STRATEGIC PLANNING FOR LEED CERTIFICATION

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Strategic Planning for LEED Certification
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Abstract

Intel Corporation has recently implemented a "green building" policy, which states that Intel will design all new facilities to achieve a minimum LEED-Silver certification. LEED (Leadership in Energy and Environmental Design) is a voluntary, consensus-driven rating system used to distinguish high performance, sustainable buildings. Buildings earn "points" in different environmental categories, and the total number of points achieved determines the certification level (Certified, Silver, Gold, or Platinum).

While LEED certification has been successfully applied to many residential and commercial buildings, and occasionally to manufacturing facilities, it has not been applied to many wafer manufacturing facilities (fabs), which house the manufacturing and production of Intel's microprocessors. Wafer fabs have much higher energy and water consumption levels than typical buildings due to their strictly controlled temperature, humidity, and particulate requirements, making LEED certification more challenging for a fab than for a typical building.

The objective of this study was to develop a planning strategy case study for Intel to achieve LEED-Silver certification for the construction of a hypothetical new wafer fab. The case study identified the main barriers to achieve LEED certification, including cost, risk, process, acceptance and alignment barriers, and outlined means to overcome them. The LEED criteria were then analyzed to determine the costs, benefits, and risks of pursuing each individual credit. The resulting "portfolio planning" model was then used to optimize a portfolio of credits for Intel to pursue. The final results indicated that for the optimized scenario, LEED-Silver certification could be achieved for a positive NPV of over $130,000. Significant cost savings were achieved through the avoidance of the credits related to energy efficiency and on-site renewable energy generation, credits that pose a significant risk to Intel due to the high energy consumption of a fab. Finally, process improvement recommendations were made for the planning, design, and construction of a LEED certified fab.

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TABLE OF CONTENTS

1 Introduction and Overview

1.1 Background and Context

The threat of global climate change has altered the business landscape for large corporations. Growing customer demands and the potential for climate change legislation has placed increased pressure on organizations to address the sustainability of their business operations. The concept of sustainability was first introduced by the Bruntland Commission, convened by the United Nations in 1983 to address the growing concern "about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development" (United Nations, 1983). The Bruntland commission defined sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). The number of companies worldwide that now publish corporate sustainability reports increased 46% from 2007 to 2009 (Global Reporting Iniative, 2009), indicating growing attention to and emphasis on sustainability within corporations.

Intel Corporation places an extremely high value on corporate sustainability. According to Intel's 2008 Corporate Responsibility Report (Intel Corporation, 2009), Intel's long-term focus on corporate responsibility and sustainability has both strategic and practical business value. Intel's role as a sustainability leader within the industry contributes to its reputation as a valued business partner and enables it to attract and retain a talented workforce, but also has tangible business benefits such as reduced energy costs. Intel measures key metrics in its pursuit of "triple bottom line" accounting, a concept that places emphasis not only on economic profits (e.g., net revenue, net income), but also social (e.g., percentage of women in the workplace, investment in training), and environmental (e.g., tons of carbon emissions) impacts as well.

To this end, Intel has implemented a host of environmental efforts to position itself as a sustainability leader within the semiconductor industry, including the following (Intel Corporation, 2009):

- Reduction of Greenhouse Gas Emissions: Intel has pledged to reduce absolute emissions from manufacturing by 20% of 2007 levels by 2012.

- Purchase of Green Power: In 2008, Intel became the largest purchaser of green power in the United States, purchasing certificates to support the generation of over 1.3 Billion kWhr per year in renewable energy.

- Sustainability Bonus for Employees: In 2008, Intel tied a percentage of the annual bonus of its employees to the achievement of several key sustainability metrics. This bonus applies to employees at all levels, from technicians to the CEO. While this sustainability bonus was only a small percentage of the total employee bonus, its existence represents Intel's commitment and accountability to its sustainability goals.

Further in pursuit of these sustainability objectives, in July 2008 Intel also implemented a "green building policy" for the design and construction of its new buildings and facilities. Recognizing the large impact that the construction and operation of its facilities have on the environment, Intel pledged to:

"Design new facilities to a minimum LEED (Leadership in Energy and Environmental Design) Silver Level by incorporating new green criteria into our standards, and minimizing costs by integrating best known methods and LEED early in programming" (Intel Corporation, 2009)

Intel has utilized this strategy successfully in the construction of a new office building in Israel, which was completed in 2008, but it has not yet been utilized for one of its manufacturing facilities. Intel's manufacturing faculties have a much greater environmental impact than its office buildings due to their larger size and higher water and energy consumption levels. Applying Intel's green building policy for the construction of its manufacturing faculties will present a greater challenge both in terms of the costs and risks of its implementation.

1.2 Leadership in Energy and Environmental Design (LEED)

1.2.1 Background

Leadership in Energy and Environmental Design (LEED) is a voluntary, consensus-driven rating system used to distinguish high performance, sustainable buildings that have less of an impact on the environment than typical buildings. LEED is administered by the United States Green Building Council (USGBC), a non-profit organization representing every sector within the building industry. The USGBC was founded in 1993 with the goal of creating unified environmental standards for the built environment. In the United States, buildings currently account for almost 30% of overall energy use and over 60% of electricity consumption (United States Green Building Council, 2009). Buildings consume energy to provide heating and cooling loads, ventilation, lighting, and process loads. An average office building consumes 93 kBtu/sf (Turner & Frankel, 2008) while a typical wafer fab utilizes 580 kBtu/sf (Westbrook, 2007). As shown in Figure 1-1, process loads comprised the majority of energy use for a typical 300-mm fab.

