PREDICTING THE GROWTH OF GREEN BUILDINGS USING "DIFFUSION OF INNOVATION" THEORY

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Keywords: green buildings, diffusion theory, LEED, business case, logistic curve, growth rates

Summary

The U.S. market for green buildings has increased at a strong pace since the LEED® green building rating system was introduced in the spring of 2000 by the U.S. Green Building Council (2005). Since then, more than 1,750 projects in five years have registered their intent to achieve LEED certification and 148 had been certified under the LEED system at the end of 2004.

How can one best understand the dynamics of this market? This paper uses the theory of “diffusion of innovations” to understand this phenomenon. Diffusion theory has been elaborated for more than 40 years and helps explain adoption of innovations across a broad variety of industries. Using this theory, this paper presents quantitative growth estimates for green buildings in the U.S. and suggests that this same approach can be applied to other countries’ domestic construction markets.

Based on this theory, annual U.S. green building (LEED) registrations are predicted to reach 50% of the available market by 2010. Specifically, by the end of 2010, nearly 13,000 LEED projects are predicted to be registered with the US Green Building Council and more than 3,200 are expected to be certified. The total registrations will represent more than 1.1 billion sq.ft. (0.1 billion sq.m.) of new and renovated buildings, averaging 85,000 sq.ft. (7,800 sq.m.) in area.

1. Current Green Building Activity in the U.S.

Current green building activity in the U.S. is shown in Figure 1, which depicts the registrations of projects under the LEED system, including the total project area and the number certified, all at the end of 2004. The challenge is to explain this level of activity in terms of a theory that would allow future predictions.

Figure 1 shows that LEED project registrations at the end of 2004 had achieved a cumulative project area of 207 million gross sq.ft., or 19 million gross sq.m., and that 148 projects had been certified under the LEED version 2.0 and 2.1 programs. At the end of 2004, a total of 1,753 projects had registered their intent to pursue LEED certification in the future (LEED certification only occurs after a project has completed construction).

In the author’s experience, LEED certifications underestimate the total green building market because many projects use the LEED guidelines but never register with the U.S. Green Building Council. This “undercount” of the total number of U.S. green buildings may exceed twice the total number of LEED registered projects, so by focusing on the LEED registrations, we are taking a conservative approach to estimating the size and growth rate of the green building movement in the U.S.

2. Classical Diffusion Theory

Classical diffusion theory, now more than 50 years old, was standardized by Everett Rogers (1995) and is widely known among marketers of new technologies. Basically, it posits a group of five distinct personality types who adopt innovations in different ways, at different times. Table 1 shows these distinctions. This theory also posits a “normal distribution” of innovation adoption, with a typical 10-year mean time to reach 50% of the potentially available market and a total time for all adoptions to occur of more than 20 years.

As might be expected, the major issues in determining the rate of adoption of innovation include:

1) Relative economic or social advantage (still being debated for green buildings, but generally considered a positive factor)
2) compatibility with existing methods (generally this is the case for sustainable design)
3) ease of trial at relatively low cost (not the case for most new building technologies or systems)
4) observability by those who would try it (this is definitely the case for green buildings)
5) simplicity of use (which LEED and sustainable design do not offer, at this time).

