Smart Growth Will Save Energy: Quantitative Analysis of the LEED®-ND Draft Proposal

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ABSTRACT

The Leadership in Energy and Environmental Design Neighborhood Development (LEED-ND) rating system will be much more likely to succeed if its requirements lead to improved performance that will satisfy stakeholder requirements, including low energy bills. Therefore, quantifying the energy savings associated with the LEED-ND credits used for certification is important to demonstrate program value. Seventy-three percent of the total 114 LEED points reflect energy savings potential. We translated energy-related LEED-ND credits into energy savings in the buildings, transportation, and water/wastewater sectors based on average household consumption data (Btu/household-yr) for these energy use categories. We then applied the metric "energy saved per LEED point" to check the consistency of point values from an energy perspective. Some credits save much more energy than others. On average, buildings credits save about the save amount of energy per point as transportation credits do, although total transportation energy savings associated with the credits are much larger than total buildings savings. Water-wastewater credits save far less. Within groups, energy savings per point among buildings credits vary by 6:1, water-wastewater by 8:1, and transportation by 70:1. Although energy saving is not the only goal of LEED-ND, it is one important criterion, in part because energy use and bills are so visible to owners and those who live in the community.

Introduction

Smart growth is an approach to development that attempts to combat the effects of poorly planned, low-density growth, or sprawl. Sprawl has been criticized for consuming open space, increasing vehicle dependence, straining infrastructure, and creating a homogeneous landscape of single-family homes. To help developers build according to smart growth principles, the U.S. Green Building Council (USGBC) has proposed a rating scheme for neighborhood development.

The USGBC has developed a series of environmental rating systems, called LEED Green Building Rating Systems. A rating system consists of a set of prerequisites and credits defined by criteria relating to environmental performance of buildings. Credits are assigned point values, and LEED certification requires the attainment of a certain point total. LEED rating systems generally cluster prerequisites and credits into categories such as Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, and Innovation & Design Process.[1]

In September 2005, the USGBC released the Preliminary Draft of the Neighborhood Development rating system (LEED-ND) intended "to develop a national set of standards for neighborhood location and design based on the combined principles of smart growth, urbanism,

[1] See, for example, LEED-NC v.2.1.

and green building" (USGBC 2005).[2] The program drew primarily on three sources: previous LEED program frameworks, the Charter of the New Urbanism, and Smart Growth Network's ten principles of smart growth. The LEED-ND categories are: Location Efficiency; Environmental Preservation; Compact, Complete & Connected Neighborhoods; and Resource Efficiency.

Earlier LEED Rating Systems have been criticized for lacking a clear analytical approach to determining relative importance of the various elements of the ratings, both within and between categories (Frangos 2005), or for not reflecting stated priorities in the distribution of points. The present study is a systematic approach to valuing the rating elements based on one important criterion: energy savings. The objective is to determine the degree of consistency in the treatment of energy savings, a key component of green performance, based on the idea that point values and benefits should be commensurate. In a sense, it is the inverse of existing informal "samizdat"[3] guides that help development teams maximize LEED points with minimum expenditure.

It should be noted that the work described below is preliminary, being neither comprehensive nor precise. In particular, only a subset of LEED credits are evaluated, and the assignment of energy savings per point is not always well supported. Furthermore, the issue of how to assign savings to credits in a way that reflects LEED-ND's prerequisites has not been resolved. The purpose of this paper is to sketch an approach to a quantitative critique of LEED-ND, and in the process show why such a critique could benefit the rating system.

LEED-ND: An Example

To give a feel for the structure of LEED-ND, consider two new residential developments, one in an urban area and another in a greenfield location, and how they fare in the Location Efficiency category of the rating system. This category is worth up to 28 points, or one-quarter of the 114 points available in LEED-ND. There are two prerequisites in the Location Efficiency category: Transportation Efficiency, requiring that the development site be located near either to already developed sites or to an existing or planned transit service, and Water and Stormwater Infrastructure Efficiency, requiring that the site be served by existing or planned water and sewer infrastructure. We assume that both the urban and greenfield projects meet these prerequisites. While this is less likely to be the case for the greenfield project, it is certainly possible, given that the prerequisites can be satisfied by the provision of transit, water, and sewer systems after the fact.

