Alliance for Water Efficiency

Water Savings & Financial Benefits of Single-Family Package Graywater Systems

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Executive Summary

Potable water is typically used by homeowners to meet all indoor and outdoor water demands; however, some demands do not require potable water quality, e.g., toilet flushing and landscape irrigation. Graywater systems use non-potable water generated from showering and clothes washing as an alternative water supply to meet demands that do not require potable water.[1] This report provides some general water savings and cost information for use by water utilities and their customers when considering the merits associated with residential graywater systems. Although financial and water savings benefits may not be the only reasons for installing a graywater system, this report attempts to highlight key life-cycle cost considerations associated with owning and operating a graywater system.

While there is no cost associated with graywater generation in the home, the costs associated with buying, installing, and maintaining systems that reuse graywater must be considered when completing a benefit/cost analysis.

There are two main types of single-family packaged graywater systems:[2]

1. Graywater used for toilet flushing
2. Graywater used for landscape irrigation

There are three main types of landscape-based graywater systems:

1. Laundry to Landscape - Water from clothes washers is discharged directly to landscape.
2. Branched Drain - Showers and/or lavatory sinks drain via gravity directly to landscape.
3. Pumped Systems - Water from showers and/or clothes washer and/or lavatory sinks is directly pumped or temporarily stored in a holding tank before being pumped to the landscape.[3]

Note: The volume of water savings achieved via the use of a graywater system is not equal to the volume of graywater generated or collected. It is equal to the volume of potable water savings (offset) achieved by the user.

The water demands associated with showering and toilet flushing tend to be relatively consistent on a daily basis; therefore, the potential water savings associated with single-family shower-to-toilet graywater systems can be estimated with some accuracy. However, because there are significant variables and uncertainties associated with landscape irrigation demands, it is much more difficult to estimate the potential for water savings associated with landscape-based graywater systems.[4]

[1] Water from kitchen faucets and dishwashers is generally not considered as a source of graywater because it may contain food particles or grease. The volume of graywater provided by lavatory faucets is minimal and is not considered in the savings estimates included in this report.
[2] A packaged system is an “off the shelf” system vs. a system that is designed and engineered for a specific site.
[3] Note that regulations and code requirements regarding the design, installation, and use of graywater storage tanks vary from state to state.
[4] Landscape-based graywater systems can also provide homeowners with a source of water during times of watering restrictions.

Graywater financial benefits are derived from reducing potable water demands. These systems provide a financial benefit to the homeowner if the total life-cycle value of the potable water savings is greater than the total life-cycle cost of the system.[5]

Shower-to-Toilet Graywater Systems

The *Residential End Uses of Water, Version 2* (REUS 2016) determined an average home produces almost twice as much shower-based graywater than would be required for toilet flushing (assuming the use of WaterSense®-labeled toilets). As such, the potential for potable water savings is related to the volume of water used for toilet flushing and not to the volume of graywater generated by showering.

The REUS 2016 also verified that, on average, each person flushes a toilet in the home about five times per day. Therefore, theoretical potable water savings associated with shower-to-toilet graywater systems is equal to about 2,336 gallons per capita per year.[6]

The annual net cost savings of a graywater system equals the annual volume of potable water savings multiplied by the marginal volumetric rate for water (or water & wastewater) minus any operations and maintenance (O&M) costs for chemicals, electricity, replacement parts, etc.

The simple payback period of a graywater system equals the total installed cost of the system divided by the average annual net cost savings. If the payback period exceeds the expected life span of the graywater system, the system will have a net cost to the customer.

A water/cost savings analysis was completed using demand values from the REUS 2016. This analysis indicates that shower-to-toilet graywater systems may not be cost-effective to the homeowner unless household occupancy is very high, and/or water rates are very high, and/or system costs are relatively low.

Landscape Irrigation Graywater Systems

The REUS 2016 determined an average home with an occupancy rate 2.64 persons produces about 28 gallons of graywater per day from showers and 23 gallons from clothes washers, equating to about 10.6 gallons per capita per day (gcd) from showers and 8.7 gcd from the clothes washer. While a total graywater production of 19.3 gcd equates to about 7,045 gallons per person per year there are three variables making it extremely unlikely 100 percent of the graywater produced would offset potable water demand:

1. Climate: Savings will be lower in areas where the irrigation season or plant water use requirements occur less than 12 months per year.
2. Weather: Even during the irrigation season there are likely to be days when precipitation provides all or part of required irrigation.

[5] Formulas used to calculate the water and cost savings associated with the different types of graywater systems are provided in the main body of the report.
[6] 1.28 gallons/flush x 5 flushes/person/day x 365 days/year = 2,336 gallons/year/person.

3. Accuracy/Timing Limitations: It is unlikely a homeowner would accurately calculate and balance irrigation demands and graywater availability on a daily basis.

Naturally, the potential for potable water savings for irrigation-based graywater systems is greater if they are installed in climates with longer irrigation seasons. While the impact of weather and accuracy/timing has not been verified by known independent third-party studies, this report assumes potable water irrigation savings equivalent to 75% of the volume of graywater produced. The theoretical annual household potable water savings are therefore:

- laundry-to-landscape systems =

  8.7 gcd x 75% x number of persons/household (pph) x irrigation season (days/year)

- branched drain systems =

  10.6 gcd x 75% x pph x irrigation season (days/year)

- pumped systems =

  19.3 gcd x 75% x pph x irrigation season (days/year)

The annual net cost savings of a graywater system equals the annual volume of potable water savings multiplied by the marginal volumetric rate for water (or water & wastewater) minus any O&M costs for chemicals, electricity, replacement parts, etc.[7]

The simple payback period of the graywater system equals the total installed cost of the system divided by the annual net cost savings. Installed costs are estimated to range from as little as a couple hundred dollars for a do-it-yourself laundry-to-landscape system to more than $5,000 for a professionally installed pumped system. If the payback period exceeds the expected life span of the graywater system, the system will have a net cost to the customer.