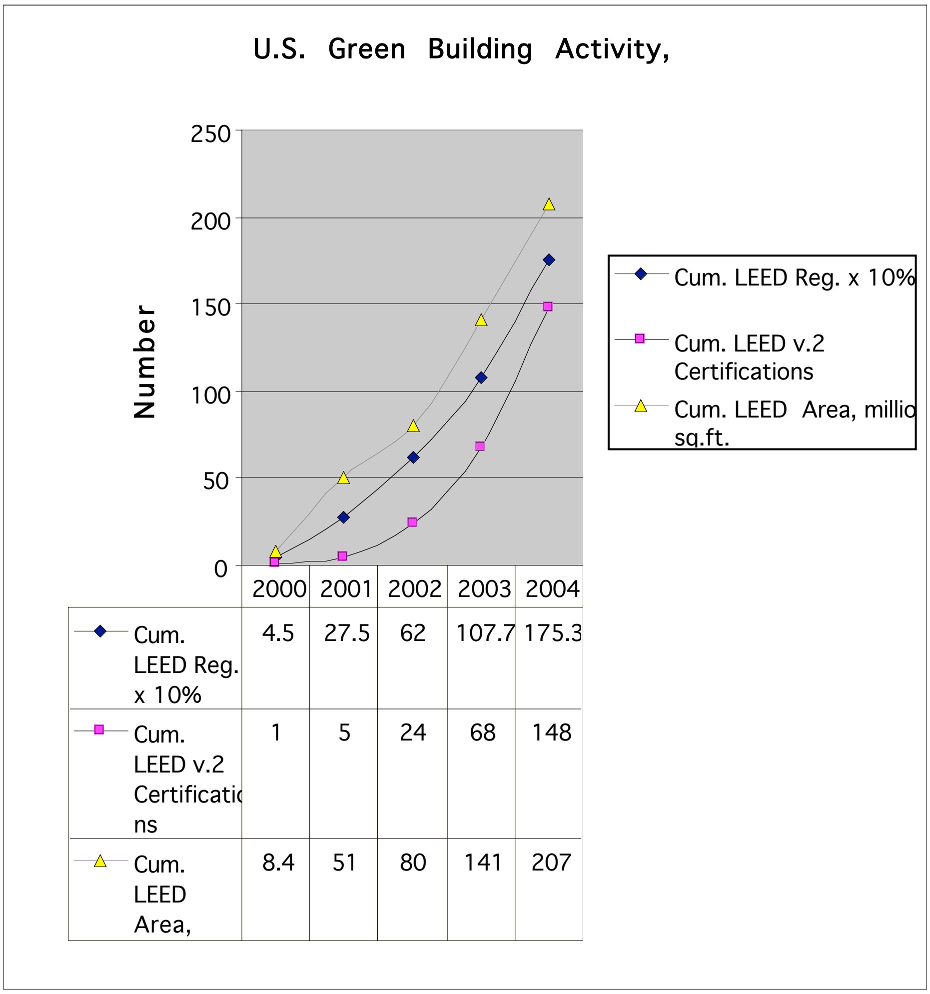

Figure 1 *LEED Project Activity in the U.S., 2000-2004*

Table 1 Categories of Responders to New Technological Innovations

Category – Responder Name	**Percentage of Total Potential Market**	**Characteristics**
Innovators	2.5	Venturesome
Early adopters	13.5	Respectable
Early majority	34.0	Deliberative
Late majority	34.0	Skeptical
Laggards (or “nevers”)	16.0	Traditional

Of these five factors, *relative economic advantage is the major driver of response to innovation*. According to Rogers, there are four overall key factors in determining the rate at which an innovation will spread from the relatively small innovator segment that welcomes new things, to broader segments that are far more risk averse and intolerant of ambiguity. See Table 2 for an expanded explanation of these factors.

1) The nature of the innovation itself, including its relative advantage
2) Communications channels used by subsequent market segments
3) Time required for the decision to innovate, the process of adoption to occur and additional adopters to learn about it (the time dimension for completing new buildings, typically two to three years, is short-circuited by the sharing of information from multiple projects, in this case).
4) Social system in which the innovation is imbedded, particularly the barriers to innovation.

At the end of 2004, LEED has gained perhaps 15% of the institutional market for new buildings but scarcely 4% of the corporate market (see Section 4.3). So, for the private sector market, the client base can be described as “innovators” and for the public buildings market, the client base is more likely of the “early adopter” category. Even in the public buildings client base, many project managers who supervise large projects could properly be characterized as “late adopters”, i.e., very risk averse, and may need strong mandates from upper management to pursue sustainable design projects.

The relative advantage of green buildings and LEED has yet to be shown in either of these markets, given the demonstrably higher capital costs and certainly higher certification costs, compared with conventional practice. Certain benefits, such as energy savings, are already a standard part of conventional project “payback” analysis. Benefits appear greater for long-term owner occupants of buildings, but many of the reported and putative benefits are harder-to-measure “soft costs” such as increased employee productivity, improved morale, reduced absenteeism and illness. From the author’s experience, these benefits have relatively little acceptance at this time among building owners, developers and project financiers.

Anecdotal evidence of benefits is strongly in favor of green buildings, but it has not filtered yet into the general marketplace enough to overcome perceived cost hurdles. Since the green building market is “project based,” it may take some time for perceived benefits to find appropriate projects, for a fuller implementation. Oftentimes, adoption of innovation is incomplete, for example, when a technology is acquired (in the way of desired outcomes such as LEED certification) but not deployed into general use; this phenomenon has been called the “acquisition gap” and has been found in a number of technology diffusion studies (Fichman and Kemerer, 1999), which observe that “knowledge barriers impede deployment.” This is happening with LEED: 20,000 people have taken the LEED training course, more than 19,000 have passed the LEED Accredited Professional exam, yet relatively few are actively pushing LEED registration for their design projects, primarily because of their own limited knowledge and possibly because of fear of client rejection.