Applying the credits within the Location Efficiency category to the two new developments in question might produce results along the lines of what is shown in Table 1.

An example of a credit within Location Efficiency is Reduced Automobile Dependence (beyond the level required to meet the prerequisite), for which a new development will be eligible if the site has superior transit service (2–6 points), demonstrably low vehicle miles per capita (2–6 points), or a nearby vehicle-sharing program (1 point). The number of points earned on the basis of a transit service, for example, is determined by total rides available per weekday: 60–124 rides earn 2 points, while 1,000 or more rides earn 6 points.

[2] The LEED-ND draft is available at https://www.usgbc.org/FileHandling/show_general_file.asp?DocumentID=959.

[3] **Samizdat** (Russian: самиздат) was the clandestine copying and distribution of government-suppressed literature or other media in Soviet-bloc countries. The idea was that copies were made a few at a time, and anyone who had a copy would make more copies, often by handwriting or typing, because copy machines were guarded by what Mikhail Bulgakov called "the secret service." See http://en.wikipedia.org/wiki/Samizdat.

Table 1. Example: Location Efficiency Credits for Two New Residential Developments

Location Efficiency Credits (points possible)	Urban Residential Development	Greenfield Residential Development
Contaminated Brownfields Redevelopment (4)	0	0
High Cost Contaminated Brownfields Redevelopment (1)	0	0
Adjacent, Infill, or Redevelopment Site (3 to 10)	3	0
Reduced Automobile Dependence (2 to 6)	6	0
Contribution to Jobs-Housing Balance (4)	4	0
School Proximity (1)	1	1
Access to Public Space (2)	0	2
TOTAL	14	3

In this hypothetical example, the urban development scores several times more points (14) on Location Efficiency than the greenfield development does (3), as one might expect.

Methods

Since the available energy consumption data do not fall neatly into the LEED-ND categories, we developed a mapping or assignment of LEED-ND credits into the energy use categories of buildings, transportation, water/wastewater, and solid waste. This mapping is summarized in Table 2 and expanded in Appendix B.

Table 2. Number of Credits in each LEED-ND Category that Translated to Energy Use Categories

	Energy Use Categories			
LEED-ND Category	Building	Transportation	Water/Wastewater	Solid Waste
Location Efficiency		4		
Environmental Preservation			4	
Compact, Complete, and Connected Neighborhoods	3	15	1	
Resource Efficiency	7	1	4	4

Note: See Appendix B for a detailed table.

To begin the evaluation, we established baseline average energy use (Btu/household-year) for buildings, transportation, and water/wastewater, respectively, using three EIA resources: the *Residential Energy Consumption Survey 2001* (EIA 2001, Table CE1-8c: Total Btu Consumption, Fuels Used [primary and excluding wood]); *Transportation Energy Data Book* (DOE 2004, Tables 2.5 and 8.1); and *Water and Wastewater Industries: Characteristics* *and Energy Management Opportunities* (EPRI 1996, Table 3-11), respectively. We used 2001 data for buildings and transportation; water/wastewater raw data was from 1988 and assumed to have a 1.5% annual increase. Table 3 shows these data.[4] No attempt was made here to evaluate energy savings associated with Solid Waste, and this category is excluded from the discussion below.

We next estimated, for each energy-related credit in LEED-ND, the fraction of energy use in the relevant category (buildings, transportation, and water/wastewater) that would potentially be affected by the credit. This fraction was estimated primarily based on the above data sources. No universal method was used in this process. Typically, a logical separation of energy consumption by type could be found within the data sources and applied to specific credits. Descriptions of the reasoning used to arrive at each fraction of energy usage can be found in the comment section for Appendix C.

Table 3. Household Annual Energy Use (Btu/Household-Year) for Buildings, Transportation, and Water/Wastewater

Buildings	162,700,000
Transportation	191,200,000
Water/Wastewater	13,550,000

Sources: See above text.

Credits were then evaluated for the percentage of the affected energy that they could be expected to save. We were not able to evaluate all credits for this analysis. Probable energy savings were determined by several methods. Some LEED-ND credits explicitly required reductions in energy usage. Other credits set goals that could be translated into a fractional reduction in energy usage. Still other credits required estimation of energy use reduction directly. We consistently used conservative evaluations of possible energy use reduction. Thus, the actual energy use reduction per residential unit that could be achieved by applying LEED-ND standards to a new project is likely greater than that stated in our findings.