Landscape-based graywater systems are more likely to be cost-effective to the homeowner if:

- Home has a high marginal volumetric water (or water/sewer) rate
- Home is located in area with long irrigation season (e.g. >7 months for landscape-based graywater systems)
- Home has a high occupancy rate
- A low cost graywater system is installed
- The graywater system has low operations and maintenance costs
- A Do-It-Yourself graywater system is installed during home construction vs. retrofit

[7] O&M costs associated with laundry-to-landscape and branched drain systems are minimal.

Graywater Financial Benefits to the Utility

Reducing customer water demands can financially benefit a water utility, especially if the utility is operating at or near its system's peak production rate or if it is faced with a shortage of water supply.[8] Utilities can compare their unit cost (e.g., $ per gallon/day) of achieving water savings through a graywater reuse program (demand-side management) to the unit cost of expanding the system's water supply. If the unit cost of the demand-side option is lower, the program is cost-effective and provides a financial benefit to the utility.

Conclusion

Due to their cost and, often, complexity, graywater reuse programs are better suited as long-term, ongoing programs rather than as short-term solutions to drought. The water savings achieved by a graywater system is equal to the **long-term reduction in potable water demands** achieved by the homeowner. While financial benefits may not be the only reason for a homeowner to install a graywater system, if the total life-cycle costs of the system exceed the total life-cycle savings from reduced potable water purchases, the system will have a net cost to the homeowner.

Water utilities are strongly encouraged to use their own values, e.g., volumetric water rates, persons per household, length of irrigation season, graywater system cost, unit cost of adding additional water supply, etc., to assess the cost-effectiveness associated with implementing a single-family graywater reuse program in their own community. As data from more independent third-party field studies becomes available (especially regarding landscape-based graywater systems) it is hoped that the values identified in this report can be further refined.

[8] Lower water demands can also reduce a utility's variable costs (e.g., energy and chemical costs).

1.0 Introduction

The Alliance for Water Efficiency (AWE) website describes graywater as, "untreated wastewater resulting from lavatory wash basins, laundry and bathing." Graywater does not include wastewater from toilets, urinals, or any industrial process. Wastewater from kitchen sinks and dishwashers is also typically excluded due to the potential presence of food particles and/or grease.

Graywater systems provide users with non-potable water generated onsite as an alternative water supply to meet demands that do not require potable water, e.g., toilet flushing and landscape irrigation. While graywater is produced onsite and available to the user at no cost, there are costs associated with buying, installing, and maintaining residential graywater systems and these costs must be considered when evaluating the financial benefits associated with the use of these systems.

Water utilities often come under well-intended pressure from the public, decision makers, non-government organizations (NGOs), and other stakeholders to promote and incentivize water demand management measures, especially during times of drought and water scarcity. It is difficult, however, for water providers to make informed water conservation and efficiency planning decisions in cases where there is insufficient or conflicting information regarding expected water savings and/or program cost-effectiveness. The AWE Water Efficiency Research Committee identified a need to develop this reference document to outline the range of expected costs and savings associated with installing and operating single-family package graywater systems.

Note: While individual homes may save more or less potable water/money than the values presented herein, it is the intent of this document to present realistic savings and costs values that average homeowners installing residential graywater systems might be expected to achieve. The information presented herein is also intended to assist water utilities considering the merits of a graywater conservation incentive program.

1.1 *Types of Graywater Systems*

There are two main types of single-family packaged graywater systems:

1. Graywater used for toilet flushing
2. Graywater used for landscape irrigation

There are three main types of landscape-based graywater systems:

1. <u>Laundry to Landscape</u> - Water from clothes washers is discharged directly to landscape.
2. <u>Branched Drain</u> - Showers and/or lavatory sinks drain via gravity directly to landscape.
3. <u>Pumped Systems</u> - Water from showers and/or clothes washer and/or lavatory sinks is pumped or temporarily stored in a holding tank before being pumped to the landscape.[9]

[9] Note that regulations and code requirements regarding the design, installation, and use of graywater storage tanks vary from State to State.

1.2 *Calculating Water Savings*

It is important to note that the volume of water savings achieved via the use of a graywater system is not equal to the volume of graywater generated or collected but rather to the resulting volume of potable water savings achieved by the user.

The volume of water savings is not equal to the volume of graywater collected.

The volume of water savings is equal to the reduction in potable water demands.

Because the volume of water generated from showering and the volume of water used for toilet flushing in single-family homes tend to be fairly consistent on a daily basis, the potential water savings associated with single-family shower-to-toilet graywater systems can be estimated with some accuracy.

There are significant variables and uncertainties associated with determining the potential potable water savings derived from landscape-based graywater systems. Irrigation demands are weather-dependent, meaning that they can vary from day to day, season to season, and from geographic location to geographic location. Irrigation demands can also vary significantly from homeowner to homeowner depending on landscape properties and customer behavior. Unfortunately, there are very few independent third-party field studies that accurately identify potable water saving values, and none which have separately measured indoor and outdoor water usage changes. As such, while verified and referenced values have been used in this report where possible, values have been assumed when necessary.

1.3 *Use of Volumetric Rates when Calculating Financial Benefit*

The financial benefit to a customer using a graywater system is equal to the volume of potable water savings multiplied by the marginal volumetric water rate (or combined water and sewer rate), minus any operations and maintenance (O&M) costs. Note that there will be no reduction in homeowner wastewater (sewer) service charges for landscape-based graywater systems in areas where these charges are billed on a flat rate basis or where these charges are based on non-seasonal (winter) water demands. It is also important that any fixed fees on the water bill, e.g., meter charges or debt reduction charges, etc., are not included when calculating the marginal volumetric rate.

When calculating financial savings associated with graywater systems, use only the volumetric cost of water and/or sewer.