In the light of the current state of the market, building owners’ and developers’ requirements for more *independent cost and performance evaluations of green buildings* are critical for building credibility and overcoming perceived barriers. In the author’s professional experience (“Yudelson’s Law” for new products), the *expectation of real benefits has to exceed the likelihood of increased costs by 25% or more* to change most decisions in favor of new technologies or methods. Many studies of the psychology of decision-making have shown that consumers and clients are likely to resist change unless the perceived “downside” risk of cost increases and possible performance failures is heavily outweighed by a well perceived “upside” benefit, such as stakeholder approval or more rapid sales and leasing of a building or housing unit.

3. Applying the “Diffusion of Innovations” to the Green Building Marketplace

To approach the green building market, it’s useful to think of it in terms of technological innovation. In order to be adopted, an innovation typically has to have a major cost or business advantage over existing methods. In the author’s experience, as this advantage has to be greater than 25%, if cost alone is the criterion. This “cost-effectiveness barrier” exists because of the costs of learning new methods, the economic risk of investing capital to try new things, and the business risk inherently involved with trying something new. In the building industry, there has been historic resistance to discontinuous innovation, so that in many ways, buildings are built much the same as 20 years ago, relying on primarily incremental innovations.

Figure 2 illustrates how innovation enters the marketplace. Initially, a group of “innovators” with typically strong technical expertise, high social status and a tolerance of risk try something new. When the size of this group reaches about 2.5% of the total potential market, then a group of “early adopters” begins to find out about what the innovators are doing, observes successful field trials and then begins to incorporate the innovation into their own work. This group of “early adopters” has less tolerance for risk, but is attracted to the benefits of the innovation. When the size of the group adopting the innovation reaches about 16% of the potential market, then a new group, the “early majority,” begins to use the innovation and begins the process of “mainstreaming” it. Finally, at about half the potential market size, a group of “late majority” signs on, not wanting to be left out forever.

Of course, many technical and technological innovations never achieve mainstream status, owing often to cost or complexity or inability to be assimilated by a larger population. Many technological innovations never have appealed to more than an “early majority, either because something better comes along, or because they have high switching costs, offer few comparative economic benefits or are just too complex for the average user.

Fell, *et al*. (2002) described how this theory can be applied to characterize residential homebuilders in terms of adoption of new wood-products technology. Early adopters had the highest level of opinion leadership and are generally viewed as experts among their peers. Studies such as this one show how new building technologies are communicated among market leaders and offer sage advice for green building marketers.

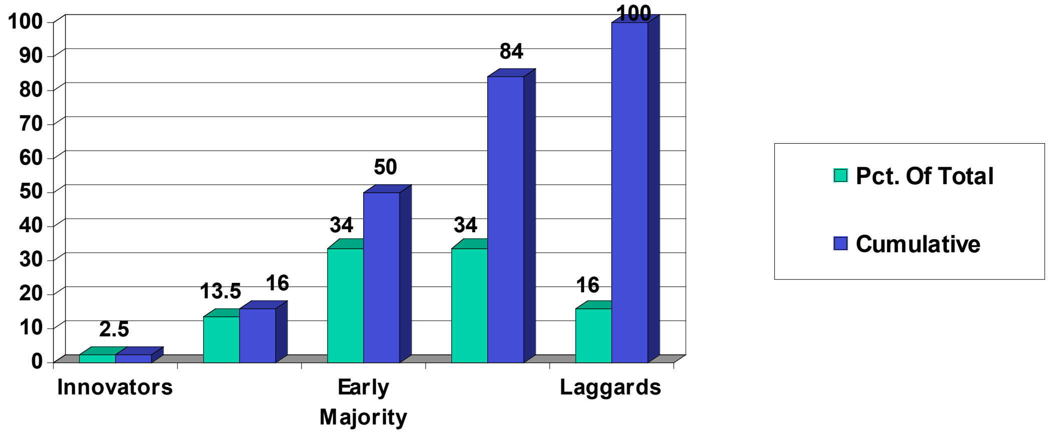

Figure 2 Diffusion Of Innovation, Showing Cumulative Adoption Rates By Psychographic Type (Early Adopter and Late Adopter labels not shown)

3.1 Fisher-Pry Model for Technological Substitution

Fisher and Pry (1971) developed a simplified model for the rate of technological substitution, which describes an S-shaped curve of cumulative substitution, shown in Equation (1). This yields the same result as integrating the annual rate of adoption over time. The Fisher-Pry equation requires us to estimate a time at which the substitution is 50% complete (t_o), and to empirically derive a rate coefficient, a. The total number of substitutions at any given time is given by estimating the total market size and multiplying by the fraction, f.

