What is Decentralized Water Infrastructure?
What is Sustainable Water Infrastructure?

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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? Depending on who you talk to, you are likely to get very different answers.

First, its important to understand that the terms “decentralized” and “sustainable” are relative terms and there are no absolute definitions here. An individual home well and septic is typically viewed as the “ultimate” decentralized water infrastructure, because there is no pipe connecting more than one structure to supply water or to collect sewage from multiple structures. But, individual home systems are not the only way to have a decentralized water infrastructure. A large publicly owned treatment works for water and wastewater is typically not considered to be decentralized, but is historically viewed as sustainable because it has been in use for several decades and is financially supported by a large number of ratepayers. The question now is whether a decentralized system can be a sustainable system? And if so, at what level and how can one assure the sustainability of a decentralized system? For discussion purposes, in this paper we will look at the wastewater system only, but a similar thought process is applicable for water system as well.

A textbook definition of a decentralized system is “a collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, or institutional facilities, as well as from existing communities, at or near the point of waste generation (Crites and Tchobanoglous, Small and Decentralized Wastewater Management Systems, 1998). One of the important ideas behind decentralized systems is that of managing wastewater onsite, nearby, thus minimizing or optimizing the cost for collection and transportation of both untreated and treated wastewater. Advances in wastewater treatment and effluent dispersal technologies now make it possible to minimize the need for collecting large quantities of wastewater to one location for treatment and disposal. However, the question still remains, how much collection is needed in order to make the wastewater system sustainable.

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. To some people, decentralized wastewater infrastructure means devolving to the lowest possible level which is each home. Therefore, one alternative to be evaluated is focused at the home level. Another alternative provides for clustering of residences into several discreet wastewater treatment and water management units. For purposes of illustration, let’s assume 5 clusters of essentially equivalent size located strategically across the property. And finally, let's evaluate establishing just 1 wastewater treatment and water management unit for the property – centralized within the 400 acre community but still decentralized when compared to typical municipal forms of water and sewer infrastructure. We can then compare each of these "decentralized" alternatives with extending pipe, say 4 miles, to the traditional municipal wastewater treatment plant. The numbers used here are just for purposes of illustration and to better understand the issues and tradeoffs.

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 to evaluate each of the above alternatives:

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. Water conservation
    e. Storm water generation and mitigation needed
    f. Roads and other site infrastructure maintenance required

2. Economics – Each configuration should be judged/evaluated based on the following cost items:
    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?

There are likely other very appropriate measures of sustainability, but for now, we will use these three as a starting point. Next, lets further detail what each water and 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 unit, packed bed filter or recirculating media filter for wastewater treatment, followed by drip or trench dispersal. Granted, there are other options such as greywater/blackwater separation, composting toilets etc., but for now let's start our analysis with what is common practice today. With this as a base, we can then project what might be possible if one were to move to even higher levels of treatment and/or other reuse/dispersal options. For this alternative, we will have 400 independently accountable wastewater systems, each occupying minimum ¾ acre lots. In this alternative, there is no "open" or "green" space allocation possible, thus overall there will be more roads i.e., paved surface area, to serve each home within the subdivision, and typically more cost for other utilities such as electricity, cable, and gas.

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.

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 for dispersal or other use within the cluster water management unit. 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 20,000 gpd capacity range include: recirculating media filters, recirculating media filters incorporating constructed wetlands, aerobic treatment plants, trickling filters or in some areas lagoons.

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

Diehard home unit decentralists, of course discount these potential advantages and there are advocates for every combination and permeation in between. The challenge, however, is to work our way through all of these claims and biases and as objectively as we can evaluate the advantages and disadvantages of each alternative to determine where each model best fits as we build sustainable and green infrastructure for the future.

There may well be technologies that come along in the future that will dramatically leapfrog where we now are, such as replacing biological treatment with physical processing. However, given that our need is now for both building new infrastructure and replacing the old, let's start our evaluation with what we can now implement.

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:

Paper 1 – Comparative Operating and Management Economics
Paper 2 – Comparative Capital Costs and Integrated Life Cycle Costs
Paper 3 – Environmental Impacts and Institutional Needs

Operating and Management Economics

For each decentralized water 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:

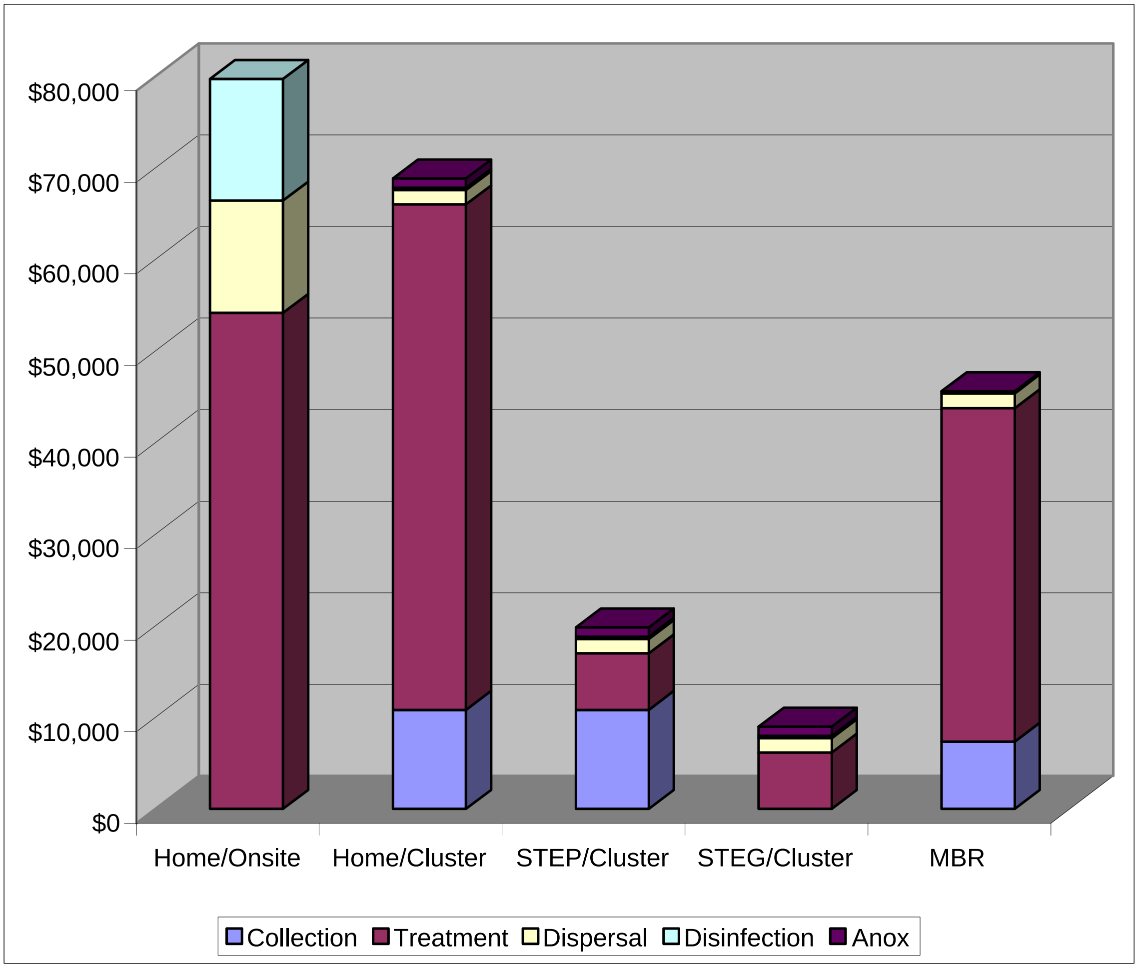
- 200 gallons per day per residence on average actual flows. Though increased conservation will likely reduce these flows overtime, the same biological treatment capacity will still be needed.
- Pump and blower run times and kwh usage per manufacturer published specifications.
- Treatment technology sludge/biosolids yields per commonly accepted industry norms

Though we have experience with many of the collection, treatment and dispersal technologies now available, for simplicity, we will narrow this matrix to the following 5 alternatives:

1. Home treatment and onsite dispersal using recirc media filter technology and drip dispersal (recirc at 5:1).
2. Home treatment using recirc media filter technology as above, low pressure sewer collection, further polishing in constructed wetlands followed by drip dispersal in 5 roughly equal 20,000 gpd clusters (recirc at 5:1)
3. 5 Clusters with STEP low pressure sewer collection, treatment using recirc media filters followed by drip dispersal (recirc at 5:1).
4. 5 Clusters with gravity STEG collection, treatment using recirc media filters followed by drip dispersal (recirc at 5:1).
5. 1 Central Cluster with gravity collection and 5 lift stations, MBR treatment and drip dispersal.

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 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, it is notable that even using this advanced technology, at least from a total system electrical usage standpoint, this technology would seem to result in substantially lower costs than current home based infrastructure.