We then calculated energy savings in Btus for each credit by multiplying three terms: average annual energy use per household in the relevant category; fraction of that energy use potentially affected by the credit; and percentage of affected energy use that the credit would save. The method is detailed in Appendix A.

In some cases, LEED-ND assigns a range of point values to a credit, corresponding to various degrees to which a given development might meet the credit requirements. For these credits, we evaluated the percentages of energy savings associated with both the lowest non-zero point value and the highest point value.

Results

Of the 114 points available in LEED-ND, 83 points (73%) are assigned to energy efficiency-related credits. Thus the rating system acknowledges the high priority of energy use and related parameters in determining environmental performance. We evaluated just over half of these energy-related points. Our findings were as follows:

[4] LEED-ND is to be applied to residential, commercial, and mixed developments. We considered residential developments only, however.

- Among the credits that we evaluated, those associated with transportation offer the greatest energy savings possibilities, totaling over three times as much as buildings and water/wastewater combined.
- The variation in savings per point can be viewed at three levels: across categories of energy use; within those categories; and within a single credit. To compare across categories, we averaged savings per point within categories and found that transportation credits save 11.5 million Btus on average, buildings credits save 11.1 million Btus, and water/wastewater save 1.7 million Btus.
- Within categories, energy savings value of points also varies widely. For instance, the 1-point Transit-Oriented Compactness credit is estimated to save over 20 million Btu per household-year. However, Contribution to Jobs-Housing Balance is estimated to save only 12.5 million Btu per household-year but is worth 4 points. Savings per point among buildings credits vary by 6:1, transportation by 70:1, and water-wastewater by 8:1.
- Variation in savings per point is far less within a single credit, but in some cases still substantial. In the case of Compact Development, for instance, savings are nearly twice as great for a single point as savings per point at the highest point value.[5]

Table 4. Energy Savings Associated with LEED-ND Credits Evaluated

Category	Energy Savings of Evaluated Credits (Btu per HH-year)	Percentage of Total Energy Savings (Btu per HH-year)	LEED-ND Points	Percentage of LEED-ND Points
Buildings	77,520,000	24	7	15
Transportation	234,940,000	71	29	63
Water/Wastewater	17,000,000	5	10	22
Total	329,340,000	100	46	100

Discussion

The assignment of energy savings to credits in our analysis is rough. As noted above, this preliminary assessment is intended simply to demonstrate that such an approach produces results that may be useful in bringing a greater degree of consistency to the LEED-ND rating system.

One difficulty we encountered in attempting to assign energy savings to each point was in defining the applicable baseline. In some cases the baseline was taken to be average over all households, even though a candidate neighborhood development may have demonstrated performance far better than average in meeting a LEED-ND prerequisite. For example, the Location Efficiency category has Transportation Efficiency as a prerequisite. This prerequisite can be met by locating near transit service or having proximity to mixed use development, both of which would typically bring about VMT generation well below average. On the other hand, the prerequisite can also be met by building in an area with "lower than average" driving rates, where "lower than average" is not quantified. The existence of this option for meeting the prerequisite precludes the setting of a baseline for transportation efficiency measures that is superior to the U.S. average for purposes of computing the energy savings associated with the

[5] The discrepancy is even greater if we include the savings in buildings energy associated with the Compact Development credit, because these savings are nearly as large at the 1-point level as at the highest point level.

credits. In short, complex relationships between credits and prerequisites, both within and across categories, are an impediment to accurate assignment of energy savings to points.

Of the credits to which we did not assign savings, some were not sufficiently well-defined to make such an assignment. In other cases, such as Comprehensively Designed Walkable Streets, there is probably sufficient information in the literature to make a quantitative assessment of savings. Given that most credits not yet evaluated are transportation-related, a more complete study is unlikely to change the outcome that transportation dominates total potential savings credited by LEED.

The relatively minor role of buildings energy savings in LEED-ND warrants further thought. Important categories of buildings energy savings opportunities associated with neighborhood design, such as district heating and cooling systems, are missing from the rating scheme. At the same time, the buildings points assigned through the rating scheme were not in general related to neighborhood development properties. The Energy-Efficiency in Buildings credit provides an example; this credit grants points for savings unrelated to neighborhood design. Whether or not this is a shortcoming of the rating system depends in part on whether individual buildings in the neighborhoods are eligible for certification under another LEED rating system as well.