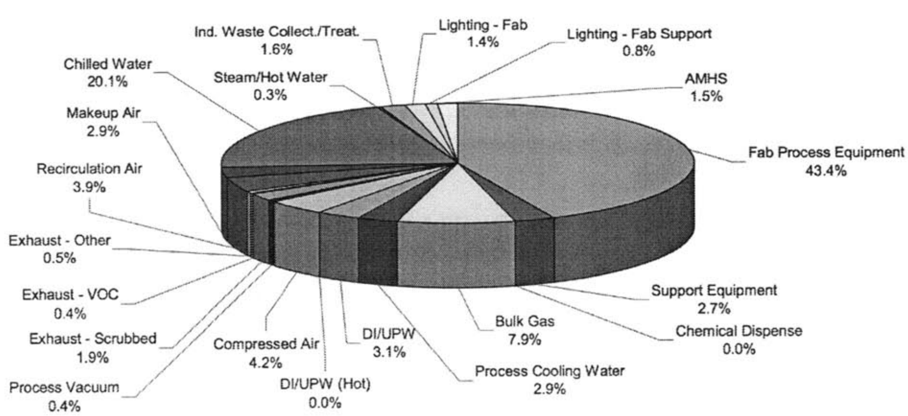

Figure 1-1: Energy consumption for a typical 300-mm wafer fab (Fenstermaker, 2008)

While there are many other rating systems applicable to the built environment (e.g., Energy Star), LEED has become the most widely used standard for new construction, mainly due to its popular name recognition. As shown in Figure 1-2, the number of LEED certified buildings that have been built has increased every year since its conception, from 40 LEED certified buildings in 2002 to over 900 in 2007 (Yudelson, 2009). Many state and local governments now require minimum LEED certification for new municipal construction projects.

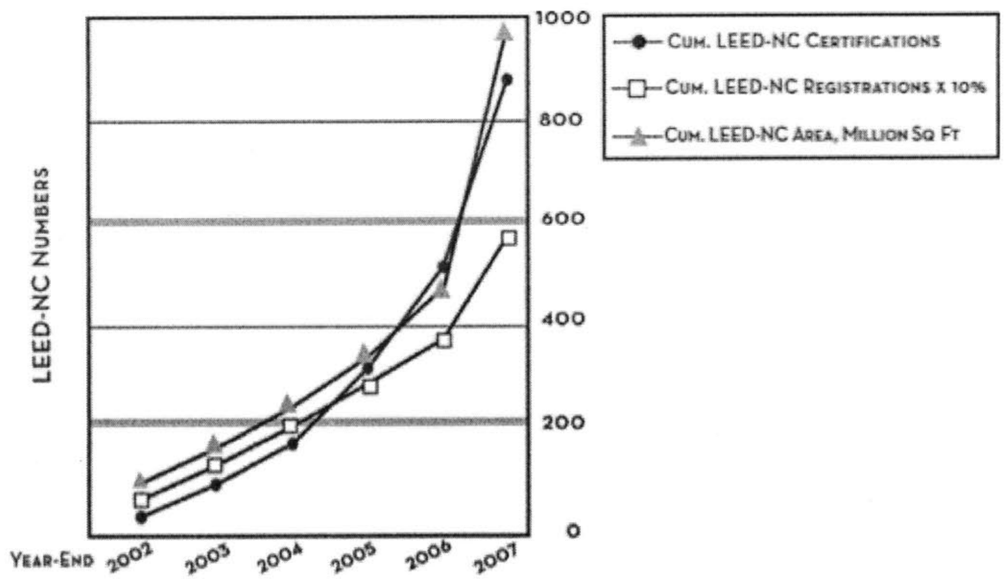

Figure 1-2: Growth in LEED Construction, 2002-2007 (Yudelson, 2009)

Buildings become LEED certified by earning "points" in five different environmental categories by incorporating environmentally sustainable design and construction practices. The five different LEED categories and the points are associated with them are as follows:

- Sustainable Sites (26 points)
- Water Efficiency (10 points)
- Energy and Atmosphere (35 points)
- Material and Resources (14 points)
- Indoor Environmental Quality (15 points)

This allocation represents the newest version of LEED, which was adopted in 2009. Points allocated to the "Energy and Atmosphere" categories were increased from the previous version of LEED, reflecting greater emphasis on controlling the greenhouse gas emissions that are responsible for climate change. The points above are all optional; building owners are free to decide which points to pursue in alignment with the building's program goals. However, within each category there are a number of "prerequisites" that all buildings must achieve to become certified.

There are four different certification levels within LEED, determined by the total number of points (out of 110) achieved:

- Certified (40-50 points)
- Silver (50-60 points)
- Gold (60-80 points)
- Platinum (80-110 points)

LEED was initially developed for residential and commercial buildings but has since been applied to a wide range of other types of buildings, including hospitals, laboratories, schools, warehouses, and manufacturing facilities. LEED has continued to evolve since its inception, going through numerous revisions and incorporating new versions to accommodate different building types. At present, there is not a version of LEED specifically for manufacturing facilities, although Texas Instruments has recently proposed LEED standards that are specifically tailored to semiconductor facilities (Giles & Huang, 2009).

1.2.2 Benefits of LEED

Numerous benefits are gained from LEED construction. The most obvious benefits are environmental, as LEED certified buildings are designed and constructed to consume less water, energy, materials, and land resources. But there are many other benefits to LEED that can often be overlooked by building owners, including financial, tax, and marketing/brand benefits. LEED proposals must be evaluated on a rational ROI basis that considers all of the benefits to LEED certification. While some benefits may be more subjective, their inclusion is significant because it balances the upfront costs that are typically more quantifiable.