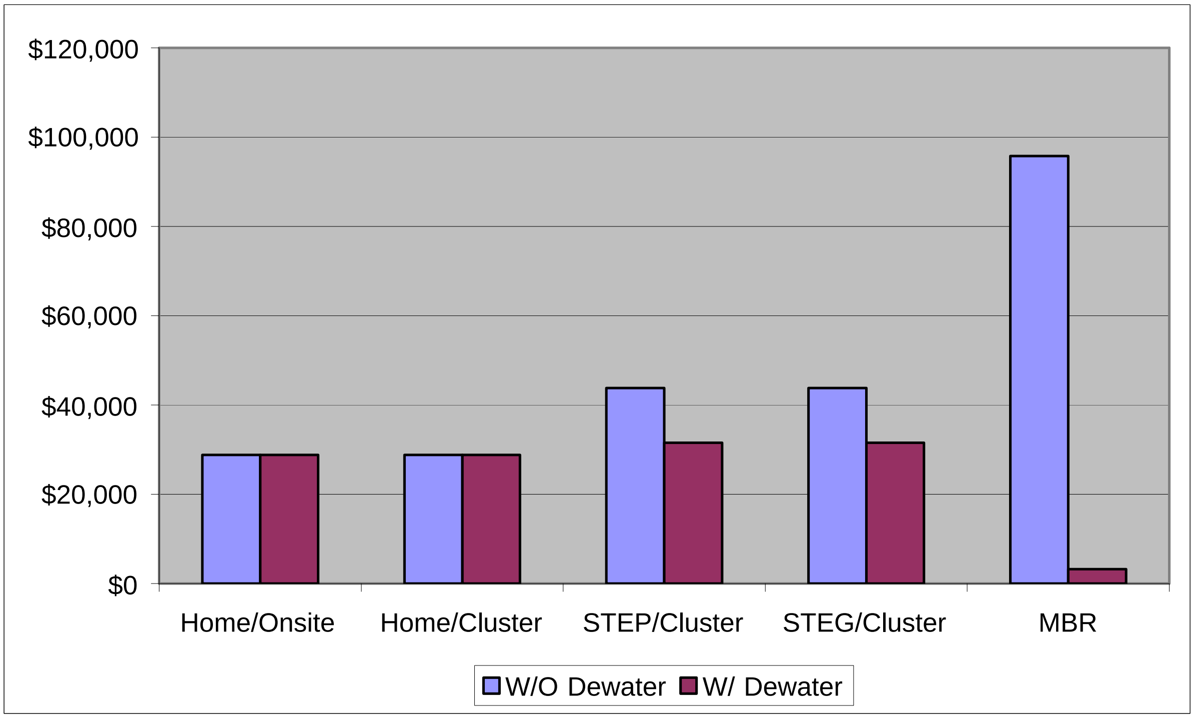
Biosolids Management

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 Residuals	
(lbs solids/lb BOD)	
Recirc Media Filters	30%
MBR	70%
Activated Sludge	75%

STEP/STEG tank pumping frequencies were assumed to be every 7 ½ years. To calculate biosolids volumes, treatment facility influent BOD concentrations were assumed to be 250 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.

Based on these assumptions, annual biosolids management costs for each alternative are estimated to be as follows:



For a 100,000 gpd MBR plant, it is very affordable (< $100,000 in capital investment) to provide complete dewatering and biosolids management with residual material available for use within the 400 home water management unit. It may also be possible to provide biosolids dewatering for 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 may not pencil even for the 5 clusters.

