

Sustainability Measured

Part 1 – Operations & Management

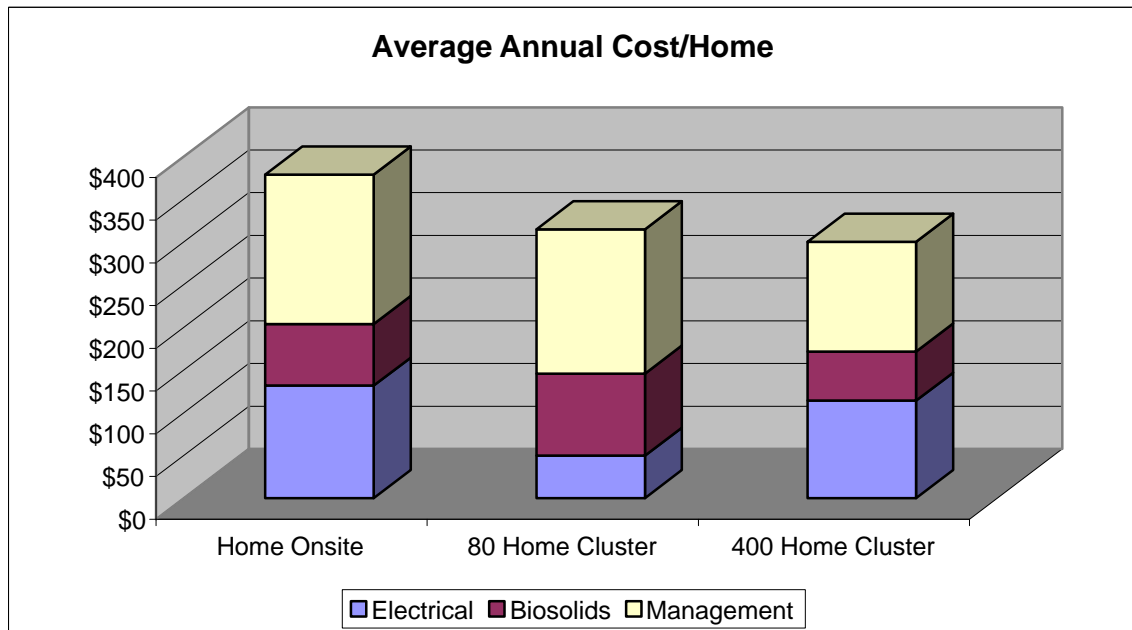
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Executive Summary

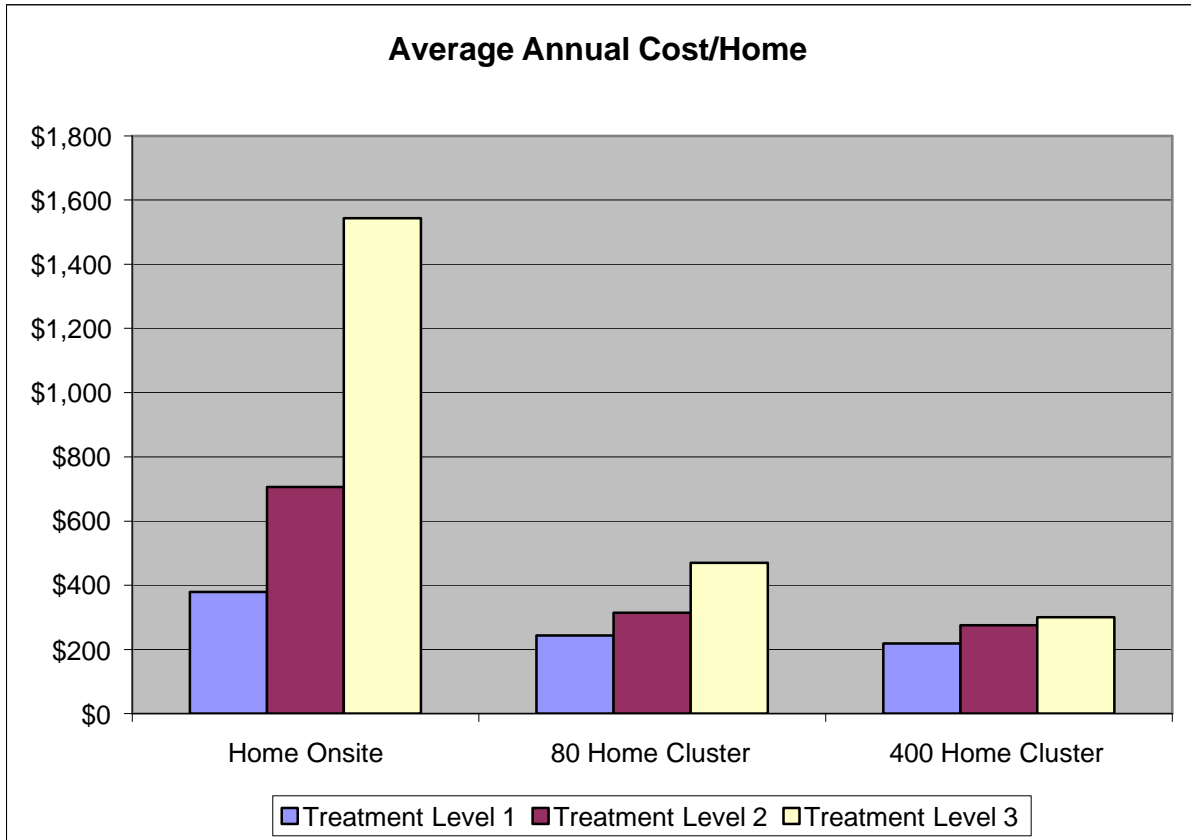
Virtually everyone seems to agree on the need to provide sustainable Water and Wastewater Infrastructure. But what does this mean and how do we know it's sustainable. The purpose of this paper is to help answer these questions. We will propose a comprehensive means to measure sustainability and evaluate an array of infrastructure and technology alternatives.