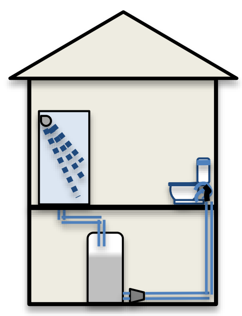
2.0 Shower-to-Toilet Graywater Systems

2.1 *Theoretical Annual Household Water Savings*

The *Residential End Uses of Water, Version 2* (REUS 2016) identifies an average occupancy rate of 2.64 persons per household (pph) with an average per capita toilet flushing rate of 5.0 times per day.[10] These values are used in many of the calculations provided in this report to estimate theoretical savings.

The REUS 2016 also found that an average home produces about 10.6 gallons of shower-based graywater per person per day.[11] Since a home fitted with WaterSense®-labeled toilets using 1.28 gallons per flush would only require about 6.4 gallons per person day for toilet flushing,[12] the volume of shower-based graywater produced each day is much greater than the volume required for toilet flushing. The potential for potable water savings, therefore, is related to the volume of water used for toilet flushing and not to the volume of graywater generated by showering.

Figure 1. ***Shower to Toilet Graywater System Schematics***



In most cases, the volume of graywater derived from showers far exceeds the volume of potable water used for toilet flushing. This is a useful example for explaining that the potential for water savings relates to the volume of potable water saved, not the amount of graywater produced.

The theoretical water savings for a shower-to-toilet graywater system in a home with 2.64 persons (as per REUS 2016) would be 6,167 gallons per year,[13] or somewhat higher than the 4,226[14] and 2,185[15] gallons per year observed in two field studies.

[10] Water Research Foundation, Residential End Uses of Water, Version 2, (2016)
[11] REUS 2016, 28.1 gallons per home per day ÷ 2.64 persons per home = 10.6 gallons per capita per day
[12] 1.28 gallons/flush x 5.0 flushes/capita/day
[13] 2.64 persons x 6.4 gallons/capita/day x 365 days/year
[14] City of Guelph Residential Greywater Field Test, 2012, homes fitted with efficient toilet fixtures, prorated to 2.64 persons per home.
[15] Craig, Madeline J., Developing a Standard Methodology for Testing Field Performance of Residential Greywater Reuse Systems, 2015, Section 5.1.6, prorated to 2.64 persons per home.

Water utilities can estimate theoretical household potable water savings associated with shower-to-toilet graywater systems by using Equation 1 or the values provided in Table 1. Note that actual savings may be somewhat less than theoretical values.

Equation 1: Shower-to-Toilet Graywater System Theoretical Annual Household Water Savings

1.28 gallons/flush x 5.0 flushes/capita/day x pph x 365 days/year

Table 1. Shower-to-Toilet Graywater System Theoretical Annual Household Water Savings

Persons per Household (pph)	***Annual Water Saving (gallons)***
1	2,336
2	4,672
3	7,008
4	9,344
5	11,680
6	14,016

Example Calculation: 3 pph x 1.28 gal/flush x 5 flushes/person/day x 365 days/year = 7,008 gal/year

2.2 *Estimated Gross Annual Cost Savings to Customer*

The gross annual cost savings for a homeowner is calculated as the annual volume of potable water savings multiplied by the marginal volumetric rate for water (or water & wastewater) – see Equation 2.

Equation 2: Shower-to-Toilet Graywater System Gross Annual Cost Savings

Annual Household Savings x Marginal Cost of Water

Table 2 illustrates gross annual cost savings for different persons per household (pph) values based on a range of volumetric water/wastewater rates.[16] Fixed fees on the water bill, e.g., meter charges or debt reduction charges, etc., should not be included when calculating the volumetric rate.

[16] Both water and wastewater rates must be considered when evaluating the savings related to shower-to-toilet graywater systems.

Table 2. Shower-to-Toilet Graywater System Gross Annual Household Cost Savings

Persons per household	***Annual Water Savings (gallons)***	***Volumetric Rate per 1,000 gallons***						
		$2	***$5***	***$8***	***$11***	***$14***	***$17***	***$20***
1	2,336	$5	$12	$19	$26	$33	$40	$47
2	4,672	$9	$23	$37	$51	$65	$79	$93
3	7,008	$14	$35	$56	$77	$98	$119	$140
4	9,344	$19	$47	$75	$103	$131	$159	$187
5	11,680	$23	$58	$93	$128	$164	$199	$234
6	14,016	$28	$70	$112	$154	$196	$238	$280

<u>Example Calculation:</u> 3 pph, 7,008 gallons/year savings, volumetric water rate of $5.00/1,000 gallons and volumetric wastewater rate of $9.00/1,000 gallons.

7.008 x 1,000 gal/year x ($5.00 + $9.00)/1,000 gal = $98 per year savings

2.3 *Net Annual Cost Savings to Homeowner*

The net annual cost savings to single-family homeowners equals the gross annual cost savings minus any operations and maintenance (O&M) costs, such as the cost of electricity, filters, chemicals, or replacement of parts – see Equation 3.

<u>Equation 3: Shower-to-Toilet Graywater System Net Annual Cost Savings</u>

Gross Annual Cost Savings – Annual O&M Costs

The National Academy of Sciences report, *Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits* (Table 7.1) estimates operational costs (i.e., chemical and energy costs) for residential graywater systems as approximately $1 per thousand gallons.

Some jurisdictions require backflow prevention devices to be installed on graywater systems if they are connected to a potable water system. In such cases it is not uncommon for the jurisdiction to require the homeowner to pay the purchase and installation costs of the backflow device as well as the annual or periodic testing or inspection of these devices to ensure they continue to function properly to avoid potential contamination of the potable water supply. Some jurisdictions may also require the homeowner to purchase a permit before installing a graywater system. Where these requirements exist, any associated costs must be included as an operational cost to the homeowner.

Maintenance costs are expected to be minimal for the first few years when the graywater system is relatively new; however, many system parts – and ultimately the entire system – will eventually need replacing. Each graywater system design will have its own maintenance requirements and costs for cleaning or replacing filters, for adding chemicals, for cleaning storage tanks, etc. While the average annual cost of maintenance will vary depending on system design, in lieu of system-specific maintenance costs identified through the implementation of independent third-party field studies, a minimum cost of

$36 per year has been assumed for calculations included in this report.[17] Actual average annual maintenance costs should be used by water utilities in calculations where possible.