First, the financial benefits of LEED have been well documented. LEED certified buildings consume less water and energy and hence tend to have lower operating costs than non-LEED buildings. In addition, LEED buildings offer better working conditions for employees, including better air quality, thermal comfort, and access to natural light, which increase employee productivity and reduce illness and absenteeism. A 2006 study compared productivity and operational costs of a company's new "green" manufacturing facility with its old facility and found that manufacturing productivity increased by 30% and energy use decreased by 25% on a square foot basis (Ries, Bilec, Gokhan, & Needy, 2006). A 2003 study by California's Sustainable Building Task Force analyzed the financial benefits of building green, including cost savings from reduced water, energy, and waste, operations and maintenance savings, and health and productivity savings, and concluded that the lifetime benefits amounted to over ten times the additional upfront costs of green construction (Katz, 2003).

Second, numerous government policies implemented in recent years provide advantageous tax incentives for the construction of green buildings. One possible location for a LEED fab location would be Oregon, which has aggressively promoted green building practices, including providing funding for the world's first urban high-rise "net zero" building. As shown in Figure 1-3, a 50,000 square foot building would receive $300,000 in tax incentives if built to LEED-Silver standards, and even higher incentives if built to LEED-Gold or LEED-Platinum. Furthermore, construction of a LEED certified building could help to mitigate against future federal carbon taxes, one proposal of which is currently under consideration in the US Congress. Even if Congress were to implement a modest tax of $10 per metric ton of carbon dioxide emitted, the cost savings could be substantial for a company that emits over 4 million metric tons annually (Intel Corporation, 2009).

Sustainable Building Facilities

(1) To be eligible for a tax credit, sustainable building facilities must achieve a minimum rating of "Silver" using the U.S. Green Building Council's LEED-NC™, LEED-CS™, or LEED-CI™ rating facility in affect as of the project registration date. Projects receiving a "Gold" or "Platinum" rating will be awarded proportionally larger tax credits, as calculated by the Energy Office; or

A facility must be rated and certified by a program approved by the Oregon Department of Energy that provides comparable performance on environmental measures and equivalent or better energy performance as documented by whole building energy modeling, is commissioned and is verified by an independent third party. In addition a facility must:

(a) In achieving its LEED™ rating, the facility must earn at least two points under Energy & Atmosphere Credit 1 (Optimize Energy Performance).

(b) In achieving its LEED™ rating, the facility must earn at least one point under Energy & Atmosphere Credit 3 (Additional Commissioning).

(c) Each LEED-NC™ or LEED-CS™ facility must calculate and report the building's annual solar income in Btu (not the site income). The calculation must account for the contribution from each face (orientation with surfaces exposed to direct sunlight) and must take into account any existing or reasonably expected shading (by other buildings or vegetation, e.g.) of these surfaces. Calculations may ignore such things as rooftop or wall-mounted mechanical facility components.

(3) Eligible cost will be calculated in accordance with the following table:

Building Area	Silver	Gold	Platinum
LEED-NC™			
First 10,000 sq. ft.	$10.00/sq. ft.	$13.57/sq. ft.	$17.86/sq. ft.
Next 40,000 sq. ft.	$5.00/sq. ft.	$5.71/sq. ft.	$9.29/sq. ft.
>50,000 sq. ft.	$2.00/sq. ft.	$2.86/sq. ft.	$5.71/sq. ft.
LEED-CS™			
First 10,000 sq. ft.	$7.00/sq. ft.	$9.50/sq. ft.	$12.50/sq. ft.
Next 40,000 sq. ft.	$3.50/sq. ft.	$4.00/sq. ft.	$6.50/sq. ft.
>50,000 sq. ft.	$1.40/sq. ft.	$2.00/sq. ft.	$4.00/sq. ft.
LEED-CI™			
First 10,000 sq. ft.	$3.00/sq. ft.	$4.07/sq. ft.	$5.36/sq. ft.
Next 40,000 sq. ft.	$1.50/sq. ft.	$1.71/sq. ft.	$2.79/sq. ft.
>50,000 sq. ft.	$0.60/sq. ft.	$0.86/sq. ft.	$1.71/sq. ft.

(4) Facilities using on-site renewable energy production technologies such as photovoltaic or wind technologies may treat these elements as a separate renewable energy resource facility for tax credit purposes, provided that any points earned for such features in the LEED™ rating are not required to achieve the rating on which the Sustainable Building facility credit is to be based. In cases where subtracting such points would result in a lowering of the LEED™ rating (e.g. from Gold to Silver), the tax credit will be awarded on the basis of the lower rating. The rating point total, net of renewable generation credits, can never be less than that required for a Silver rating.

Figure 1-3: Overview of Oregon's Sustainable Building Tax Credit (Oregon DOE, 2008)

Finally, LEED buildings have significant marketing benefits over non-LEED buildings. For example, according to a 2008 study, LEED certified apartment buildings garnered rent premiums of $11.33 per square foot over their non-LEED counterparts and have 4.1 percent higher occupancy rates (Miller, Spivey, & Florance, 2008). For Intel, the construction of a LEED-certified fab could enhance its brand both with its customers and its own employees. More and more, consumers and employees are beginning to make conscious decisions to be associated with products and employers that operate in an environmentally conscious manner. As many surveys over the past couple of years have shown, there are an increasing number of consumers who are concerned about climate change and who say they are willing to make changes in their purchasing and lifestyle choices (Mercer, 2006). It is also important to note that, as discussed further in this report, many of Intel's competitors have already begun the transition to green construction certifications of their manufacturing facilities.