For the rate of LEED adoptions, we assume that the total number of potential projects is 120,000 (6,000 per year for a 20-year substitution cycle), hence t_o = 2010; the figure of 6,000 per year is based on 25% of a $264 billion U.S. non-residential construction market (at $11 million average per LEED project). Based on the first five years of data on LEED registrations, we estimate the rate coefficient, a, at 0.175. This gives an excellent fit to the first five years of data (see Figure 3) and gives confidence in the predictions to 2010. The R-squared correlation between actual and modeled data for 2000 to 2004 is above 99%, with these numbers.

$$f = 1/2 * (1 + \tanh a(t - to)) \qquad (1)$$

3.2 Green Buildings as an Innovative Product

To the degree that green buildings are simply "higher performing" buildings, one can argue that there's not much new here, that designing and building better buildings can readily be accomplished by the existing industry. However, if one considers the innovation to be rating and certifying buildings against various energy and environmental design criteria, as in the LEED green building rating system, then we can apply the classical theory of diffusion of innovation to forecast market demand. This theory encompasses the substitution of new ways of doing things for old ways, in a predictable pattern.

Cumulative adoption rates will follow some version of Figure 2, depending on how economically beneficial the innovation turns out to be. Each of the innovations listed above faces challenges to its adoption based on conventional economics, technical performance in the field, relative ease of specification, introduction by established competitors in the building industry, government and business mandates for change, and financial incentives from the government and utility sectors. These variables are shown in Table 2.

One should also consider the effect of a critical mass on the rate of adoption. According to Rogers (1995, page 314):

> The critical mass occurs at the point at which enough individuals have adopted an innovation so that the innovation's further rate of adoption becomes self-sustaining.…An interactive innovation is of little use to an adopting individual unless the individuals with whom the adopter wishes to communicate also adopt. Thus a critical mass of individuals must adopt an [interactive communication] technology before it has utility for the average individual in the system.

1. Perceived Attributes of Innovation	Examples: Relative (economic) advantage; compatibility with existing systems; complexity; trial-ability at reasonable cost; observable to others who might try it out
2. Type of Decision Required	Examples: Optional; group or committee decision; made by authority figure

Table 2 Variables Determining the Rate of Adoptions of Innovations (after Rogers, 1995)

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While this example deals explicitly with communications technologies such as telephones, faxes, PDAs, teleconferencing and the like, it has clear relevance for green buildings. Given the large numbers of people now trained in the LEED system (more than 19,000 LEED Accredited Professionals, and more than 20,000 who have attended the LEED training workshop), one can argue that LEED has all the hallmarks of a self-sustaining innovation. Therefore, its adoption rate can be predicted by utilizing this classical theory of innovation diffusion.

According to Rogers, decisions to adopt an innovation often may have a great deal of interdependence with each other, for example, with such technologies as cell phones, fax machines, the Internet, instant messaging. Green buildings may represent a similar phenomenon, given the vast interconnected industry of designers, specifiers, builders, product suppliers and equipment vendors, all of whom are dependent on each other, in some form or another, to design, specify, supply and build with innovative products and systems.

4. Forecasting Demand for LEED Green Buildings

4.1 Short-term Demand Forecasts to 2007

Given the latest full year's data (2004) and the annual rates of increase from the Fisher-Pry theory, one can estimate the following growth rates for the next three years and derive the results shown in Table 3:

<u>Year over Year Projected Growth in Cumulative LEED</u>

<u>Registrations and Registered Project area:</u>

Calendar Year 2005	50%
Calendar Year 2006	45%
Calendar Year 2007	40%

There are obviously some key issues here. For example, the biggest hindrance today in registering and certifying LEED buildings is the perceived (and often real) additional cost. This has been demonstrated in several surveys, including two proprietary surveys the author conducted in 2004 (Yudelson, 2004). In assessing the diffusion of innovation as an operating principle for projecting demand for LEED buildings, one should make the point that *it is cost-effectiveness above all* that determines the rate of adoption of new technologies. As individual building owners and developers, along with design and construction teams, get more experience with LEED buildings and with sustainable design measures and technologies, it is reasonable to expect the "cost premium" for LEED buildings to decrease, resulting in perhaps a substantial increase in LEED project registrations above these estimates.

