	23.6	40.4	10.02
RG-3	27.5	6.82	0.46	0.11
RG-4	24.8	6.16	0.42	0.10
RG-5	43.3	10.7	8.25	2.04