The primary question explored here is the consistency of credit value with respect to energy savings. Energy savings are not the only metric for a LEED rating system, so consistency in this regard is not generally to be expected. In the case of water/wastewater systems, for example, several of the credits we evaluated were aimed primarily at an objective unrelated to energy savings. Reduce Stormwater Runoff, for example, is a credit associated mainly with improving water quality. Therefore, the finding above that energy savings per point are much higher in the transportation and buildings categories than for water/wastewater is not necessarily indicative of a problem.

In the case of transportation, however, energy savings are a good surrogate for vehicle miles traveled (VMT) reduction, which is in turn directly proportional to the principal transportation-related benefits of smart growth. Variations in energy savings per point in this case may therefore signal a shortcoming in the rating scheme. A good example is the Compact Development credit, which assigns up to 5 points on the basis of development density. Points awarded increase linearly with the density. Empirical studies have established, however, that VMT and therefore energy use decline with a fractional power of the density of development (Holtzclaw et al. 2002). This suggests that LEED-ND could benefit from a more rigorous, quantitative approach to assigning points.

This study's focus on energy efficiency is not intended to detract from the importance of criteria addressing other concerns such as environmental preservation, neighborhood character, and aesthetics. Indeed, we would suggest that this study could be used as a template to examine other reference parameters. One such parameter could be based on cost of amenities. A cost parameter could be applied to LEED-ND credits such as Access to Public Space, Brownfield Redevelopment, Support Off-Site Land Conservation, and Community Outreach and Involvement.

Conclusion

LEED-ND is an important effort to inform and motivate the construction industry, land use planners, and zoning and building code officials by showing the environmental value of green buildings and neighborhoods. One key factor of environmental sensitivity is energy efficiency. It is important in its own right, and it is one of the few green attributes that give direct and quick feedback to the owner through energy bills. Thus, for both philosophical and operational reasons, LEED ratings should pay great attention to energy efficiency.[6]

LEED-ND has done a good job in identifying many of the critical factors of smart growth. LEED-ND will save energy as it is written in the proposal. One significant weakness of the proposed LEED-ND rating system is its lack of a transparent method of point distribution among and within credits. This study has presented one possible way to address this problem. The approach presented here may be generally useful in further developing LEED's yardsticks for the value of green buildings.

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[6] In this, we include renewable energy. What the owner values in this arena is economic value: reduced energy expenditures relative to expectations and investments.

Appendix A. An Example of Calculating Energy Savings Associated with a Credit

Calculation Method Example

This example will follow the steps of how calculations were made for the Energy Efficiency in Buildings credit in Rows 12 and 13 of the energy analysis of LEED-ND spreadsheet in Appendix C.

1. Establish the Buildings Baseline (Cell C2)

Primary Electricity	11.63
Natural Gas	4.84
Fuel Oil	0.71
Kerosene	0.05
LPG	0.38
Total	$17.61^\wedge 10^{15}$ Btu per year

Taken from EIA (2001, Table CE1-8c) (in Quadrillion Btu per year)

Number of households = 108,209,000

$17.61^\wedge 10^{15}$Btu per year ÷ 108,209,000 Households = **162,700,000 Btu/Household-year**

2. Determine Fraction of Baseline Energy Use Affected by Credit (Column C)

In this case, the LEED team influences the non-plug loads, roughly 65% of energy.

3. Determine from the LEED-ND Documentation the Number of Points Available for this Credit

In this case, up to 3 points are available. One point is the lowest non-zero value.

4. Determine Percent of the Affected Energy Use the Credit Would Save (Column I)

The credit requires a minimum of 15% reduction in energy usage from standards at the 1-point level (Row 12) and a minimum of 35% at the 3-point level (Row 13).

5. Determine Energy Savings for the Credit (Column J)

In this case, it is the per household buildings energy use (Cell C2) multiplied by the fraction of buildings energy affected by the credit (Column C) and by the percent energy savings at the low (Row 12) and high (Row 13) point values.