To estimate LEED certifications from projections of LEED registrations, we have taken an empirical approach of assuming that each building takes an average of 2.0 years from the time of registration to the time of certification. On this basis, we have estimated the total LEED certifications at 20% of the previous two year's registration data. This approach may dramatically underestimate the number of certified projects in coming years, but it is based on the author’s observation that many registered projects do not proceed to full certification, owing to cost reasons, changes in building owner’s reasons for certifying, etc.

Table 3 Estimated LEED Registrations, Project Area and Certifications, 2004-2007

Year Ending December 31st	New LEED project registrations	Cumulative LEED registrations	Cum. LEED project area (million sq.ft.)	New LEED project certifications	Cumulative LEED certifications
2000	45	45	8.4	1	1
2001	230	275	51	4	5
2002	345	620	80	19	24
2003	457	1077	141	44	68
2004 (actual)	686	1763	207	80	148
2005 (estimated)	881	2644	310	229	377
2006 (estimated)	1190	3834	450	313	690
2007 (estimated)	1534	5368	630	414	1104

4.2 Size of the Non-Residential Building Market

LEED has always been aimed at just 25% of the building market at any given time (personal communication, Nigel Howard, US Green Building Council, 2004). With that in mind, it is useful to estimate the total available market for LEED registrations. Table 4 shows data on US non-residential building markets, from the US Department of Commerce web site, www.census.gov/const/C30/release.pdf .

This analysis leaves out the relatively few LEED residential projects at the present time (even though residential construction represents 55% of the total US construction market). Of the non-residential building market, only 40% ($105/$263 billion in 2004) is public construction, which constitutes the largest LEED market at the present time, representing more than 70% of total project registrations.

4.3 LEED Market Share

Assuming that the average building cost is $110 per sq.ft. for new construction, that leaves a potentially available LEED market of about 600 million sq.ft. per year. With a split of 60% private and 40% public, the private LEED market could be about 360 million sq.ft./year and the public LEED market would be potentially 240 million sq.ft./year.

Over the five-year period, 2000-2004, LEED estimates its registered projects to contain about 207 million sq.ft. This total represents about 145 million sq.ft. of public projects (at 70%) and 62 million sq.ft. of private projects.

During that four-year period, the public market would have been about 960 million sq.ft., so LEED’s market share would be about 15.1% of the total available public market, putting it squarely in the “early adopter” stage of market maturity from diffusion theory.

The private market would have been about 1,440 million sq.ft., and LEED’s market share would represent about 4.3% of the total available private market, putting this market maturity barely past the “innovator” stage.

Overall, LEED’s market share in 2004, based on 2004 results of 66 million new sq.ft. of project registrations, would be about 11% of the total available market, or about 2.75% of the total U.S. non-residential building market (less if one removes the LEED-registered multifamily residential projects which constitute 8% of total registrations).

Table 4. US Non-residential Building Market, 2002-2004 (Billions of dollars)

Building Sector	**2004**	**2003**	**2002**	**Estimated Total LEED Market at 25%**
Total	**$264.60**	**$266.40**	**$257.90**	**$66.20**

Source: US Department of Commerce, Construction Starts (monthly)

Looking at the 660 million sq.ft. of new (potential LEED) non-residential building construction per year, and an average LEED project size of 110,000 sq.ft., this *gives a potential LEED market of 6,000 buildings per year*. If LEED is planning to register about 881 projects in 2005 with 103 million sq.ft. of project area (our projection, Table 3), the market share for this year would be about 17% of the potentially available market for LEED buildings (and remember, these are defined to represent only 25% of the total building activity.) This is sizable, but still a long way from the level of market penetration to which LEED aspires.

Looked at another way, nearly 20,000 building industry professionals have taken the basic LEED workshop, and more than 19,000 have passed the exam to become a LEED Accredited Professional (AP), yet there were only 686 projects registered in 2004, representing the involvement of perhaps only 10% of the total LEED APs. One could look at these numbers and say that perhaps there is significant capability for the LEED-registered project numbers to grow rapidly, since most people (perhaps 90%) who have attended LEED workshops and become "LEED Accredited" have yet to work on their first LEED project.