In Part 1 of what we plan as a 3 Part Series, the focus is on measuring ongoing Operations and Management costs for alternative wastewater infrastructure profiles. Presumably, the lower ongoing operational costs are, the more affordable and sustainable infrastructure is. We will examine several technology options available for individual home onsite systems, for cluster systems serving 80 residences and for larger cluster systems serving 400 residences. We will measure electrical costs, biosolids residual costs, management, sampling and other operating costs for collection, treatment and dispersal/reuse.

One way to do this is to compare the costs of (1) home onsite systems, producing secondary quality treatment and soil dispersal with (2) cluster systems providing advanced secondary treatment and nutrient reduction followed by soil dispersal with (3) larger cluster systems producing advanced nutrient reduction and meeting wastewater reclamation and reuse quality standards suitable for toilet reuse and landscape irrigation. This comparison, as detailed in this paper, provides the following results:



These results, however, are like comparing apples with pears and oranges. When we evaluate different levels of required treatment performance, we get different results:



Soils as a treatment component can be very important but can also be quite limiting. For example, if we need high levels of nutrient reduction to protect groundwater or surface water quality but have soils that offer low nutrient reduction efficiency, we need higher levels of “mechanical” treatment. Or when we want to use reclaimed wastewater in applications suitable for human contact such as for toilets or landscape irrigation, we must rely on higher levels of mechanical treatment to meet this need. Our point is not to draw conclusions, but to point out the variables we need to understand, particularly when the levels of mechanical treatment required increase. This data represents just one measure of sustainability and needs to be considered in full context with the other critical variables to be addressed in Parts 2 and 3. We encourage input and comment.

Background

There is much talk these days about the need for low impact development and decentralized and sustainable water and wastewater infrastructure. Yet adherents, passionate in their beliefs, are often short on specifics and data to support their position. What is decentralized water infrastructure and what does it look like? What is sustainable water infrastructure and how do we know its sustainable?

The U.S. Environmental Protection Agency (EPA) defines sustainability as “meeting the needs of the present without compromising the ability of the future generations to meet their own needs.” (<http://www.epa.gov/Sustainability/>) In economic terms, we believe that a wastewater system that one can truly afford to pay for capital and operational cost on a permanent basis is a sustainable system. We all need to be interested in having a sustainable wastewater system, not just a decentralized wastewater system.

In an effort to better understand these issues, we have posited a theoretical 400 acre parcel zoned for a total of 400 residences with public water available but no sewer. If 40 residences were planned for this property, there would be little debate. Decentralized infrastructure would be appropriate and the only question would be which home onsite system makes the most sense. But at densities of one home per 2 acres or one home per 1 acre, the issues become more complex and the trade-offs far more acute. Therefore, we will focus this discussion where we have higher densities.

To judge sustainability, there needs to be some means of measuring the relative sustainability of alternative infrastructure profiles. As a starting point, we propose to use three measurement criteria:

1. Environmental Impacts – Each configuration should be judged/evaluated based on the following:
 - a. Land use patterns and conservation
 - b. Energy requirements
 - c. Groundwater quality and aquifer impacts
 - d. Surface water quality impacts
 - e. Water conservation
 - f. Storm water generation and mitigation needed
 - g. Roads and other site infrastructure maintenance required
2. Economics – Each configuration should be judged/evaluated based on the following economic criteria:
 - a. Initial capital costs,
 - b. Ongoing operating costs, and
 - c. 30+ year life cycle costs.
3. Institutional – What institutional structures are in place or need to be in place to insure the long term integrity of the infrastructure profile proposed? Specifically, this should include:
 - a. Regulatory framework,
 - b. Compliance checks and balances,
 - c. Management infrastructure and long term sustainability.

Next, let’s further detail what each of the wastewater infrastructure alternative looks like.

Home Unit Based Infrastructure

Community infrastructure built using the home unit as the fundamental building block would today typically rely on an aerobic treatment unit, packed bed filter or recirculating media filter for wastewater treatment, followed by drip or trench dispersal with pressure distribution. Granted, there are other more conventional alternatives such as a septic tank followed by gravity distribution. However, these alternatives typically become much less viable as density increases, can fail in time and therefore will not be considered here. For this alternative, we will have 400 independently accountable wastewater systems.

80 Home Clustered Infrastructure

Dividing the 400 acres into 5 roughly equal water management units, allows us to cluster residences into smaller lot sizes leaving significant community open space and requiring less investment in roads and other utilities. Each cluster unit will be designed for managing wastewater generated by 80 residences.

Some have advocated placing home scale wastewater treatment units, such as those identified above, at each residence and then pumping treated effluent to a common area for final “polishing” and dispersal. Using constructed wetlands for polishing and denitrification is often mentioned.

Some advocate placing septic tanks at each residence and then pumping (S.T.E.P.) or gravity flow (S.T.E.G.) in smaller diameter sewer mains to deliver wastewater to common areas for treatment to the level required. Others prefer using grinder pumps if low pressure collection is determined to be appropriate or simply conventional gravity sewer collection to a cluster treatment facility and dispersal center.

Treatment technologies now most commonly used for wastewater flows in this 15,000 to 20,000 gpd capacity range include: recirculating media filters, aerobic treatment plants and trickling filters.

400 Home Clustered Infrastructure

Using larger cluster water management units in the 100,000 gpd range requires some greater investment in sewage collection (S.T.E.P., S.T.E.G., grinder pumps, vacuum valve pits, or gravity sewer with or without pump stations) but also may offer some advantages including:

- Economies of scale in treatment facilities
- Ability to achieve higher levels of treatment for nutrient reduction and reclamation/reuse
- Management efficiency
- Greater flexibility in land use and layout and higher potential for land conservation

Treatment technologies currently most commonly used in the 100,000 gpd range and up include activated sludge plants, sequencing batch reactors (SBR's) and membrane bio-reactors (MBR's). Since MBR technology is commonly viewed as providing the highest potential level of treatment but at the highest capital and operating cost, we will use this technology alternative as the primary point of comparison for larger 100,000 gpd+ community cluster systems.