1.2.3 Criticisms of LEED

Along with the benefits outlined in the previous section, there are many valid criticisms to LEED. One major criticism is that LEED does not take into account geographic specific characteristics; hence a facility in Oregon receives the same points for water conservation as a facility in Arizona. Another major criticism of LEED is the discrepancy between the level of effort to pursue certain credits and the benefits that result from those credits. A University of Michigan study concluded "in many cases the economic basis of the calculations led to results which the specific measured environmental impacts did not align with the LEED rating method" (Scheuer & Kelleian, 2002). In other words, some LEED credits are relatively easy to achieve and do not have significant environmental benefits, but are given the same weighting as those that are more difficult to achieve but do have significant benefits. This may give building owners incentive to pursue the credits that are more economical but do not have the greatest environmental benefit. However, the Michigan study concludes that this limitation is common in almost every green building rating system, and that there is a certain degree of subjectivity that is difficult to avoid.

Perhaps the biggest and most problematic criticism of LEED is that, after a building becomes certified, there is no mechanism of enforcement to ensure that the building is meeting its environmental objectives. The newest version of LEED does require that buildings submit their energy and water consumption levels to the USGBC, but it does not require buildings to retroactively make changes or revoke certification if LEED objectives are not met. According to the New York Times, many LEED certified buildings are actually less efficient than their non-LEED counterparts (Navarro, 2009). A 2008 study by the New Building Institute compared the energy performance of 121 newly constructed LEED certified buildings with non-LEED buildings (Turner & Frankel, 2008). This study concluded that while LEED buildings, on average, performed better than the entire stock of buildings in the United States, less than half of LEED buildings performed to the minimum Energy Star Rating[1]. According to this study, as shown in Figure 1-4, on average LEED buildings use only 7% less energy than non-LEED buildings. One can conclude that the actual performance of LEED buildings does not always match their intended performance.

Building Type	No. buildings surveyed	LEED building energy consumption (kBTU/sf)	Non-LEED building energy consumption (kBTU/sf)	LEED/non-LEED consumption %
Data Center	6	216	164	132%
Health Care	1	238	188	127%
Lab	10	284	356	80%
Recreation	2	126	164	77%
Supermarket	2	225	200	112%
AVERAGE		**242**	**260**	**93%**

Figure 1-4: Energy performance of LEED buildings compared with non-LEED buildings (Turner & Frankel, 2008)

[1] The minimum Energy Star Rating is a designation given to buildings that perform in the top 25% of US buildings with respect to energy efficiency (Energystar.gov)

1.2.4 Application to Semiconductor Facilities

Intel's wafer manufacturing facilities (fabs) house the production of Intel's microprocessors. The actual production area consists of a very large "cleanroom", which has very controlled temperature, humidity, and cleanliness requirements. The optimal controlled environment of a 200,000 square foot cleanroom for 300-mm wafer production consists of (Westbrook, 2007):

- Temperature of 70 degrees Fahrenheit (+/- 2 degrees)
- Relative Humidity of 45% (+/- 3%)
- ISO Class 5 cleanroom standards (10,000 times cleaner than room air)

Maintaining this controlled environment requires over 4,400,000 cfm of recirculated airflow and 650,000 cfm of makeup air (Westbrook, 2007). Within the cleanroom itself there are hundreds of process tools, fans, pumps, and support equipment, which consume large amounts of energy. Additionally there is extensive use of dionized water to rinse and clean the wafers during the production process. As mentioned before, LEED was originally proposed for residential and commercial buildings, which use energy and water in much different ways from a wafer fab. This is critical as it affects how LEED energy and water credits are applied to fabs in two very different ways, as discussed below.

<u>LEED Energy Efficiency Credits Applied to Semiconductor Facilities:</u>

A typical fab consumes over 170,000 MWhr of electricity per year (Westbrook, 2007), or the equivalent of 10,000 homes. The majority of LEED energy credits are based on a percentage energy use reduction or a percentage renewable energy generation. For example, one particular energy credit calls for 1% of a building's energy to be derived from on-site renewable resources, such as solar or wind power. This may be viable for the typical office building, but may be cost prohibitive for a semiconductor fab that consumes over 170,000 MWhr of electricity annually. Therefore many of the LEED energy credits may not be viable from a cost perspective. Figure 1-5 outlines the requirements of LEED energy efficiency credits and their compatibility with energy consumption in a wafer fab.

LEED Credit	Compatibility	Remarks
Credit 1: Optimize Energy Performance	Yes/No	Small energy reductions are possible, but difficult to achieve higher reductions due to high energy consumption of fab
Credit 2: On-Site Renewable Energy Generation	No	Too expensive to produce on site due to high energy consumption of fab
Credit 3: Enhanced Commissioning	Yes	Likely already part of fab design
Credit 4: Enhanced Refrigeration Management	Yes	Likely already part of fab design
Credit 5: Measurement and Verification	Yes	
Credit 6: Green Power	No	Too expensive to purchase green power due to high energy consumption of fab

Figure 1-5: Compatibility of LEED Energy Efficiency credits with wafer fabs (Jain, 2009)

LEED Water Efficiency Credits Applied to Semiconductor Facilities:

A typical fab consumes 3 Million gallons of water per day (Westbrook, 2007), or the equivalent of 6,000 homes. However, the challenge discussed above for LEED energy credit does not apply to LEED water credits. This is because approximately 96% of water consumed in a wafer fab is *process water* (Curcie, Hill, Jones, Meire, & Stagg, 2007), and LEED standards do not apply to process water. LEED water credits only apply to commercial applications of water, such as water closets, sinks, and landscaping. Therefore, while it becomes likely that LEED water credits are achievable because process water is not included, it may still be necessary to consider process water improvements because process water comprises the vast majority of the impact. Figure 1-6 outlines the requirements of LEED water efficiency credits and their compatibility with water consumption in a wafer fab.