In Table 3, the estimated annual O&M costs (i.e., operations costs of $1 per thousand gallons and an average annual maintenance costs of $36 for replacement parts) are deducted from the annual gross cost savings values identified in Table 2. Table 3 identifies the annual net cost savings associated with shower-to-toilet graywater systems for various household occupancy rates and volumetric water/wastewater rates. The negative annual net savings values in Table 3 illustrate examples where the costs associated with using a graywater system may exceed the annual savings from reduced water purchases.

Table 3. Shower to Toilet System Annual Net Cost Savings

Persons per household	***Annual Water Savings (gallons)***	***Volumetric Rate per 1,000 gallons***						
		$2	***$5***	***$8***	***$11***	***$14***	***$17***	***$20***
1	2,336	-$34	-$27	-$20	-$13	$6	$1	$8
2	4,672	-$31	-$17	-$3	$11	$25	$39	$53
3	7,008	-$29	-$8	$13	$34	$55	$76	$97
4	9,344	-$27	$1	$29	$57	$85	$114	$142
5	11,680	-$24	$11	$46	$81	$116	$151	$186
6	14,016	-$22	$20	$62	$104	$146	$188	$230

<u>Example Calculation</u>: 3 pph, 7,008 gallons/year savings, volumetric water/wastewater rate of $14/1,000 gallons, $1/1,000 gallons operational costs (energy and chemicals), $36/year average maintenance cost

7.008 x 1,000 gal x $14/1,000 gal – (7.008 x $1) – ($36) = $55 / year

2.4 *Estimated Simple Cost Payback to Homeowner*

The simple payback for installing a graywater system is calculated as the total installed cost of the system divided by the average annual net cost savings – see Equation 4. If the payback period exceeds the expected life span of the graywater system, the system will have a net cost to the homeowner. For example, a $3,000 graywater system[18] with a 15-year life-cycle[19] would need to achieve an annual net savings of at least $200 per year to be cost-effective, i.e., to have a payback period less than the system's expected life span.[20]

[17] A 2014 article by Donna Ferguson posted on www.theguardian.com (*Greywater Systems: Can They Really Reduce Your Bills?)* estimates maintenance costs of $36 per year (converted from £30 per year). Several reports identify higher costs, e.g., *Economic Assessment Tool for Greywater Recycling Systems* estimates costs of about $73 per year (converted from £60 per year for inspection and maintenance), F.A. Memon, PhD, et al.

[18] *A Guide to Greywater Systems*, https://www.choice.com.au/home-improvement/water/saving-water/articles/guide-to-greywater-systems, identifies a system cost of $4,000 Australian or about $3,000 USD.

[19] *Cost-Benefit Analysis of Onsite Residential Graywater Recycling – A Case Study: the City of Los Angeles*, Zita L.T.Yu, et al., estimates an average service lifetime of 15 years.

[20] $3000 ÷ 15 years = $200 per year

Equation 4: Shower-to-Toilet Graywater System Payback Period (years)

Total Installed Cost ÷ Net Annual Cost Savings

As an example, Table 4 illustrates payback periods in years for a $3,000 shower-to-toilet graywater system using different household occupancy rates and volumetric water/wastewater rates. Shaded cells indicate conditions where the anticipated payback period would be less than 15 years, i.e., where installing a $3,000 system with a 15-year life span would be cost-effective to the homeowner. Cells containing no values indicate conditions where annual costs exceed annual savings and, therefore, the system will never pay for itself.

Table 4. Shower-to-Toilet System Payback Period for a $3,000 Graywater System (Years)

Persons per household	***Annual Water Savings (gallons)***	***Volumetric Rate per 1,000 gallons***						
		$2	***$5***	***$8***	***$11***	***$14***	***$17***	***$20***
1	2,336	-	-	-	-	-	2,180	358
2	4,672	-	-	-	280	121	77	57
3	7,008	-	-	230	88	55	39	31
4	9,344	-	2,180	102	52	35	26	21
5	11,680	-	280	66	37	26	20	16
6	14,016	-	150	48	29	21	16	13

Example Calculation: 3 pph, volumetric water/wastewater rate of $14/1,000 gallons, net annual savings of $55 (Table 3), total installed graywater system cost of $3,000

$3,000 installed cost ÷ $55 net annual cost savings = 55 years

As illustrated in Table 4, shower-to-toilet graywater systems are unlikely to be cost-effective to homeowners except in cases where household occupancy is very high, and/or water rates are very high, and/or system costs are much lower than the $3,000 cost assumed in Table 4.

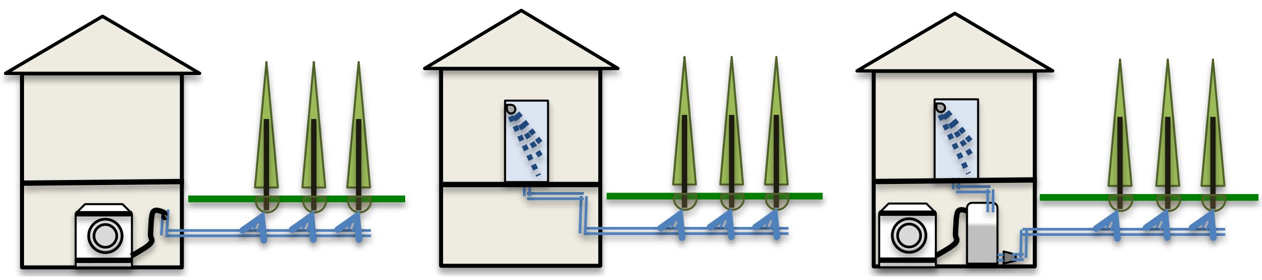
3.0 Landscape Irrigation Graywater Systems

3.1 *Potential Potable Water Savings*

While the volume of graywater production in a single-family home is equal to the total volume of water used for showering and clothes washing (the volume of water contributed by lavatory sinks is minimal), the financial benefit associated with the use of graywater systems is directly related to the volume of potable water saved by the homeowner. Because of the large number of variables associated with landscape irrigation (e.g., climate, weather, system efficiency, etc.) it is difficult to accurately estimate the potential for potable water savings.