Operating Costs

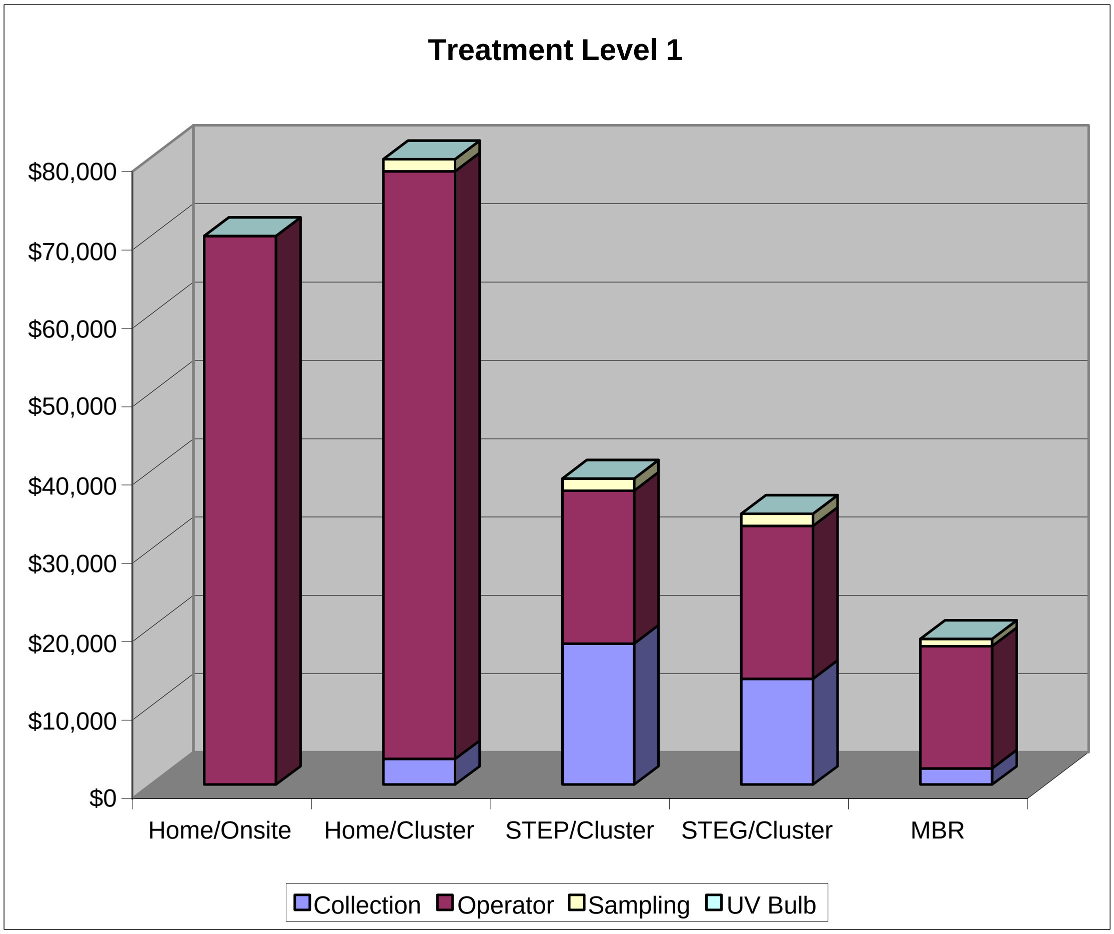
Operating costs will vary considerably depending on treatment performance requirements. Following is a summary of the assumptions used to evaluate three different levels of treatment and management:

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

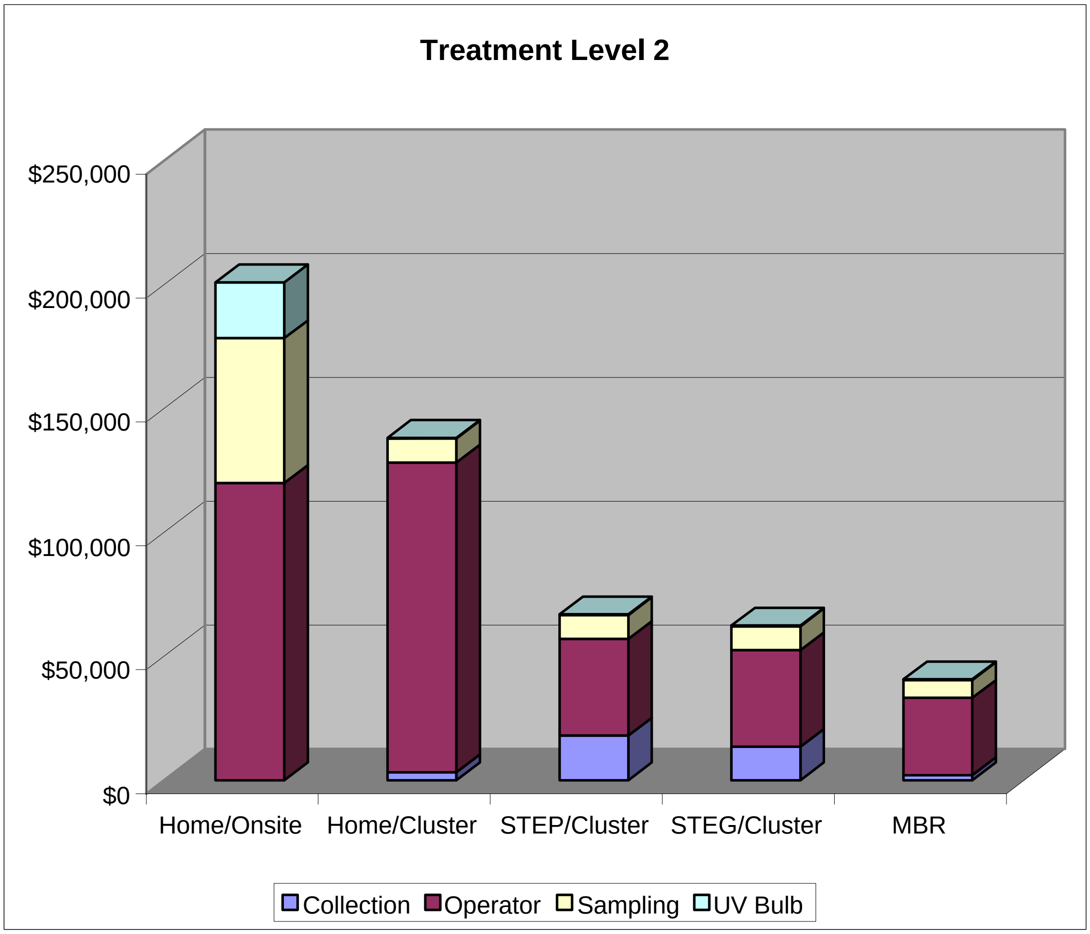
For all levels of treatment, we assumed that STEP/STEG sewer collection systems required inspection every 2 years, lift stations need to be inspected quarterly and gravity mains jetted every 5 years. If applicable, we assumed that UV bulbs must be replaced every 2 years.