The purpose, of what we plan to be a series of papers, is to help inform the debate about decentralized and sustainable water infrastructure, and as constructively and as objectively as we can, evaluate these alternatives in measurable sustainability terms – environmental impact, economics and institutional fit. Therefore, we will break our analysis down into more digestible bites:

Part 1 – Comparative Operating and Management Economics

Part 2 – Comparative Capital Costs and Integrated Life Cycle Costs

Part 3 – Environmental Impacts and Institutional Needs

Comparative Operating and Management Economics

For each decentralized wastewater infrastructure alternative we have attempted to quantify the economics of operations and management focusing on energy requirements, biosolids management, consumables such as methanol, alum and UV bulbs, operator requirements and sampling/reporting needs. Several assumptions common to all alternatives include:

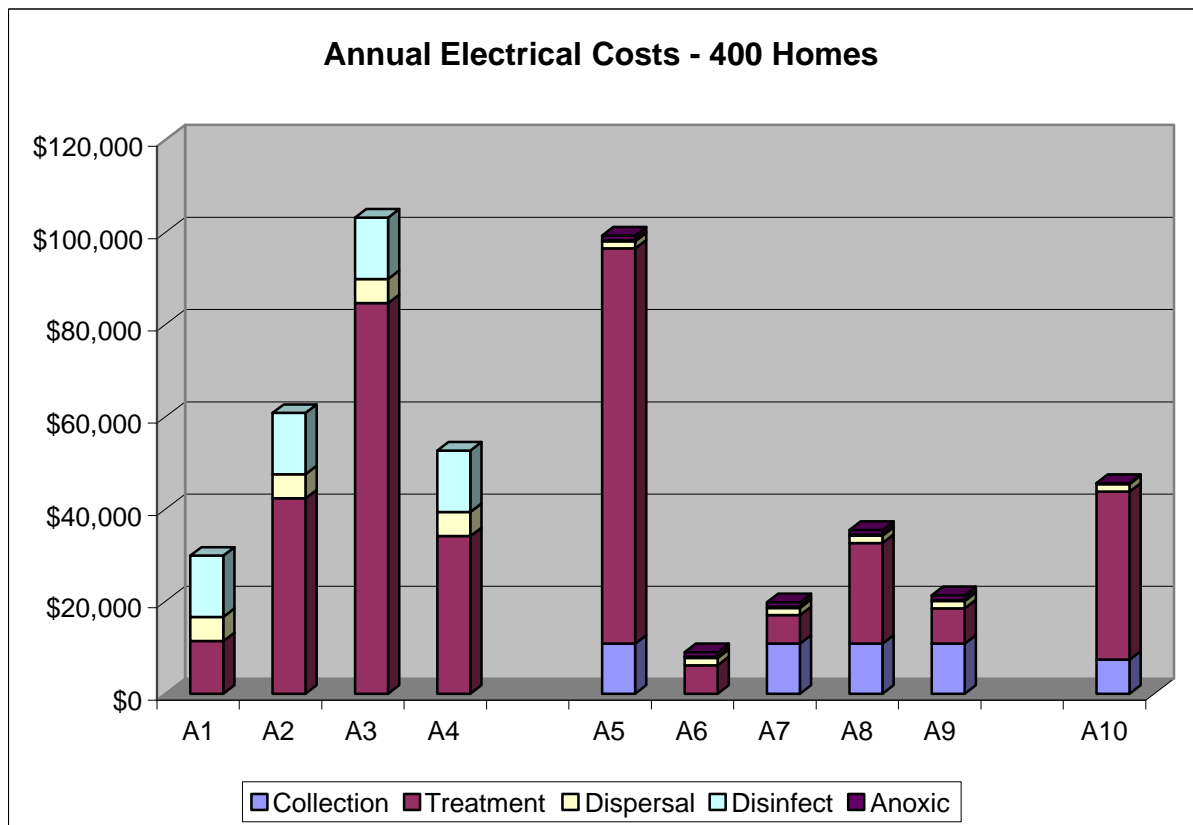
- 200 gallons per day per residence on average actual flows. Though increased conservation will likely reduce these flows overtime, the same biological treatment capacity will still be needed.
- Pump and blower run times and kwh usage per manufacturer published specifications.

Though there are many alternative configurations, for simplicity we will narrow this matrix to the following 10 alternatives, including four home onsite systems, five 80 home cluster systems and one for a 400 home cluster system:

	Collection	Treatment	Dispersal
400 Home Onsite Systems			
Alternative 1	N/A	Recirc Filter	Low Pressure
Alternative 2	N/A	ATU - 1	Low Pressure
Alternative 3	N/A	ATU - 2	Low Pressure
Alternative 4	N/A	Pack Bed Filter	Low Pressure
5 - 80 Home Cluster Systems			
Alternative 5	STEP	Home ATU - 1	Wetland + Drip
Alternative 6	STEG	Recirc Filter	Drip
Alternative 7	STEP	Recirc Filter	Drip
Alternative 8	STEP	ATU	Drip
Alternative 9	STEP	Trickling Filter	Drip
1 - 400 Home Cluster System			
Alternative 10	5 Lift Stations	MBR	Drip

Electrical (Energy) Costs

The following chart summarizes estimated annual electrical costs for wastewater infrastructure serving 400 homes assuming \$0.10/kwh billing rate for each of the above alternatives:



Though disinfection and use of anoxic reactors for nitrogen removal will not be needed in many if not most cases, it is important to understand the potential impact of these higher levels of treatment.

Given the much higher level of consistently reliable treatment provided by MBR technology (<5 BOD, <5 TSS, <5 TN, <1 TP, <1 NTU and < 2.3 fecal), it is perhaps unfair to compare apples with oranges and pears. However, we need to better understand these issues and what can be gained or sacrificed and at what cost depending on the choices we make.