Appendix B. Mapping LEED-ND Categories into Energy Data Categories

	Building	Transportation	Water/Wastewater	Solid Waste
Location Efficiency		* Adjacent, Infill, or Redevelopment Site * Reduced Automobile Dependence * Contribution to Jobs-Housing Balance * School Proximity		
Environmental Preservation			* Maintain Stormwater Runoff Rates * Reduce Stormwater Runoff Rates * Stormwater Treatment * Outdoor Hazardous Waste Pollution Prevention	
Compact, Complete & Connected Neighborhoods	* Compact Development[+] * Applying Regional Precedents in Urbanism and Architecture * Adaptive Reuse of Historic Buildings	* Compact Development[+] * Transit-Oriented Compactness * Diversity of Use * Block Perimeter * Locating Buildings to Shape Walkable Streets * Designing Building Access to Shape Walkable Streets * Designing Buildings to Shape Walkable Streets * Comprehensively Designed Walkable Streets * Street Network * Pedestrian Network * Maximize Pedestrian Experience * Superior Pedestrian Experience * Transit Subsidy * Transit Amenities * Access to Nearby Communities	* Reduced Parking Footprint	
Resource Efficiency	* Certified Green Building * Energy Efficiency in Buildings * Heat Island Reduction * Infrastructure Energy Efficiency * On-Site Power Generation * On-Site Renewable Energy Sources * Light Pollution Reduction	* Regionally Provided Materials	* Water Efficiency in Buildings * Efficient Irrigation * Greywater & Stormwater Reuse * Wastewater Management	* Reuse of Materials * Recycled Content * Construction Waste Management * Comprehensive Waste Management

[+] The Compact Development Credit was determined to combine aspects of both buildings and transportation but was only counted once for purposes of developing the point system.

Appendix C. Quantification of the Contribution of the Draft LEED-ND Credits As Written to Energy Efficiency

	A	B	C	H	I	J	K	
2	B = Buildings	2001 Annual Buildings Baseline (Btu/household)	162,700,000					
3	T = Transportation	2001 Annual Transportation Baseline (Btu/household)	191,200,000					
4	W = Water	2001 Annual Water Treatment Baseline (Btu/household)	13,550,000					
5				**High Point Value**				
6	**Category**	**Description**	**Fraction of Respective Baseline Affected by Credit**	**LEED-ND (Draft) Point Value**	**Energy Savings Percent**	**Energy Savings (Btu)**	**MBtu per Point**	
11	B	Compact Development—high (buildings contribution)	0.41	1	0.3	20,010,000	20.0	
12	B	Energy Efficiency in Buildings—low	0.65	1	0.15	15,860,000	15.9	
13	B	Energy Efficiency in Buildings—high	0.65	3	0.35	37,010,000	12.3	
14	B	Heat Island Reduction	0.41	1	0.2	13,340,000	13.3	
16	B	On-Site Power Generation	0.44	1	0.05	3,580,000	3.6	
17	B	On-Site Renewable Energy Sources	0.44	1	0.05	3,580,000	3.6	
18		Sums within category (high point values only)		**7**		**77,520,000**	**11.1**	**average**
19	T	Adjacent, Infill, or Redevelopment Site—low	0.98	3	0	0	0.0	
20	T	Adjacent, Infill, or Redevelopment Site—high	0.98	10	0	0	0.0	
21	T	Reduced Automobile Dependence—low	0.98	2	0.2	37,480,000	18.7	
22	T	Reduced Automobile Dependence—high	0.98	6	0.6	112,430,000	18.7	
23	T	Contribution to Jobs-Housing Balance	0.26	4	0.25	12,430,000	3.1	