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

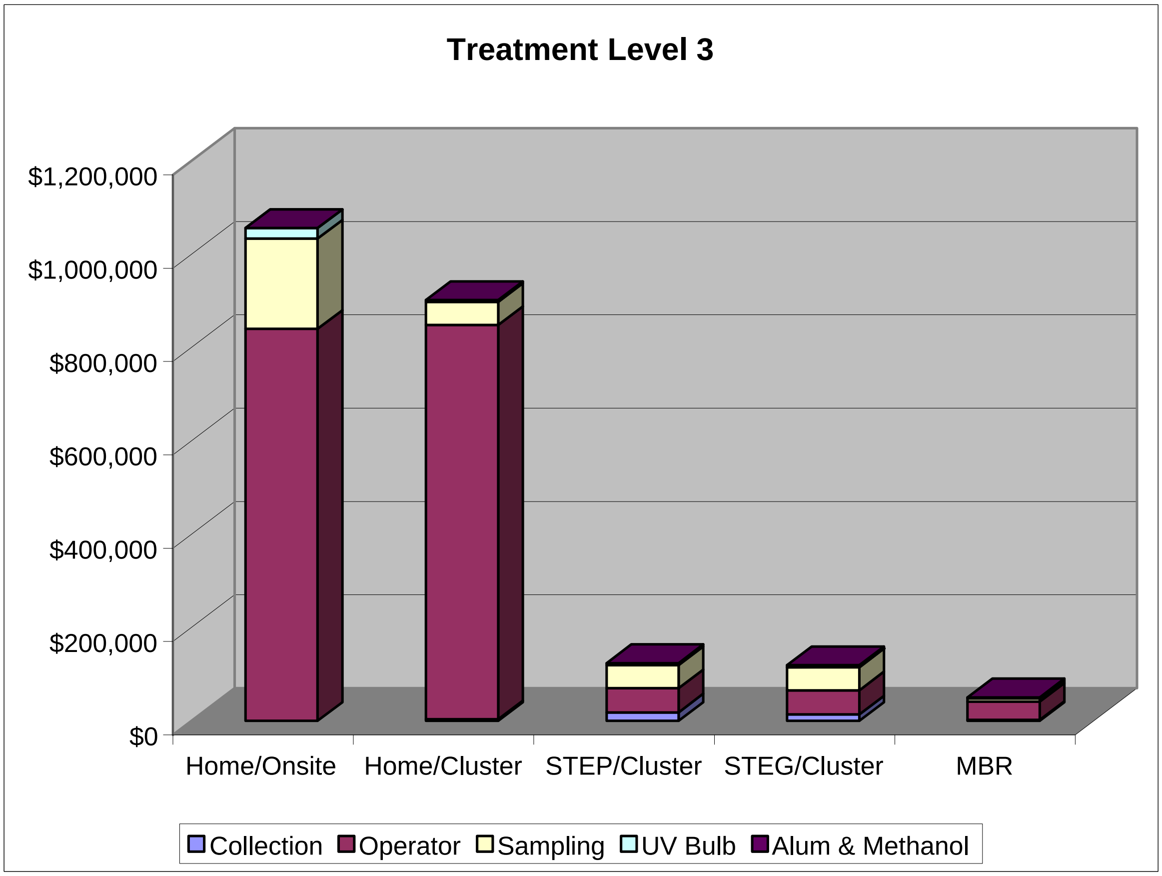
	Level 1 Treatment/Management		
	Home Onsite	**80 Home Cluster**	**400 Home MBR**
Operator Frequency			
Hrs/Week		1.5	4
Hrs/Year		78	208
$/Hour		$50.00	$75.00
Visits/Yr.	1		
$/Residence/Yr.	$175		
Sampling Frequency - Treatment Plant	N/A	1/Qtr.	1/Mo.
Sampling Frequency - Groundwater	N/A	N/A	N/A
Sample 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
Sampling Budget			
# Samples/Event	0	5	1
Total/Yr.	$0	$1,560	$936