4.5 Long-Term Forecasts Of Demand For LEED Projects

We provide also a long-term forecast, based on diffusion theory and the first five years of data on LEED project registrations, assuming a potentially available market of 120,000 LEED projects (20 years at 6,000 projects per year), shown in Table 5 and Figure 3. Note that this forecast differs a little from the numbers in Table 3 and reflects different approaches to short-term forecasting. Here, the Fisher-Pry model of technological substitution yields an "S-shaped" curve predicted by the diffusion of innovation theory (what we see here is the lower half of the long-term curve.). The theory predicts a steady slowing of the rate of growth, but a cumulative total LEED registrations more than 7.25 times the 2004 year-end total by 2010. If the average LEED project is $11 million (100,000 sq.ft. @ $110 per sq.ft.) then the LEED building market would be $33 billion in 2010, encompassing 300 million sq.ft. of project area.

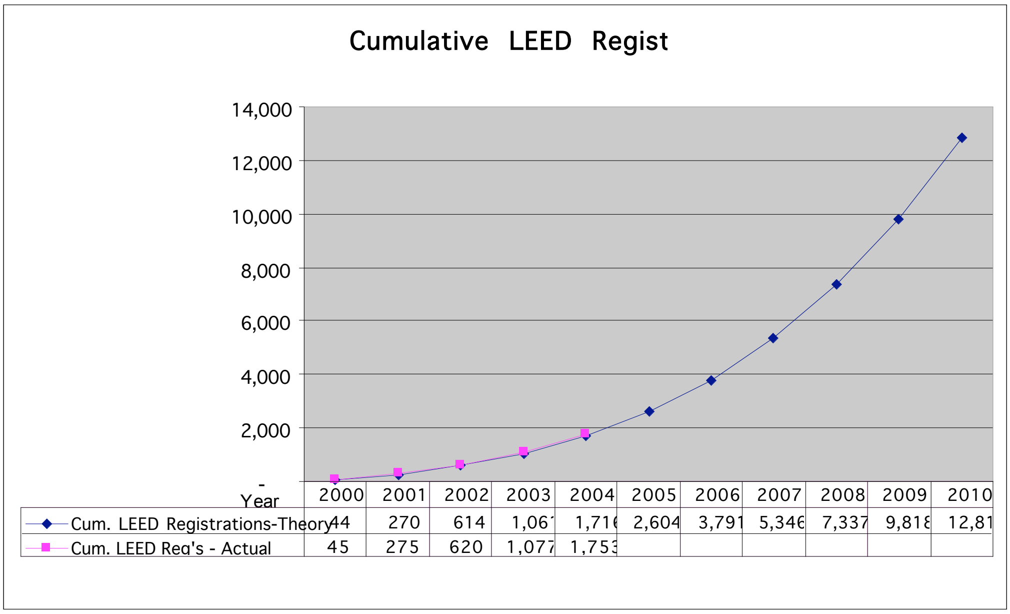

Figure 3 Long-Term Projection Of Cumulative LEED Registrations To 2010, vs. Actual Data to 2004

Table 5 below gives the data shown in Figure 3 and shows the estimated annual growth rates of LEED registrations. From Table 5, we can see that the annual growth rate in new LEED registrations slows from 62% in 2004 to about 31% in 2010. However, we should note that 30% annual growth in a notoriously slow growing U.S. building industry is still rapid.

5. Conclusion

LEED activity already represents a significant part of the building industry activity in the U.S. at the end of 2004, and it will certainly have an influence on many other aspects of the industry in the next half-decade. *From a diffusion of innovation perspective, by 2010 one can see that the green building movement will have moved through the "early majority" phase of the total available market, with much of what is now still considered innovative becoming commonplace.* If this happens, it will represent a dramatic change in what has traditionally been a slow moving and fairly conservative design and construction industry.

Table 5 Predicted Year-end Cumulative LEED Registrations and Growth Rate

Year	Cum. LEED-NC Registrations (2000 to 2004 data are actual)	Predicted Annual LEED-NC Registrations	% Growth of Cumulative LEED Registrations
2000	44	44	
2001	270	226	
2002	614	344	127%
2003	1,061	447	73%
2004	1,716	655	62%
2005	2,604	888	52%
2006	3,791	1,187	46%
2007	5,346	1,555	41%
2008	7,337	1,991	37%
2009	9,818	2,480	34%
2010	12,818	3,000	31%

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