LEED Credit	Compatibility	Remarks
Credit 1: Water Efficient Landscaping	Yes	Has little effect on overall water use in fab because it does not impact process water
Credit 2: Innovative Wastewater Technologies	Yes	Has little effect on overall water use in fab because it does not impact process water
Credit 3: Water Use Reduction	Yes	Has little effect on overall water use in fab because it does not impact process water

Figure 1-6: Compatibility of LEED Water Efficiency credits with wafer fabs (Jain, 2009)

1.2.5 Case Studies

Currently, there are only two semiconductor facilities in the world that have achieved LEED certification. Texas Instruments (TI) constructed the world's first LEED certified fab in Dallas, TX in 2005; Taiwan Semiconductor Manufacturing Company (TSMC) completed the world's second LEED certified fab in Taiwan in 2008. Both facilities received LEED-Gold certification at less than 1% of the overall project costs, indicating that Intel's goal of LEED-Silver is certainly achievable. These two facilities serve as valuable case studies for semiconductor industry fab construction.

Figure 1-7 outlines the individual LEED points that were achieved by both TI (Westbrook, 2007) and TSMC (Chang, 2008). Figure 1-7 also shows the percentages of LEED-Silver buildings in the United States that have achieved each individual credit (Silva & Ruwanpura, 2009). The frequencies at which these credits are obtained serve as an indication of the likelihood that they can be achieved for Intel. For example, Intel will likely be successful in pursuing the points that both TI and TSMC achieved; likewise those points that both TI and TSMC did not achieve will likely be more difficult for Intel to achieve. These two case studies will be used in the analysis that follows and serve as important examples of the strategies that other semiconductor manufacturers could implement.

No.	Credit Name	TI	TSMC	% Silver Certified Buildings Achieving Credit
SS1	Site Selection	yes	yes	93
SS2	Development Density and Community Connectivity	no	yes	32
SS3	Brownfield Redevelopment	no	no	0
SS4.1	Alt. Transportation - Public Transportation Access	yes	yes	69
SS4.2	Alt. Transportation - Bicycle Storage and Changing Rooms	yes	yes	82
SS4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	no	yes	12
SS4.4	Alternative Transportation—Parking Capacity	yes	yes	38
SS5.1	Site Development—Protect or Restore Habitat	yes	no	44
SS5.2	Site Development—Maximize Open Space	yes	no	70
SS6.1	Stormwater Design—Quantity Control	yes	yes	63
SS6.2	Stormwater Design—Quality Control	yes	yes	63
SS7.1	Heat Island Effect—Nonroof	yes	yes	82
SS7.2	Heat Island Effect—Roof	yes	yes	64
SS8	Light Pollution Reduction	yes	yes	94
WE1	Water Efficient Landscaping (Reduce 50%)	yes	yes	94
WE1	Water Efficient Landscaping (Reduce 100%)	yes	yes	31
WE2	Innovative Wastewater Technologies	yes	yes	26
WE3	Water Use Reduction (Reduce 30%)	yes	yes	18
WE3	Water Use Reduction (Reduce 35%)	no	no	0
WE3	Water Use Reduction (Reduce 40%)	no	no	0
EA1	Optimize Energy Performance (12%)	yes	yes	88
EA1	Optimize Energy Performance (14%)	yes	yes	88
EA1	Optimize Energy Performance (16%)	yes	yes	44
EA1	Optimize Energy Performance (18%)	yes	yes	4
EA1	Optimize Energy Performance (20%)	yes	yes	4
EA1	Optimize Energy Performance (22%)	yes	no	0
EA1	Optimize Energy Performance (24%)	yes	no	0
EA1	Optimize Energy Performance (26%)	yes	no	0
EA1	Optimize Energy Performance (28%)	yes	no	0
EA1	Optimize Energy Performance (30%)	yes	no	0
EA1	Optimize Energy Performance (32%)	yes	no	0
EA1	Optimize Energy Performance (34%)	yes	no	0
EA1	Optimize Energy Performance (36%)	yes	no	0
EA1	Optimize Energy Performance (38%)	yes	no	0
EA1	Optimize Energy Performance (40%)	no	no	0
EA1	Optimize Energy Performance (42%)	no	no	0
EA1	Optimize Energy Performance (44%)	no	no	0
EA1	Optimize Energy Performance (46%	no	no	0
EA1	Optimize Energy Performance (48%)	no	no	0
EA2	On-site Renewable Energy (1%)	no	no	26
EA2	On-site Renewable Energy (3%)	no	no	26
EA2	On-site Renewable Energy (5%)	no	no	26
EA2	On-site Renewable Energy (7%)	no	no	26