The REUS 2016 (Figure 6.12) determined an average home with an occupancy rate 2.64 persons produces about 51 gallons of graywater per day split between 28 gallons from showers and 23 gallons from clothes washers. These demands equate to about 10.6 gallons per capita per day (gcd) from showers and 8.7 gcd from the clothes washer, for a total graywater production of 19.3 gcd.

Figure 2. ***Landscape Irrigation Graywater System Schematics***



Graywater irrigation systems can be configured in a few ways. Combining graywater from showers and clothes washers is estimated to yield 51 gallons of graywater per day for an average household. Though significant, it's unlikely that there would be a complete offset of potable water demand for irrigation purposes.

While 19.3 gcd equates to about 7,045 gallons of graywater production per person per year, there are three variables that make it extremely unlikely that 100 percent of the graywater produced would offset potable water demand:

1. Climate: Savings will be lower if a landscape-based graywater system is installed in a location where irrigation is required for fewer than 12 months per year.
2. Weather: Even during the irrigation season there are likely to be days when precipitation provides all or part of required irrigation.
3. Accuracy and Timing Limitations: It is unlikely a homeowner would accurately calculate and balance irrigation demands and graywater availability on a daily basis.[21]

[21] Many homeowners significantly over-water or under-water their landscapes, further complicating savings estimates.

As stated earlier, there are very few independent third-party field studies that accurately quantify the potable water saving values associated with use of landscape-based graywater systems. The National Academy of Sciences report *Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits* (page 57) states "the maximum possible potential for demand reduction that can be achieved through graywater reuse…does not reflect what can be realistically achieved in the near future" and the conclusion of the report (page 87) states "water savings associated with graywater irrigation at the household scale have not been demonstrated with confidence."

While it appears likely that less than one gallon of potable water will be offset for each gallon of graywater produced in a home, there are currently no known studies that accurately identify the relationship between graywater production and potable water savings. As such, Equations 5a, 5b, and 5c assume the combined impact of weather and accuracy and timing limitations (weather/accuracy) will conservatively reduce potable water savings to 75% of the theoretical value, thus reducing the potential savings from laundry-to-landscape systems to 6.5 gcd (75% x 8.7 gcd), the potential savings from shower-based (branched drain) systems to 8.0 gcd (75% x 10.6 gcd), and the potential savings from pumped systems to 14.5 gcd (75% x 19.3 gdc).[23]

The study, ***Residential Greywater Systems in California***,[22] analyzed water consumption data from 37 homes with irrigation-based graywater systems. The study found a large range in water savings with an average savings of 11 gallons per person per day in homes that installed graywater systems but did not implement any other water savings measures. The study also found that many homeowners implemented other water efficiency measures in addition to installing a graywater system, resulting in an average overall program water savings of 17 gallons per person per day. Some of the participating homes added new plant beds after installing their graywater system and experienced a slight increase in water demand, though not as great an increase as if they had not installed the graywater system.

As stated earlier, the potential for potable water savings is greater for irrigation-based graywater systems installed in climates with longer irrigation seasons. Water utilities should use the length of their own irrigation season when using Equations 5a through 5c. For illustration purposes, Table 5 provides examples of annual household savings values for the three types of systems using Equations 5a, 5b, and 5c and assuming an irrigation season of 274 days (9 months).

Equation 5a: Laundry-to-Landscape System Annual Household Savings, gallons

6.5 gcd x pph x irrigation season (days/year)

Equation 5b: Branched Drain System Annual Household Savings, gallons

8.0 gcd x pph x irrigation season (days/year)

Equation 5c: Pumped System Annual Household Savings, gallons

14.5 gcd x pph x irrigation season (days/year)

[22] The complete study *Residential Greywater Irrigation Systems in California: An Evaluation of Soil and Water Quality, User Satisfaction, and Installation Costs*, Laura Allen, et al., is available at https://greywateraction.org/residential-greywater-system-study/.
[23] An actual-to-theoretical savings factor has been assumed until sufficient independent third-party field study data becomes available to more accurately quantify the combined impact of weather and precision limitations.

Table 5. Landscape Irrigation Graywater Systems, Estimated Annual Household Water Savings (gallons) for 274-day Irrigation Season

Persons per Household	*Laundry-to Landscape (6.5 gcd x 274 days/yr)*	*Branched Drain (8.0 gcd x 274 days/yr)*	*Pumped (14.5 gcd x 274 days/yr)*
1	1,781	2,192	3,973
2	3,562	4,384	7,946
3	5,343	6,576	11,919
4	7,124	8,768	15,892
5	8,905	10,960	19,865
6	10,686	13,152	23,838

3.2 *Gross Cost Savings to Homeowner*

The gross annual cost savings to a homeowner installing a graywater system is calculated as the annual volume of potable water savings multiplied by the marginal volumetric rate for water (or water & wastewater) – see Equations 6a, 6b, and 6c.

Equation 6a: Laundry-to-Landscape System Gross Annual Cost Savings

6.5 gcd x pph x irrigation season (days/year) x Volumetric Cost of Water

Equation 6b: Branched Drain Systems Gross Annual Cost Savings

8.0 gcd x pph x irrigation season (days/year) x Volumetric Cost of Water

Equation 6c: Pumped Systems Gross Annual Cost Savings

14.5 gcd x pph x irrigation season (days/year) x Volumetric Cost of Water

Tables 6a, 6b, and 6c provide examples of gross annual cost savings values for different persons per household values and different volumetric water/wastewater rates assuming a 274-day (9-month) irrigation season. Water utilities with shorter or longer irrigation seasons should expect to achieve different annual savings values than those illustrated in Tables 6a, 6b, and 6c.