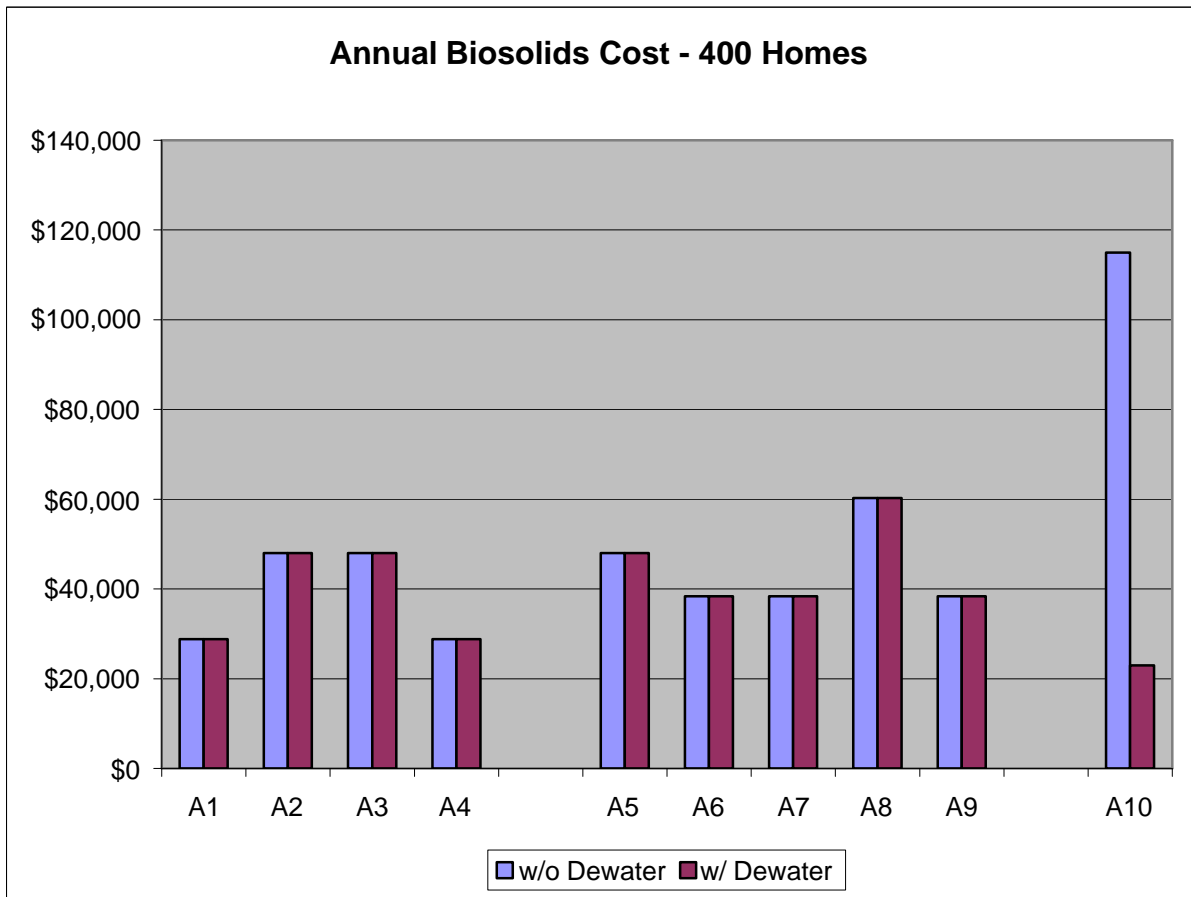
Biosolids Management

All biological treatment processes generate residual biosolids. The volume of residual biosolids generated will vary depending on the treatment technology used and collection method used. To evaluate these tradeoffs, we made the following assumptions:

Treatment Plant Residuals	
(lbs/solids/lb BOD)	
Recirc Media Filters	35%
Trickling Filters	35%
Fixed Film ATU	50%
Activated Sludge	75%
MBR	70%

STEP/STEG tank pumping frequencies were assumed to be every 7 ½ years (the typical debated range is from 5 to 10 years). To calculate biosolids volumes, treatment facility influent BOD concentrations were assumed to be 300 mg/L and 150 mg/L respectively for gravity/grinder collection and STEP/STEG. We also assumed that treatment facility biosolids will be 2% solids consistency when pumped unless dewatering and further processing is provided.

As with septage, small treatment facility biosolids are typically hauled to municipal treatment plants, disposed of in land fills or hauled to special land application sites. Septage hauling and disposal costs were assumed to be \$0.30 per gallon. There are certainly locations where these rates are as low as \$0.12/gallon, but we also have had to pay as high as \$0.60/gallon in the greater Atlanta area. So plug in the rates applicable to your area and calculate the numbers. They will only go up. Based on these assumptions, annual biosolids management costs for each alternative are estimated to be as follows:



For a 100,000 gpd plant, it is very affordable (\$100,000 ± in capital investment) to provide complete dewatering and biosolids management with residual material available for sustainable use within the 400 home water management unit. It may also be possible to provide biosolids dewatering for 80 home clustered or to a lesser extent the individual home sites within the 400 acre water management unit. However, pumping and transport costs would still be significant and payback from this investment will not likely pencil even for the 5 clusters.