	A	B	C	H	I	J	K	
	Category	**Description**		**LEED-ND (Draft) Point Value**	**Energy Savings Percent**	**Energy Savings (Btu)**	**MBtu per Point**	
24								
38	T	Compact Development—low	0.98	1	0.16	29,980,000	30.0	
40	T	Compact Development—high	0.98	4	0.39	73,080,000	18.3	
41	T	Transit-Oriented Compactness	0.54	1	0.2	20,650,000	20.7	
42	T	Diversity of Use—low	0.52	1	0.14	13,920,000	13.9	
43	T	Diversity of Use—high	0.52	3	0.14	13,920,000	4.6	
44		sums within category (high point values only)		**29**		**232,940,000**	**8.0**	**average**
45	W	Maintain Stormwater Runoff Rates	0.11	1	0.25	370,000	0.4	
46	W	Reduce Stormwater Runoff Rates	0.11	1	0.31	460,000	0.5	
47	W	Stormwater Treatment	0.25	2	0.8	2,710,000	1.4	
48	W	Outdoor Hazardous Waste Pollution Prevention	0.25	1	0.5	1,690,000	1.7	
71	W	Water Efficiency in Buildings—low	0.9258	1	0.2	2,510,000	2.5	
72	W	Water Efficiency in Buildings—high	0.9258	2	0.3	3,760,000	1.9	
74	W	Greywater & Stormwater Reuse	0.9258	2	0.5	6,270,000	3.1	
75	W	Wastewater Management	0.25	1	0.5	1,690,000	1.7	
84		sums within category (high point values only)		**10**		**17,000,000**	**1.7**	**average**

Cell Notes:

C2- Total primary from EIA Energy Consumption Survey 2001 (excluding wood) 17.61*10^15 Btu/ 108209000 households

C3- From Transportation Data book Table 2.5 (light duty, buses highway & passenger rail) & 8.1 16160.6 trillion BTU/ 108209000 households * 28% For upstream production

C4- From MWW Table 3-11 69693600 kWhr/day * 3412 *365*(1.015*13)*1.28 / 108209000 households; 1kWhr = 3412 Btu from TDB; assumes 1.5% yearly increase from 1988 to 2001

C11, C14, C17- From EIA 2001 Residential Energy Consumption: Space heating and cooling (Electric heating & cooling adjusted at 3x to show primary usage) 7.25*10^15 Btu/108209000 households = 66999972

H11- This is one of five pts. For compact development - high. The 5 pts. Were split 20-80 with transport.

I11 - due to shared walls implicit with higher density

C13- .85 to .65 times ASHRAE 90.1-1999

I14-From FSEC "Demonstration of Cooling Savings of Light Colored Roof Surfacing in Florida Commercial Buildings"

I16, I17- From requirements as written in LEED-ND Draft

C16- From EIA Table CE1-8c Difference between primary and end use electricity consumption11.63-3.89/17.61 (in 10^15 Btu)

I19- CCAP at www.ccap.org/guidebook/index.html assigns VMT reduction of 15-50% to infill development; assume adjacent site (3 pts.) achieves lowest level of reduction.

C20- Fraction of xport energy in passenger vehicles.

I20- See note for cell I-19; assume previously developed site achieves relatively high reduction of 40%.

C22- 98% of transport energy is auto

C23- From TDB Table 8.9 Work Commute is 27% of VMT and autos account for 98% of transportation energy usage

I23- From Credit description. Half of project would be within walking distance of potential jobs and half might be assumed to be employed at those jobs.

C24- TDB: School Buses Table 2.5 TDB

I24, C42, I43 - Since half of community would be within walking distance

I38- Doubling density from prerequisite level reduces VMT by 20%. Prerequisite already 20% below average. 0.8*0.8=0.64; reduction is 16%

H40- This is one of five pts. For compact development - high. The 5 pts. Were split 20-80-20 with buildings.

I40- Doubling twice more (actually, going from 15 to >39; but assume higher density is 60): 0.8^4=0.41, so reduction from prerequisite level is 39%

C41- From TDB Table 8.9, Sum of Trip purposes including, To/From Work 27.0% and an estimated half of other uses: Shopping 14.5%; Other family 18.7; School/church 3.7; Medical/dental 2.2; other social/recreational 13.2; Total = 27+ (.5*52.3)= 53.6%

I41- Assume moderate increase in transit usage.

I42- Minimum credit is for 2 of the 14 possible non-residential uses. 2/14=.14"

C43- From TDB Table 8.9: Sum of Trip purposes including: Shopping 14.5%; Other family 18.7; School/church 3.7; Medical/dental 2.2; other social/recreational 13.2; Total = 52.3% (should be considered a high estimate)

C45, 46- From MWW Table 2-13. Average of >10mgd Wastewater pumping. 21809 kWhr/day / 189683 kWhr/day

C47, 48- From MWW Table 2-16 Difference between activated sludge system using secondary & tertiary treatment