Table 6a. Laundry-to-Landscape Graywater System Gross Annual Household Cost Savings

Persons per Household	*Annual Water Savings (gallons)*	*Volumetric Rate per 1,000 gallons*						
		$2	*$5*	*$8*	*$11*	*$14*	*$17*	*$20*
1	1,781	$4	$9	$14	$20	$25	$30	$36
2	3,562	$7	$18	$28	$39	$50	$60	$71
3	5,343	$11	$27	$43	$59	$75	$91	$107
4	7,124	$14	$36	$57	$78	$100	$121	$142
5	8,905	$18	$44	$71	$98	$125	$151	$178
6	10,686	$21	$53	$85	$117	$149	$181	$214

Example Calculation: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons.

5,343 gal/year x $14/1,000 gal = $75/year gross savings

Table 6b. Branched Drain Graywater System Gross Annual Household Cost Savings

Persons per Household	***Annual Water Savings (gallons)***	***Volumetric Rate per 1,000 gallons***						
		$2	***$5***	***$8***	***$11***	***$14***	***$17***	***$20***
1	2,192	$4	$11	$18	$24	$31	$37	$44
2	4,384	$9	$22	$35	$48	$61	$74	$88
3	6,576	$13	$33	$53	$72	$92	$112	$131
4	8,768	$18	$44	$70	$96	$123	$149	$175
5	10,960	$22	$55	$88	$120	$153	$186	$219
6	13,152	$26	$66	$105	$145	$184	$223	$263

Example Calculation: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons.

6,576 gal/year x $14/1,000 gal = $92/year gross savings

Table 6c. Pumped Graywater System Gross Annual Household Cost Savings

Persons per Household	***Annual Water Savings (gallons)***	***Volumetric Rate per 1,000 gallons***						
		$2	***$5***	***$8***	***$11***	***$14***	***$17***	***$20***
1	3,973	$8	$20	$32	$44	$56	$67	$79
2	7,946	$16	$40	$64	$87	$111	$135	$159
3	11,919	$24	$60	$95	$131	$167	$202	$238
4	15,892	$32	$79	$127	$175	$222	$270	$318
5	19,865	$40	$99	$159	$218	$278	$337	$397
6	23,838	$48	$119	$191	$262	$333	$405	$477

Example Calculation: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons.

11,919 gal/year x $14/1,000 gal = $167/year gross savings

3.3 *Net Cost Savings to Homeowner*

The annual net cost savings to a homeowner is calculated as the gross annual cost savings minus any operations and maintenance (O&M) costs, such as the cost of electricity, filters, chemicals, or replacement of parts – see Equation 7.

Equation 7: Landscape Irrigation Graywater Systems Net Annual Cost Savings

Gross Annual Cost Savings – Annual O&M Costs

There are few O&M costs associated with laundry-to-landscape and branched drain systems. In laundry to landscape systems the clothes washer pumps graywater directly to the landscape[24] and in branched drain systems the graywater flows directly to the landscape by gravity. As such, the net annual cost savings

[24] The clothes washer will either pump graywater to the sewer or to the landscape. There are no 'additional' energy costs associated with pumping graywater to the landscape.

to customers for these two types of systems is essentially equal to the gross annual cost savings – see Table 7a and 7b.

Table 7a. Laundry-to-Landscape Graywater System Net Annual Household Cost Savings

Persons per Household	***Annual Water Savings (gallons)***	***Volumetric Rate per 1,000 gallons***						
		$2	***$5***	***$8***	***$11***	***$14***	***$17***	***$20***
1	1,781	$4	$9	$14	$20	$25	$30	$36
2	3,562	$7	$18	$28	$39	$50	$60	$71
3	5,343	$11	$27	$43	$59	$75	$91	$107
4	7,124	$14	$36	$57	$78	$100	$121	$142
5	8,905	$18	$44	$71	$98	$125	$151	$178
6	10,686	$21	$53	$85	$117	$149	$181	$214

<u>Example Calculation</u>: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons, $0 per year O&M costs

5,343 gal/year x $14/1,000 gal - $0/year O&M = $75/year net savings

Table 7b. Branched Drain Graywater System Net Annual Household Cost Savings

Persons per Household	***Annual Water Savings (gallons)***	***Volumetric Rate per 1,000 gallons***						
		$2	***$5***	***$8***	***$11***	***$14***	***$17***	***$20***
1	2,192	$4	$11	$18	$24	$31	$37	$44
2	4,384	$9	$22	$35	$48	$61	$74	$88
3	6,576	$13	$33	$53	$72	$92	$112	$131
4	8,768	$18	$44	$70	$96	$123	$149	$175
5	10,960	$22	$55	$88	$120	$153	$186	$219
6	13,152	$26	$66	$105	$145	$184	$223	263

<u>Example Calculation</u>: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons, $0 per year O&M costs.

6,576 gal/year x $14/1,000 gal - $0/year O&M = $92/year net savings

For pumped systems, however, the National Academy of Sciences report *Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits* (Table 7.1) estimates operations costs (i.e., chemical and energy costs) to be about $1 per thousand gallons.

Maintenance costs associated with pumped systems are expected to be minimal for the first few years when the system is relatively new; however, many system parts – and ultimately the entire system – will eventually need replacing. Each pumped graywater system design will have its owns maintenance requirements and costs for cleaning or replacing filters, for adding chemicals, for cleaning storage tanks, etc. While the average annual cost of maintenance will vary depending on system design, in lieu of system-specific maintenance cost field data, a cost of $36 per year has been assumed for calculations in this report.[25]

Table 7c presents the annual net cost savings for pumped systems using an operational cost of $1 per thousand gallons and an annual maintenance cost of $36. The negative annual net savings values in Table 7c illustrate examples where the costs associated with using a graywater system may exceed the annual savings from reduced water purchases.