No.	Credit Name	TI	TSMC	% Silver Certified Buildings Achieving Credit
EA2	On-site Renewable Energy (9%)	no	no	6
EA2	On-site Renewable Energy (11%)	no	no	8
EA2	On-site Renewable Energy (13%)	no	no	0
EA3	Enhanced Commissioning	yes	yes	88
EA4	Enhanced Refrigerant Management	yes	yes	75
EA5	Measurement and Verification	yes	no	38
EA6	Green Power	no	no	0
MR1.1	Building Reuse—Maintain Existing Walls, Floors and Roof (55%)	no	no	7
MR1.1	Building Reuse—Maintain Existing Walls, Floors and Roof (75%)	no	no	7
MR1.1	Building Reuse—Maintain Existing Walls, Floors and Roof (95%)	no	no	0
MR1.2	Building Reuse—Maintain Interior Nonstructural Elements	no	no	0
MR2	Construction Waste Management (50% recycled)	yes	yes	100
MR2	Construction Waste Management (75% recycled)	yes	yes	70
MR3	Materials Reuse (5% reused)	no	no	6
MR3	Materials Reuse (10% reused)	no	no	0
MR4	Recycled Content (10% content)	yes	yes	95
MR4	Recycled Content (20% content)	yes	yes	26
MR5	Regional Materials (10%)	yes	yes	100
MR5	Regional Materials (20%)	yes	yes	12
MR6	Rapidly Renewable Materials	no	no	6
MR7	Certified Wood	yes	no	44
IEQ1	Outdoor Air Delivery Monitoring	yes	yes	70
IEQ2	Increased Ventilation	no	no	50
IEQ3.1	Construction Indoor Air Quality Management Plan—During Construction	yes	yes	94
IEQ3.2	Construction Indoor Air Quality Management Plan—Before Occupancy	yes	yes	94
IEQ4.1	Low-Emitting Materials—Adhesives and Sealants	yes	no	100
IEQ4.2	Low-Emitting Materials—Paints and Coatings	yes	no	94
IEQ4.3	Low-Emitting Materials—Flooring Systems	yes	yes	100
IEQ4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	yes	yes	75
IEQ5	Indoor Chemical and Pollutant Source Control	yes	yes	70
IEQ6.1	Controllability of Systems—Lighting	no	no	31
IEQ6.2	Controllability of Systems—Thermal Comfort	no	no	7
IEQ7.1	Thermal Comfort—Design	yes	yes	94
IEQ7.2	Thermal Comfort—Verification	yes	yes	50
IEQ8.1	Daylight and Views—Daylight	no	no	56
IEQ8.2	Daylight and Views—Views	no	no	62
ID1.1	Innovation in Design	no	yes	81
ID1.2	Innovation in Design	no	yes	44
ID1.3	Innovation in Design	no	yes	25
ID1.4	Innovation in Design	no	yes	12
ID1.5	Innovation in Design	no	no	0
ID2	LEED Accredited Professional	yes	yes	100

Figure 1-7: Review of LEED credits obtained by TI and TSMC; Percentage of LEED-Silver buildings achieving each individual credit (Chang, 2008), (Silva & Ruwanpura, 2009), & (Westbrook, 2007)

<u>Case Study 1: Richardson Fab, Texas Instruments, Dallas</u> (Westbrook, 2007)

TI's Richardson Fab (RFab) was completed in 2005 as the world's first LEED certified semiconductor facility, achieving a Gold rating at a cost of less than $2 Million or 1% the total project cost. TI implemented specific improvements beyond the exact requirements of LEED that are discussed below. Among the strategies to which TI attributed to its success are (Westbrook, 2007):

- The project team conducted a tour of a "high performance" building for key stakeholders at the very beginning of the project
- The project team formed a strategic partnership with the Rocky Mountain Institute, an organization dedicated to the efficient use of resources and eliminating the global economy's dependence on foreign oil
- The project team conducted a 3-day design charrette at the beginning of the project[2]

TI made specific improvements that resulted in 20% reduction in energy use and 35% reduction in water use, resulting in operational cost savings of over $4 Million per year, giving the project a payback period of less than six months (Texas Instruments, 2006). Some of the notable achievements for TI that resulted from LEED certification include (Westbrook, 2007):

- Use of native plants which required no municipal water for irrigation
- Recycling of rejected Ultra-Pure Water (UPW) to the beginning of the process and recycling of used UPW for use in cooling tower (this achievement was not required; as mentioned above, LEED water credits do not apply to process water)
- Use of heat recovery system for chiller plant
- Optimization of the dual temperature chilled water systems for the process loads required (See Figure 1-10)
- Use of variable frequency drives (VFD) and premium efficiency motors

Case Study 2: Fab 14, Taiwan Semiconductor Manufacturing Company, Taiwan

TSMC's Fab 14 received Gold certification in 2008 at a cost of less than $1 Million (or 1% of the project cost). TSMC began the certification process by visiting TI's RFab (discussed above) in 2006 and consulted with TI frequently during the design and construction process. According to TSMC officials, "TSMC did not understand LEED" (Chang, 2008) and hence the education it received from TI proved valuable to its success. Some of the strategies used by TSMC included:

- Developing a "green strategy" team, green specification, in-house LEED training
- Forming a strategic alliance with a local university to conduct the energy modeling required to obtain certain energy credits

TSMC reduced its overall energy consumption by 20% and water consumption by 55%, resulting in operational cost savings of $8 Million per year (Chang, 2008) and a payback period of less than 2 months. TSMC reduced its energy and water consumption in various innovative ways, including (Chang, 2008):

- Using captured rainwater and recycling condensed water from its Makeup Air Handlers (MAH) for irrigation (See Figure 1-8)

[2] A design charrette is "an intensely focused activity intended to build consensus among participants, develop specific design goals and solutions for a project, and motivate participants and stakeholders to be committed to reaching those goals. Participants represent all those who can influence the project design decisions" (Lindsey, Todd, & Jayter, 2003).