	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
$/P	N/A	N/A	N/A
Sampling Budget			
# Samples/Event	400	5	1
Total/Yr.	$58,400	$9,620	$7,180



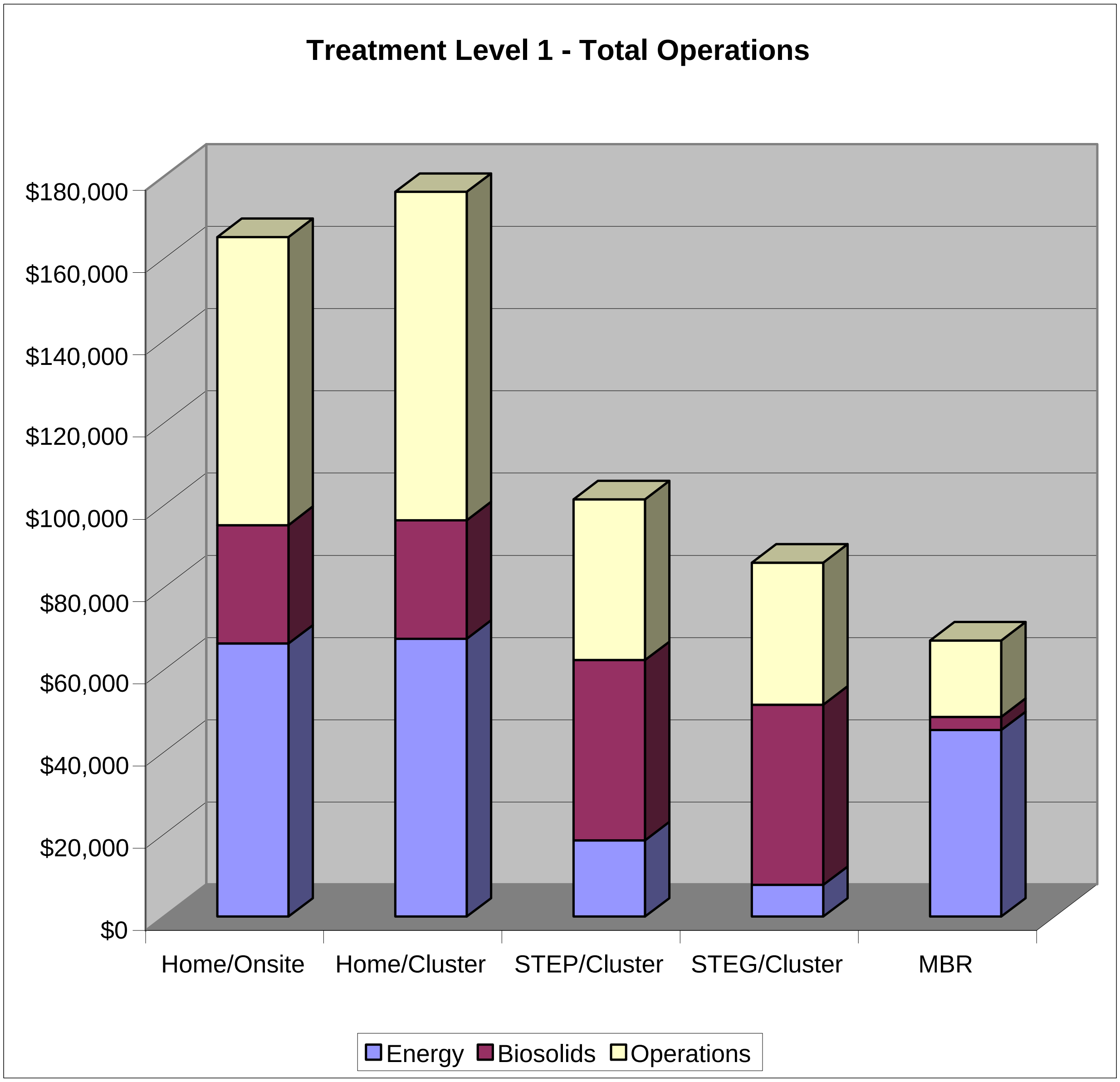
	Level 3 Treatment/Management		
	Home Onsite	**80 Home Cluster**	**400 Home MBR**
Operator Frequency			
Hrs/Week		4	10
Hrs/Year		208	520
$/Hour		$50.00	$75.00
Visits/Yr.	12		
$/Residence/Yr.	$2,100		
Sampling Frequency - Treatment Plant	1/Qtr.	1/Wk.	1/Wk.
Sampling Frequency - Groundwater	N/A	1/Qtr.	1/Qtr.
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
Sampling Budget			
# Samples/Event	400	5	1
Total/Yr.	$193,600	$49,312	$7,008