Table 7c. Pumped Graywater System Net Annual Household Cost Savings

Persons per Household	***Annual Water Savings (gallons)***	***Volumetric Rate per 1,000 gallons***						
		$2	***$5***	***$8***	***$11***	***$14***	***$17***	***$20***
1	3,973	-$32	-$20	-$8	$4	$16	$28	$39
2	7,946	-$28	-$4	$20	$43	$67	$91	$115
3	11,919	-$24	$12	$47	$83	$119	$155	$190
4	15,892	-$20	$28	$75	$123	$171	$218	$266
5	19,865	-$16	$43	$103	$163	$222	$282	$341
6	23,838	-$12	$59	$131	$202	$274	$345	$417

Example Calculation: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons, $12/year operations costs (i.e., $1 per 1,000 gallons x 11.919 thousand gallons), $36/year maintenance cost.

11,919 gal/year x $14/1,000 gal - $12 /year operations - $36/year maintenance = $119/year net savings

3.4 *Estimated Simple Cost Payback to Homeowner*

The simple payback to a homeowner installing a graywater system is calculated as the total installed cost of the system divided by the annual net cost savings – see Equation 8.

Equation 8: Landscape Irrigation Graywater Systems Payback Period

Total Installed Cost ÷ Net Annual Cost Savings

Two reports – the National Academies of Sciences, *Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits* and the Greywater Action report *Residential Graywater Irrigation Systems in California: An Evaluation of Soil and Water Quality, User Satisfaction, and Installation Costs* estimate the costs for landscape-based graywater systems provided in Table 8.

[25] A 2014 article by Donna Ferguson posted on www.theguardian.com (*Greywater Systems: Can They Really Reduce Your Bills?)* estimates maintenance costs of $36 per year (converted from £30 per year). Several reports identify higher costs, e.g., *Economic Assessment Tool for Greywater Recycling Systems* estimates costs of about $73 per year (converted from £60 per year for inspection and maintenance), F.A. Memon, PhD, et al.

Table 8. Purchase/Installation Cost of Landscape Irrigation Graywater Systems

Reference	***Laundry-to Landscape DIY***	***Laundry-to Landscape Professional Installation***	***Branched Drain DIY***	***Branched Drain Professional Installation***	***Pumped System DIY***	***Pumped System Professional Installation***
National Academies of Sciences	$120	$1,250	NA	NA	$2,300	$10,000*
Greywater Action	$250	$750	$700	$1,750	$1,800	$3,800
Average	**$185**	**$1,000**	**$700**	**$1,750**	**$2,050**	**$6,900**

**Report identifies a range in costs from $5,000 to $15,000. An average cost of $10,000 has been assumed.*

In Tables 9 through 11 shading indicates conditions that result in a payback period of 15 years or less based on the assumption that the average life span of a graywater system is about 15 years, i.e., shaded cells show conditions where the system should provide a net cost savings to the customer.[26]

Table 9a. Do-it-Yourself Laundry-to-Landscape Payback Period in Years (@$185)

Persons per Household	***Annual Water Savings (gallons)***	***Volumetric Rate per 1,000 gallons***						
		$2	***$5***	***$8***	***$11***	***$14***	***$17***	***$20***
1	1,781	52	21	13	9	7	6	5
2	3,562	26	10	6	5	4	3	3
3	5,343	17	7	4	3	2	2	2
4	7,124	13	5	3	2	2	2	1
5	8,905	10	4	3	2	1	1	1
6	10,686	9	3	2	2	1	1	1

<u>Example Calculation</u>: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons.

$185 installed cost ÷ $75 /year net savings (Table 7a) *= 2 years*

[26] The report *Life Cycle Impact Assessment of Greywater Recycling Technology for New Developments*, F.A. Memon et al. (revised 2007) estimates an average design life of 15 years.

Table 9b. Professional Installation Laundry to Landscape Payback Period in Years (@$1,000)

Persons per Household	Annual Water Savings (gallons)	Volumetric Rate per 1,000 gallons						
		$2	$5	$8	$11	$14	$17	$20
1	1,781	281	112	70	51	40	33	28
2	3,562	140	56	35	26	20	17	14
3	5,343	94	37	23	17	13	11	9
4	7,124	70	28	18	13	10	8	7
5	8,905	56	22	14	10	8	7	6
6	10,686	47	19	12	9	7	6	5

Example Calculation: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons.

$1,000 installed cost ÷ $75 /year net savings (Table 7a) *= 13 years*

Table 10a. Do-it-Yourself Branched Drain Payback Period in Years (@$700)

Persons per Household	Annual Water Savings (gallons)	Volumetric Rate per 1,000 gallons						
		$2	$5	$8	$11	$14	$17	$20
1	2,192	160	64	40	29	23	19	16
2	4,384	80	32	20	15	11	9	8
3	6,576	53	21	13	10	8	6	5
4	8,768	40	16	10	7	6	5	4
5	10,960	32	13	8	6	5	4	3
6	13,152	27	11	7	5	4	3	3

Example Calculation: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons

$700 installed cost ÷ $92 /year net savings (Table 7b) *= 8 years*

Table 10b. Professional Installation Branched Drain Payback Period in Years (@$1,700)

Persons per Household	Annual Water Savings (gallons)	Volumetric Rate per 1,000 gallons						
		$2	$5	$8	$11	$14	$17	$20
1	2,192	388	155	97	71	55	46	39
2	4,384	194	78	49	35	28	23	19
3	6,576	129	52	32	24	18	15	13
4	8,768	97	39	24	18	14	11	10
5	10,960	78	31	19	14	11	9	8
6	13,152	65	26	16	12	9	8	6

Example Calculation: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons.

$1,700 installed cost ÷ $92 /year net savings (Table 7b) *= 18 years*

Table 11a. Do-it-Yourself Pumped Systems Payback Period in Years (@$2,050)

Persons per Household	Annual Water Savings (gallons)	Volumetric Rate per 1,000 gallons						
		$2	$5	$8	$11	$14	$17	$20
1	3,973	-	-	-	550	131	74	52
2	7,946	-	-	104	47	30	22	18
3	11,919	-	176	43	25	17	13	11
4	15,892	-	74	27	17	12	9	8
5	19,865	-	47	20	13	9	7	6
6	23,838	-	35	16	10	7	6	5

Example Calculation: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons.