Operating and Management Costs

Operating costs will vary considerably depending on treatment performance requirements and monitoring/sampling needs. Following is a summary of the assumptions used to evaluate three different levels of treatment and management:

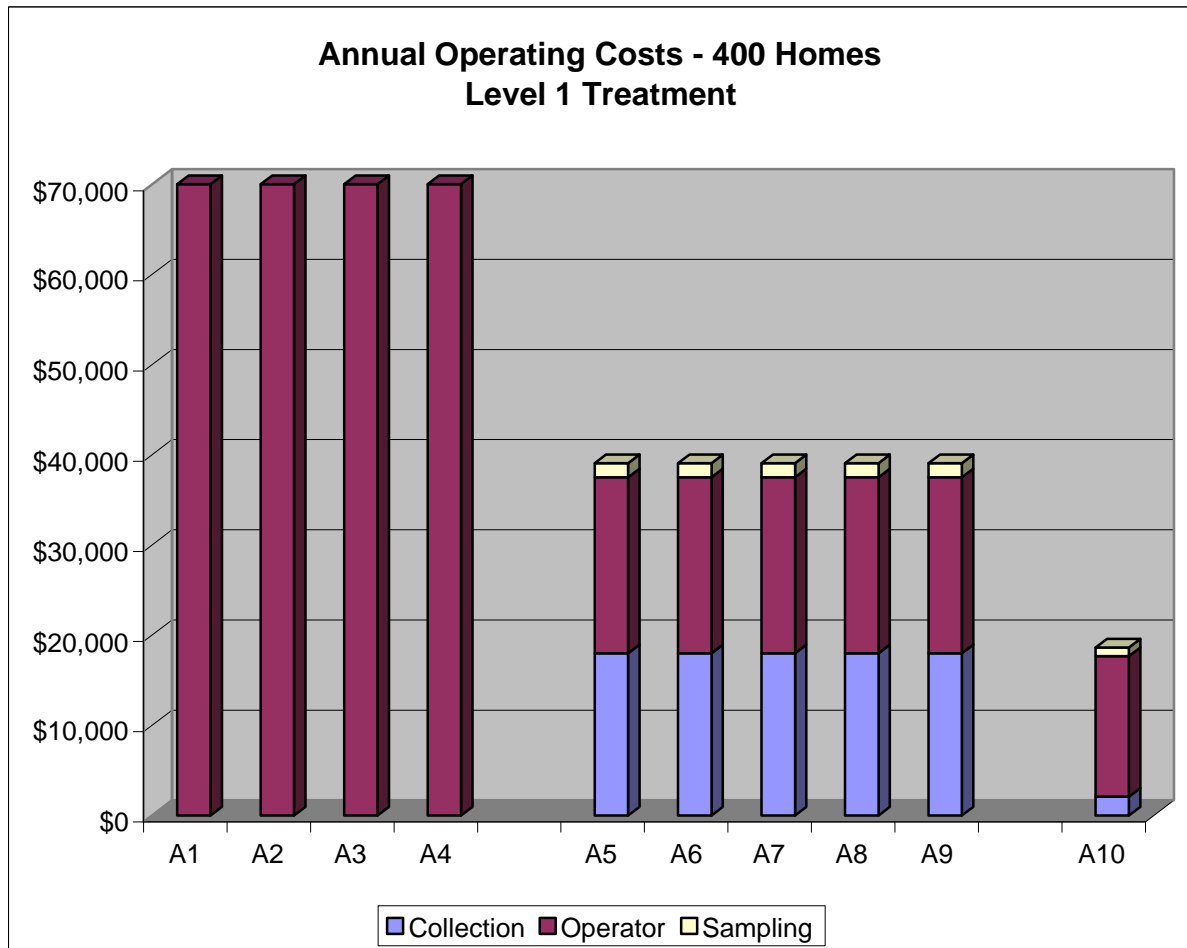
Treatment Performance	Level 1	Level 2	Level 3
BOD	30	10	10
TSS	30	10	10
Fecal	N/A	200	2.3
Total N	N/A	15 - 20	8
Total P	N/A	N/A	1

For all levels of treatment, we assumed that STEP/STEG sewer collection systems required inspection every 2 years, lift stations need to be inspected quarterly and gravity mains jetted every 5 years. If applicable, we assumed that UV bulbs must be replaced every 2 years.

One may ask why we are even considering the cost of disinfection for individual home onsite systems. The answer is that States such as ours (Washington State) permit the installation of NSF 40 certified home onsite systems with UV disinfection at sites that otherwise would not meet groundwater separation requirements.

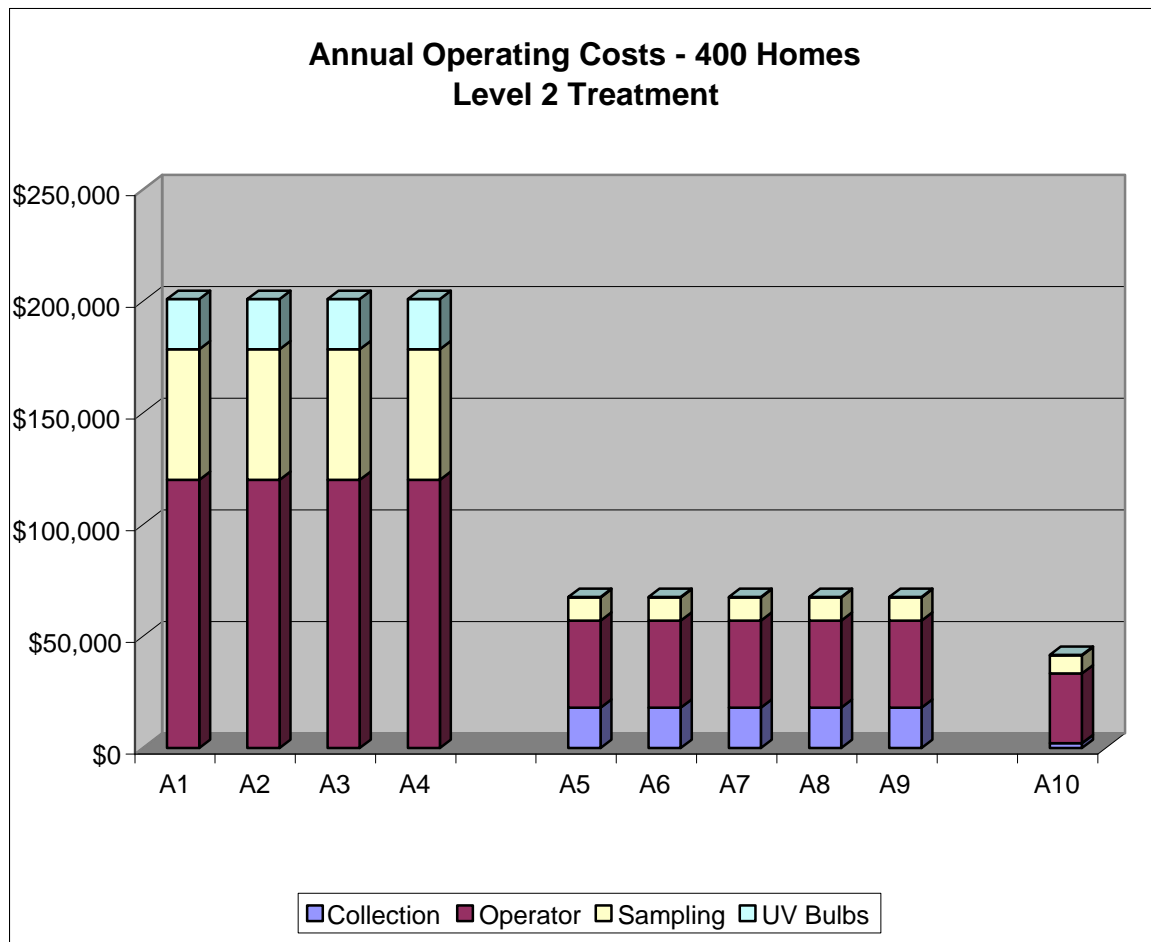
For level 1 treatment, operating costs can then be summarized as follows:

	Level 1 Treatment/Management		
	Home Onsite	80 Home Cluster	400 Home MBR
Operator Frequency			
Hrs/Week		1.5	4
Hrs/Year		78	208
\$/Hour		\$50.00	\$75.00
Visits/Yr.	1		
\$/Residence/Yr.	\$175		
Sampling Frequency - Treatment Plant	N/A	1/Qtr.	1/Mo.
Sampling Frequency - Groundwater	N/A	N/A	N/A
Sample Cost			
\$/BOD	N/A	\$52.00	\$52.00
\$/TSS	N/A	\$26.00	\$26.00
\$/TN	N/A	N/A	N/A
\$/Fecal	N/A	N/A	N/A
\$/P	N/A	N/A	N/A



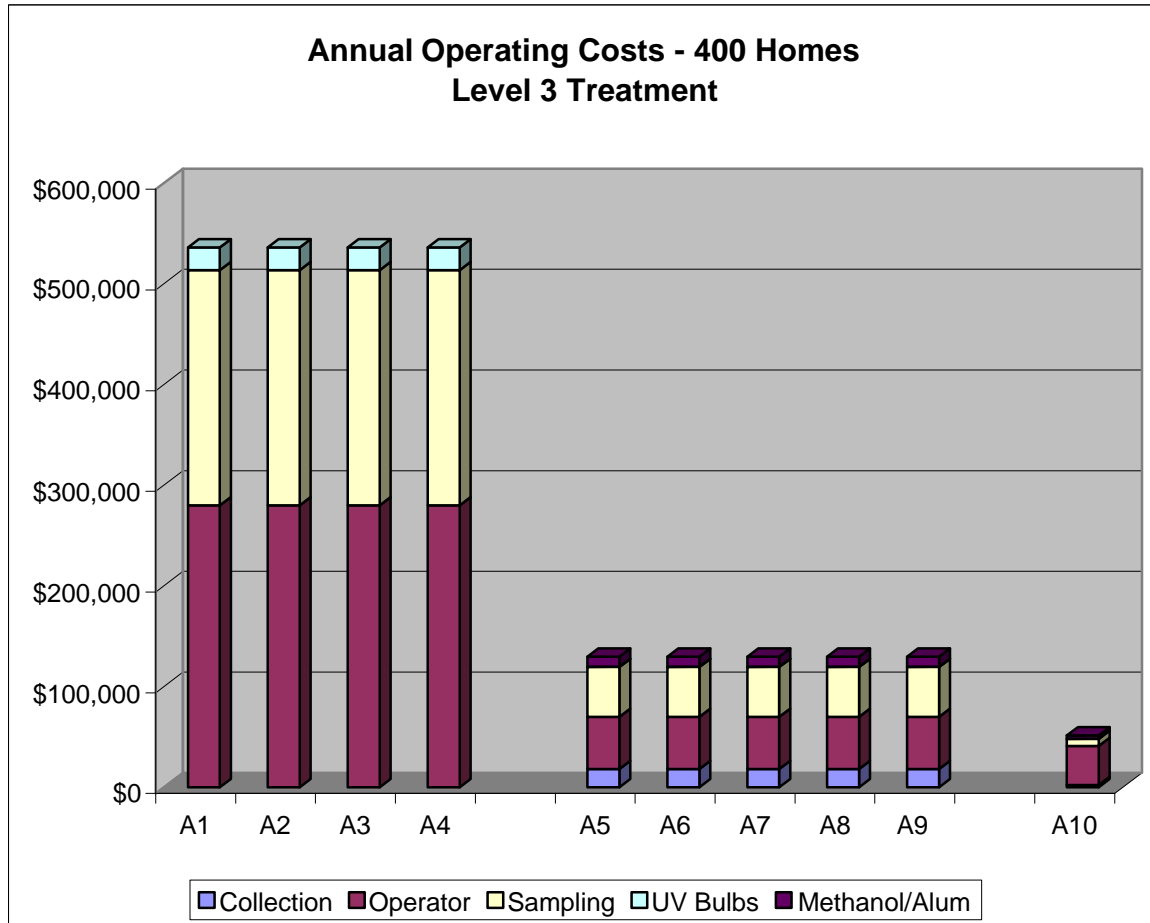
For level 2 treatment, operating costs can be summarized as follows:

	Level 2 Treatment/Management		
	Home Onsite	80 Home Cluster	400 Home MBR
Operator Frequency			
Hrs/Week		3	8
Hrs/Year		156	416
\$/Hour		\$50.00	\$75.00
Visits/Yr.	2		
\$/Residence/Yr.	\$300		
Sampling Frequency - Treatment Plant	1/Yr.	1/Mo.	1/Wk.
Sampling Frequency - Groundwater	N/A	1/Qtr.	1/Qtr.
Sample Cost			
\$/BOD	\$52.00	\$52.00	\$52.00
\$/TSS	\$26.00	\$26.00	\$26.00
\$/TN	\$43.00	\$43.00	\$43.00
\$/Fecal	\$25.00	\$25.00	\$25.00



For level 3 treatment, operating costs can be summarized as follows:

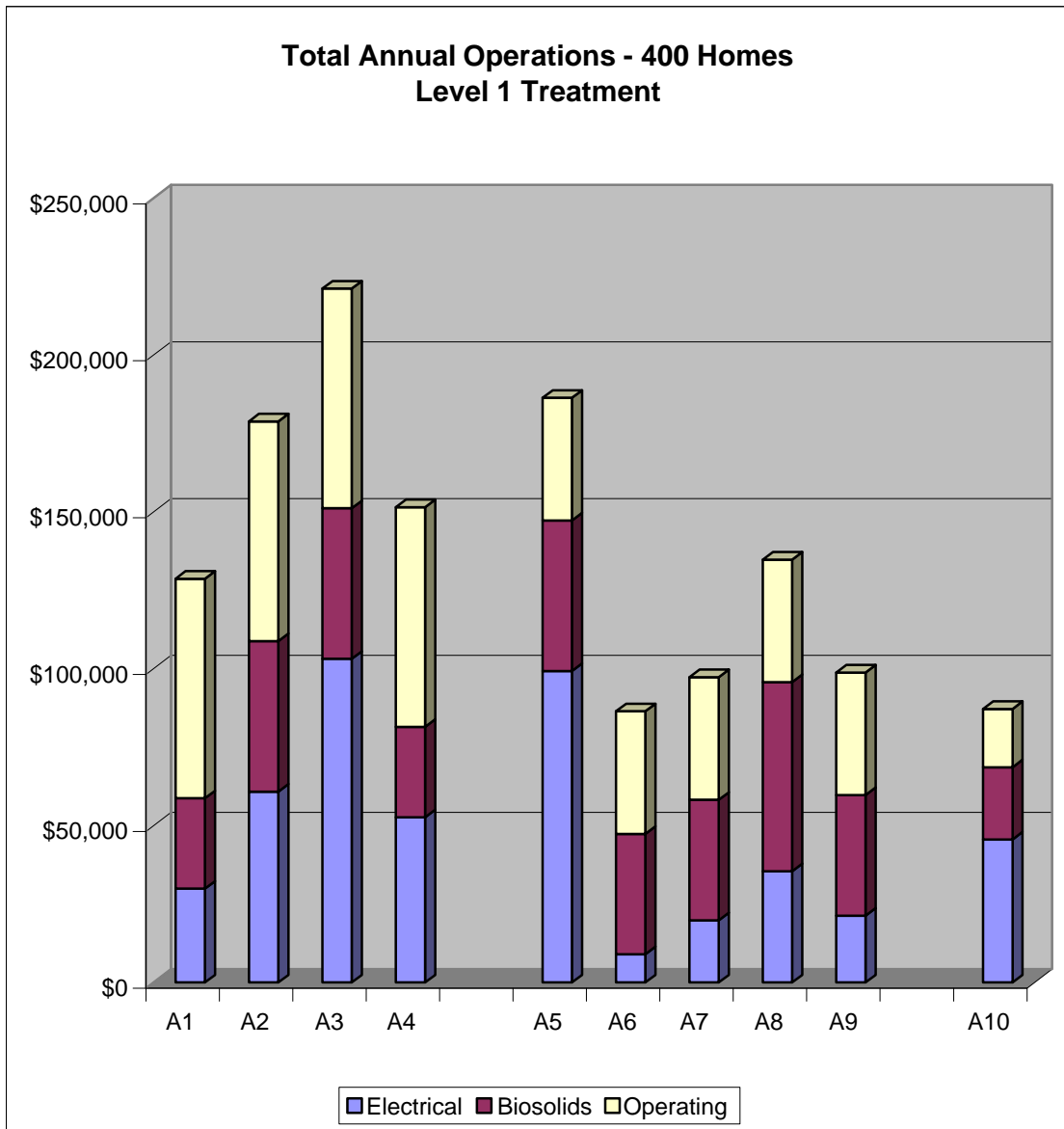
	Level 3 Treatment/Management		
	Home Onsite	80 Home Cluster	400 Home MBR
Operator Frequency			
Hrs/Week		4	10
Hrs/Year		208	520
\$/Hour		\$50.00	\$75.00
Visits/Yr.	12		
\$/Residence/Yr.	\$2,100		
Sampling Frequency - Treatment Plant	1/Qtr.	1/Wk.	1/Wk.
Sampling Frequency - Groundwater	N/A	1/Qtr.	1/Qtr.
Sample Cost			
\$/BOD	\$52.00	\$52.00	\$52.00
\$/TSS	\$26.00	\$26.00	\$26.00
\$/TN	\$43.00	\$43.00	\$43.00
\$/Fecal	\$25.00	\$25.00	\$25.00
\$/P	N/A	\$43.00	\$43.00