- Reclaiming 85% of process water (see Figure 1-9)
- Use of dual temperature water systems, similar to the strategy implemented by Texas Instruments; this one improvement resulted in cost savings of $400,000 per year (See Figure 1-10)
- Use of variable flow control for chilled and warm water, which resulted in 7.2% energy savings
- Use of variable flow control for HVAC and exhaust fans, which resulted in 5.6% energy savings
- Use of heat recovery from chillers, which resulted in 6% energy savings
- Optimization of lighting systems, which resulted in 1% energy savings

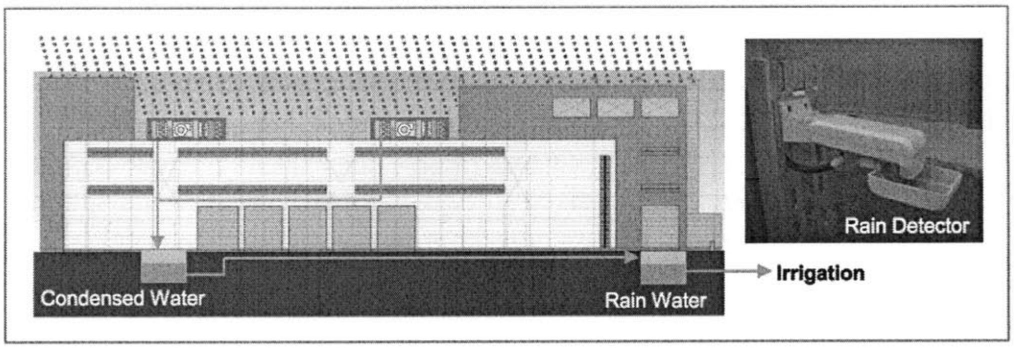

Figure 1-8: Strategies for water conservation at TSMC: TSMC utilized a rainwater collection system with a 700-ton capacity to provide a steady water supply for irrigation, eliminating the use of municipal water for irrigation. The collection system also collected condensed water from its air conditioning systems. (Chuang & Chen, 2009)

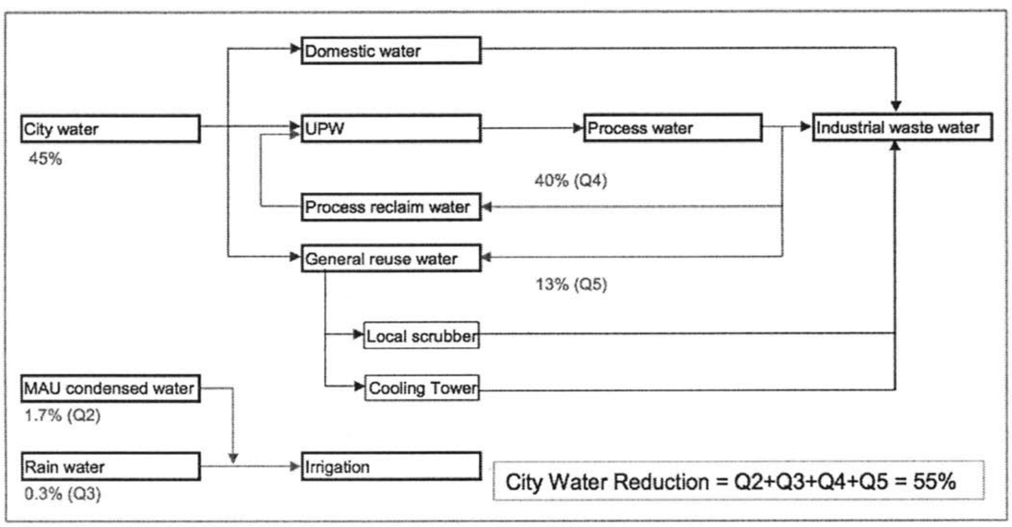

Figure 1-9: Strategies for water conservation at TSMC: TSMC reduced the overall use of municipal water by 55% by reclaiming process water and recycling MAU condensed water and rain water (Chuang & Chen, 2009)

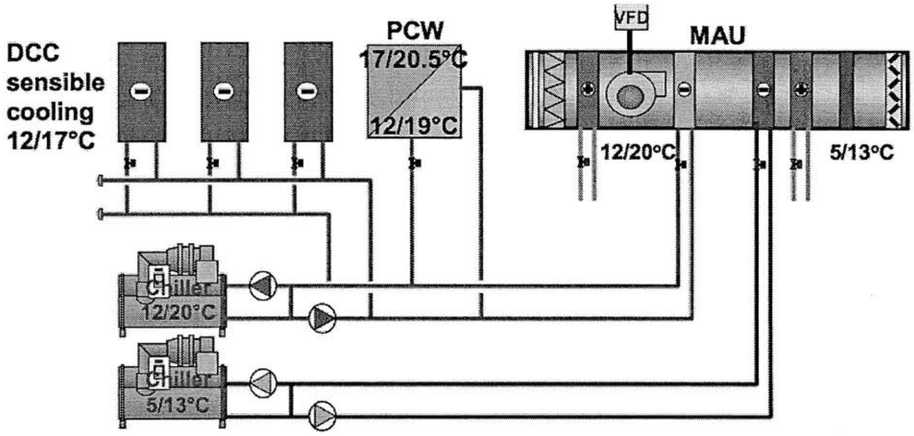

Figure 1-10: Strategies for energy conservation at TSMC: TSMC optimized its chilled water systems that provide cooling loads to its facilities. Instead of only one chilled water system that provides a single cooling load to the entire facility, TSMC developed dual chilled water systems that were optimized for the cooling load required for the specific facility (Chuang & Chen, 2009)

These cases show that LEED can survive a rational cost/benefit analysis for wafer manufacturing facilities. TSMC recently conducted a study that looked at the current practices of 58 "high tech manufacturing facilities" and concluded that 85% of these facilities were able to meet a goal of LEED-Gold certification (Chuang & Chen, 2009).