$2,050 installed cost ÷ $119 /year net savings (Table 7c) *= 17 years*

Table 11b. Professional Installation Pumped Systems Payback Period in Years (@$6,900)

Persons per Household	Annual Water Savings (gallons)	Volumetric Rate per 1,000 gallons						
		$2	$5	$8	$11	$14	$17	$20
1	3,973	-	-	-	1,850	441	250	175
2	7,946	-	-	352	159	103	76	60
3	11,919	-	591	145	83	58	45	36
4	15,892	-	250	92	56	40	32	26
5	19,865	-	159	67	42	31	24	20
6	23,838	-	116	53	34	25	20	17

Example Calculation: 3 pph, 274-day irrigation season, volumetric rate of $14/1,000 gallons.

$6,900 installed cost ÷ $119 /year net savings (Table 7c) *= 58 years*

4.0 Financial Benefit to the Utility

Utilities can benefit financially from reducing customer water demands, but the magnitude of these benefits vary from utility to utility depending on their own unique conditions. For example, benefits can be significant if the utility is operating at or near its system's peak production rate or if it is faced with a shortage of water supply, whereas the benefit to a utility with a plentiful water supply and an adequately sized water treatment and distribution infrastructure will not be as great.[27]

One way to evaluate the financial benefit of lowering water demands to a utility is to compare the unit cost of achieving water savings through the implementation of water efficiency programs (demand-side management) to the unit cost of expanding the system's water supply.[28] If the unit cost of the demand-side option is lower, the water efficiency program is cost-effective and provides a financial benefit to the utility.

Many water utilities provide financial incentives in the form of rebates to customers installing water-efficient products. Ideally the level of the rebate is set such that it is high enough to entice customers to participate in the program[29] but low enough to be cost-effective to the water utility. Stated another way, the unit cost of implementing the demand-side option must be lower (or at least no higher) than the unit cost of implementing the supply option if the program is to be cost-effective to the utility.

Water utilities can calculate their maximum rebate level for any water efficiency measure by multiplying their unit cost of providing additional supply ($/gallon/day) by the expected average daily water savings per participating customer (e.g., gallons/day)[30] – see Equation 9.

<u>Equation 9: Maximum Per Customer Rebate Level Based on Equivalent Unit Cost of Supply</u>

gcd x pph x Irrigation Season (days) ÷ 365 days x Utility Unit cost of Supply ($/gallon/day)

<u>Example Calculation</u>: Maximum cost-effective rebate, landscape-based graywater system saving 14.5 gcd, 3 pph, 274-day irrigation season, and a Unit Cost of Supply of $8 per gallon/day.

14.5 gcd x 3 pph x 274/365 days/year x $8 per gal/day = $261

[27] Lower water demands will also reduce a utility's variable costs (e.g., energy and chemical costs).

[28] The capacity of a water treatment plants is expressed as its maximum daily production rate, e.g., gallons/day. In this example the unit cost of supply would be expressed as dollars per gallons/day or $/gallon/day.

[29] If a rebate level is relatively low compared to the total customer cost to participate in a program (e.g., to buy and install a graywater system) the rebate may not be sufficient to entice customers that would not participate in the program without a rebate. Thus many of the program participants might be considered "free riders."

[30] While it is acknowledged that there may be other benefits associated with reducing water demands, e.g., environmental benefits, the focus of this document is specifically on the financial benefits.

5.0 Conclusion

While most homes produce significant volumes of graywater each day, this water is typically discharged to the sewer or septic tank as wastewater. While graywater could be seen as a "free" alternative source of water for such uses as toilet flushing or landscape irrigation, there are generally costs associated with purchasing, installing, operating, and maintaining graywater systems. Although financial benefits are not the only reason homeowners may choose to install a graywater system, if the total life-cycle cost of owning/operating a graywater system is greater than the total cost savings achieved through lower potable water purchases, the graywater system would not be considered cost-effective to the homeowner. Features that may result in a greater potential customer cost savings include:

- High marginal volumetric water (or water/sewer) rates
- Home is located in area with long irrigation season (e.g. >7 months for landscape-based graywater systems)
- Home has a high occupancy rate
- Lower installed costs for graywater systems
- Lower operations and maintenance costs
- Do-it-Yourself Graywater system is installed during home construction vs. retrofit

While reducing customer demands during times of drought can be beneficial to water utilities, graywater reuse programs are better suited as long-term, ongoing programs rather than as short-term solutions to drought. Sustained reductions in customer demands are especially beneficial to water utilities with limited water supplies or that need to expand their water supply/treatment infrastructure. Utilities faced with growing water demands must either increase the supply or reduce the demand (or a combination of both). Utilities must consider the net "yield" and unit costs associated with both supply-side and demand-side options – the solution with the lowest overall unit cost of implementation (e.g., $/gallon/day) that delivers the required incremental or total supply or demand offset will be the most cost-effective solution for the utility.

One of the key messages in this report is that the water savings achieved by a home installing a graywater system is not equal to the volume of graywater produced or captured but rather to **the long-term reduction in potable water demands** achieved by the homeowner. While it is relatively easy to estimate the potential potable water savings associated with the use of shower-to-toilet graywater systems, it is difficult to estimate the potential potable water savings associated with the use of landscaped-based graywater systems because of the large number of variables involved. The completion of more independent field studies may help to quantify these savings.

The savings values provided in this report are based on clearly identified references and assumptions and are meant to provide insight regarding the key parameters that affect savings. Water utilities are strongly encouraged to apply their own values to the equations provided in this report, e.g., volumetric water rates, persons per household, length of irrigation season, graywater system cost, unit cost of adding additional water supply, etc., to assess the cost-effectiveness associated with implementing a single-family graywater reuse program in their own community. As data from more independent third-party filed studies becomes available (especially regarding landscape-based graywater systems) it is hoped that the values identified in this report can be further refined.

Additional information on graywater systems is available on the Alliance for Water Efficiency website: http://www.allianceforwaterefficiency.org.