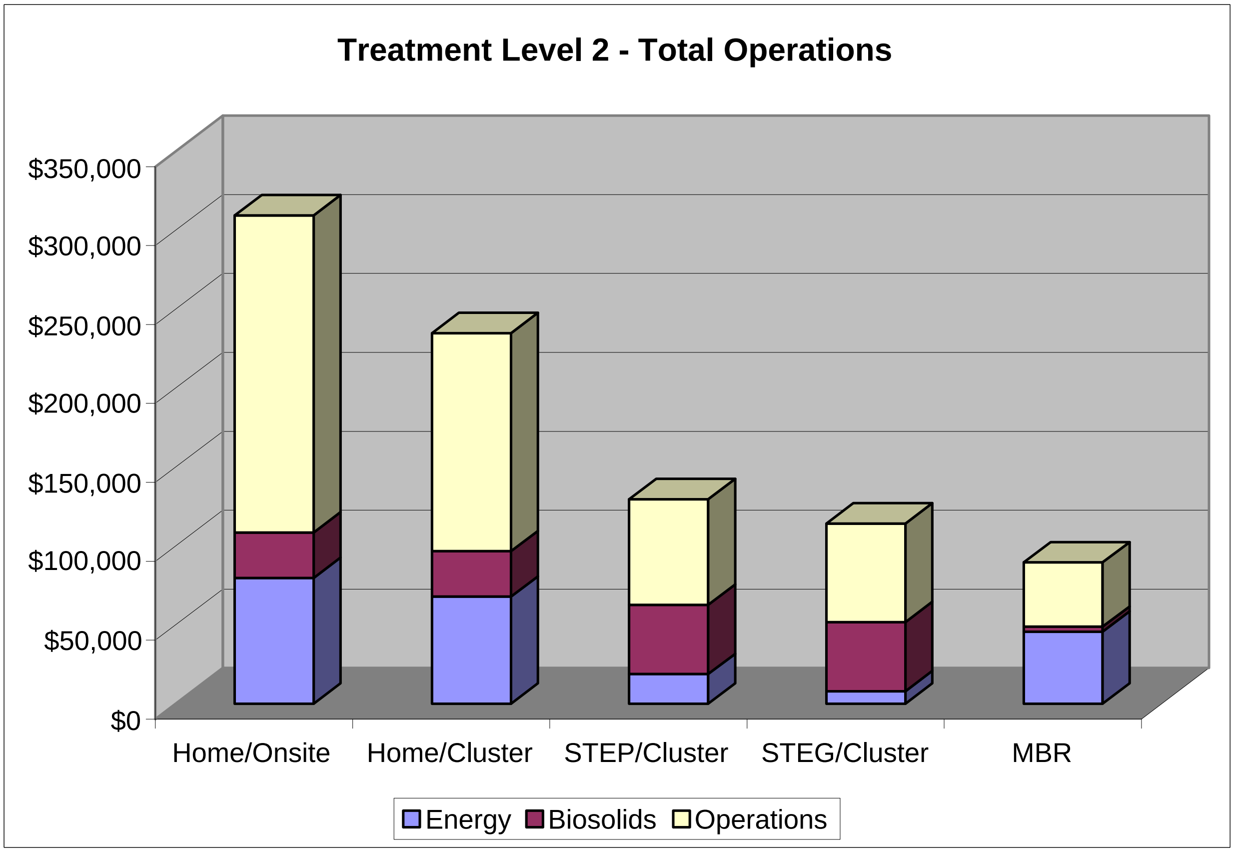


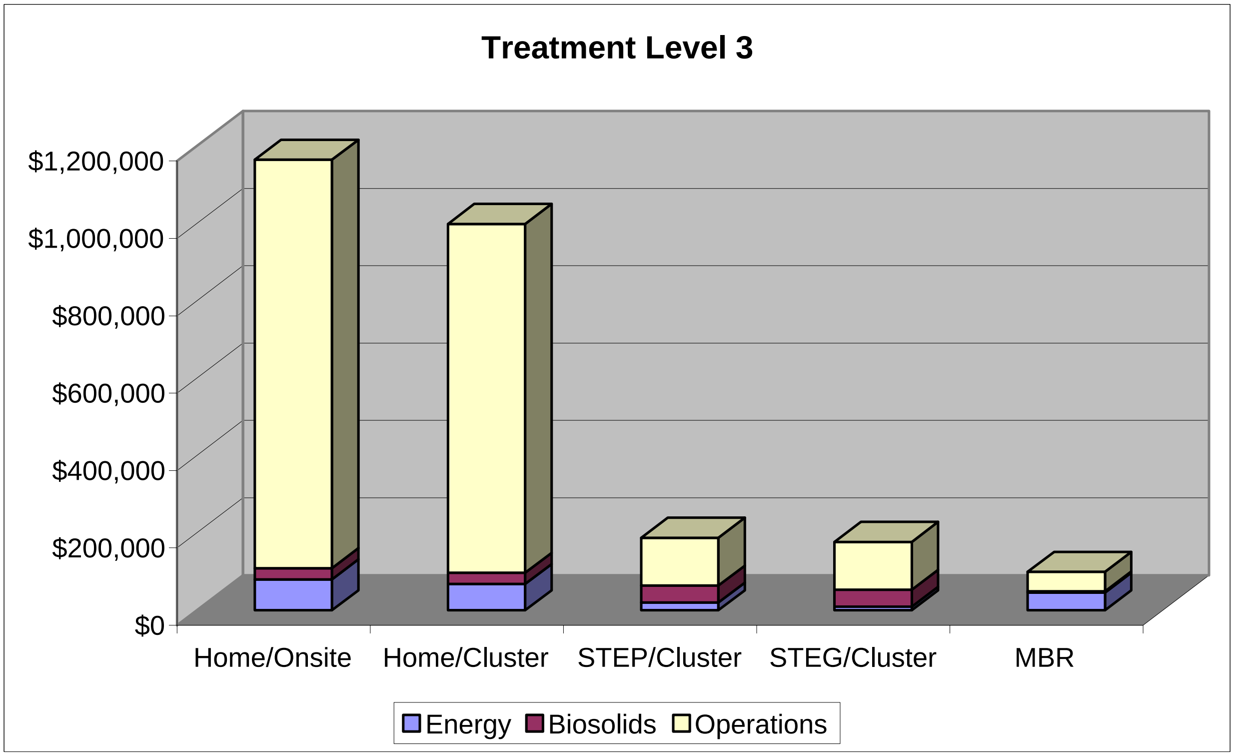
Surprisingly, MBR treatment technology in the 100,000 gpd capacity range appears to offer significant operating cost advantages at nearly all levels of treatment and in particular as treatment requirements increase.

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:




Treatment Level 2 - Total Operations
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Home/Onsite
Home/Cluster
STEP/Cluster
STEG/Cluster
MBR
Energy
Biosolids
Operations


Treatment Level 3
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
Home/Onsite
Home/Cluster
STEP/Cluster
STEG/Cluster
MBR
Energy
Biosolids
Operations

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. 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. To some point, bigger may well be better, although it is counter to the "decentralized" mantra. We still have to consider capital costs and life cycle costs for pump replacement, membrane replacement etc.and evaluate other critical measures of sustainability such as environmental impact and institutional fit.

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

Footnote:

What prompted us to focus on this subject at this time? From what we read and hear, it seems that ideology is increasingly hijacking the debate about decentralization and sustainability – replacing sound science, facts and data. If you subscribe to the EPA Decentralized LISTSERVE, you will quickly find that for some, if its small and decentralized, it is by definition good and sustainable. The following example of ideology trumping science, facts and data from a community in Virginia will serve to illustrate:

A developer in this community wanted to build a 200 home subdivision. Whether or not to extend central sewer (which has excess capacity) or rely on "decentralized" sewer was the focus of much community debate. What ended up being approved and constructed was what the community calls a hybrid solution with STEP low pressure sewer connecting to central sewer mains. Because there is a septic tank and pump at each home, it was deemed to meet the “decentralized” criteria. There are certainly good reasons for using STEP collection and we have designed and built our fair share using this technology, but why in your right mind would you ever design and install a pressure sewer when gravity could have been used, either STEG or conventional?

Good question – we should ask the equipment distributor who designed the system. Plagued by nuisance alarms and servicing challenges, the community public works department is now in the final stages of taking out all of the pumps, boring new openings in the concrete tanks and converting the system 100% to gravity flow. Was sustainability ever really considered to begin with?

As professionals in this industry we owe it to our clients and the public to be disciplined in our analyses and use sound science to present alternatives and to debate their appropriateness and tradeoffs. We don’t believe that we have all of the answers or that all of our numbers at this point are “correct”. We do hope to inform the debate, learn from the input others and our own experiences and offer our clients truly sustainable solutions that deliver results.