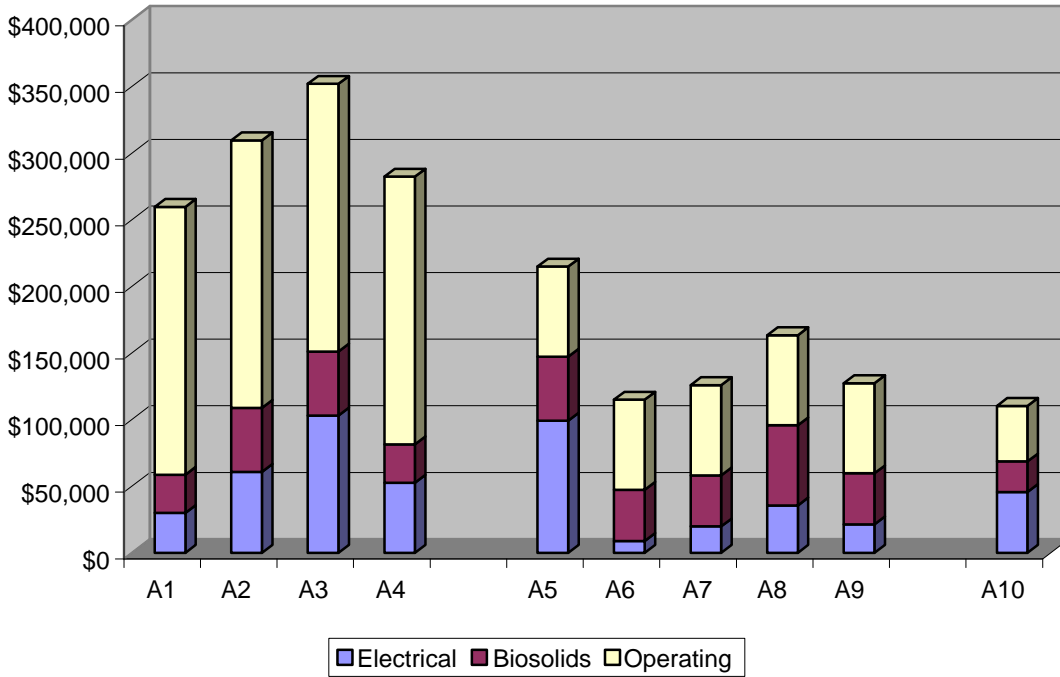
You may note that we have thus far assumed the same operator costs per frequency of inspection for each technology of equivalent capacity. Reality, we know is different. With one technology, we may need 1 hour and another may require 3 hours of time. However, at this point we should not get side tracked by trying to over-analyze this and favor one technology over another (though we have our biases). Instead, let's focus on the significant differences between a home onsite system structure versus moderate size cluster versus larger cluster development.

Total Operations Cost Summary

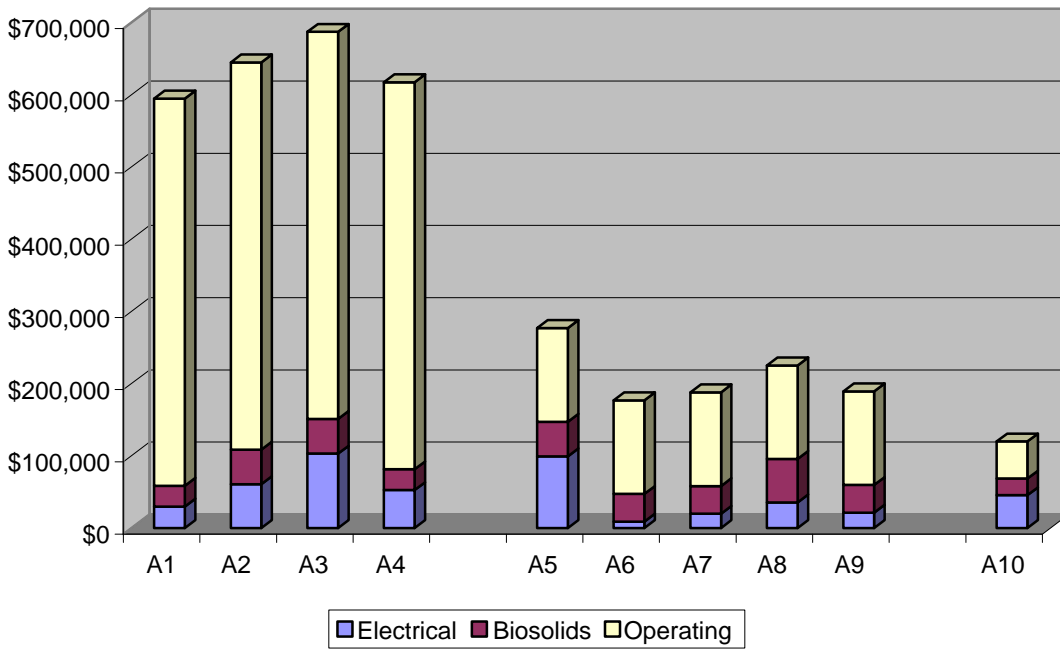
Pulling all of this together (i.e., operations + energy costs + biosolids), comparative system annual operating costs for each alternative and treatment level can be summarized as follows:



**Total Annual Operations - 400 Homes
Level 2 Treatment**



**Total Annual Operations - 400 Homes
Level 3 Treatment**



Conclusions:

Not yet, but the results of this analysis are a bit surprising. It is clear, that focusing on just a single variable, such as comparative energy usage for a treatment plant is short sighted. All costs of operation need to be considered for collection, treatment and dispersal and for each level of treatment. Where soil cannot be relied upon to meet environmental nutrient constraints or for wastewater reclamation and reuse, we need to consider the need to meet higher treatment standards. These costs will vary from location to location and we should not generalize, but exercise discipline as we consider the tradeoffs in planning for specific infrastructure. The value of water availability for reuse needs to be explicitly accounted for. Reliability of performance also deserves consideration. We still have to consider capital costs for design, permitting and installation and life cycle costs for pump replacement, membrane replacement, etc., and evaluate other critical measures of sustainability such as environmental impact and institutional fit.

Part 2 in this series will focus on comparative capital and life cycle costs. In the meantime, additional input is always appreciated.

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NCS Wastewater Solutions, a Division of Northwest Cascade Inc., Puyallup Washington designs, builds and operates decentralized water and wastewater infrastructure for commercial and residential developments across the country. For additional information, please visit our website at www.ncswastewater.com