1.3 Objective of Study

The objective of this study is to provide a case study using Intel assumptions to identify gaps to LEED-Silver certification. The study attempts to answer the following three key questions:

1. What are the historical "barriers" to LEED certification and what are the strategies to overcome those barriers? Barriers and strategies to overcome them were determined from empirical data taken from projects that were not successful in achieving their LEED objectives, and included interviews and surveys of key stakeholders in those projects. Barriers to LEED certification are discussed in Chapter 3.

2. Which individual LEED credits would it make the most strategic sense for Intel to pursue and how would Intel's current processes have to change to implement them? Methods used to achieve this objective included a determination of LEED credits that Intel has already achieved with its current design and construction policies, and cost/benefit and risk analyses of those credits that Intel has not yet achieved. The methodology and results of this analysis are discussed in Chapters 4 and 5.

3. Is LEED the right rating system for Intel, and if so, what should Intel do beyond LEED and what its competitors have accomplished in order for it to meet its corporate sustainability

objectives? This is a qualitative determination of the appropriateness of LEED to Intel's corporate social responsibility objectives and its commitment to sustainability. This issue is discussed in Chapter 6.

averse when dealing with costs that are unknown and/or difficult to quantify, priority should be given to the strategies where the costs are known with reasonable certainty.

2.2 Risk Barriers

Along with cost, an adequate understanding of the risks involved in LEED certification is essential for a successful outcome. Often the strategy to achieve LEED certification is a tradeoff between cost and risk: certain credits, while inexpensive to implement, carry higher risks; likewise certain credits may be costly but once achieved present virtually no risk to the organization. In the semiconductor industry, companies tend to be very risk adverse when it comes to construction of their manufacturing facilities for two main reasons: construction schedule and process technology.

First, the construction schedule within the semiconductor industry tends to operate on a very swift timeline, with design, construction, and tooling occurring in as little as 16 months (Binder, 2004). There is an advantage to swift completion as it enables product to be delivered to the market more quickly. Hence Intel has a well-defined planning and construction timeline that is designed to implement production as quickly as possible. Certain LEED credits, especially those dealing with sourcing of materials, can often result in construction delays because they require higher-than-normal standards from the construction team. These requirements may lead to misunderstandings and delay if the construction team is not familiar with LEED requirements. Many construction schedule risks can be mitigated with proper planning that begins early within the project cycle.

Second, process technology within the semiconductor industry, which refers to the equipment, tools and technology used during the production process, tends to have ultimate control over design and construction decisions. As discussed above, production of Intel's microprocessors requires a tightly controlled environment, where lighting, temperature, humidity and particulates are strictly controlled, and Intel designs its facilities with these factors in mind. Hence there may be resistance to implementing credits that pose a perceived threat to control of these conditions, such as credits that require controllability of lighting and thermal comfort. An analysis of LEED credits achieved by TI and TSMC indicates there are certain credits that were deemed to risky to pursue.

Therefore an adequate understanding of risks involved for an industry that is very risk averse is essential. Specific risks to obtaining certain LEED credits are further discussed and quantified later in this report.

2.3 Process Barriers

Understanding and incorporating the process of LEED certification is another barrier that must be overcome for a successful LEED project. Not understanding the correct process can contribute to schedule delays, cost increases, or can even force building owners to abandon LEED certification. Intel's current design and construction processes must be updated to incorporate LEED criteria. Some of these process barriers, which will be expanded upon later in this report, include project timing, project team, and documentation:

<u>Project timing:</u> It is important that LEED goals and criteria are incorporated early in the project. Projects that attempt to add LEED late in the design process are often met with large cost increases and schedule delays.

2 Barriers to LEED Certification

While LEED is growing in popularity, the current state of the built environment suggests that there are still considerable barriers to LEED certification. According to the USGBC, only 3% of buildings currently under construction are built to LEED standards (United States Green Building Council, 2009). Furthermore, as of June 2008, of the nearly 7200 LEED projects that were registered with the UGGBC, slightly less than 1100 projects had achieved certification (Yudelson, 2009). In other words, 7200 projects stated their attempt to achieve LEED certification, but only 1100 have actually achieved LEED certification, suggesting a low success rate for projects that attempt LEED. Research, interviews, and surveys (Johnson, 2005), (Hanby, 2004) have indicated that there are multiple barriers, both real and perceived, that must be understood in order to achieved a successful LEED project.

This section attempts to outline these barriers and recommend ways to overcome them. These barriers discussed are taken from several sources that examine empirical data from projects that were not successful in achieving their LEED objectives (Johnson, 2005) & (Hanby, 2004). These barriers are examined within the context of policies and culture of Intel. There are five main barriers to LEED certification. The first three barriers (Cost, Risk, and Process) are more quantitative in nature and can apply to any industry or organization; a comprehensive analysis of these three comprises the remainder of this report. The remaining two (Acceptance and Alignment) are more qualitative and reflect the unique culture of the organization in question. All five of these barriers will be discussed in the following sections. It is important to note that these barriers are not mutually exclusive; there is a great amount of overlap among them.

2.1 Cost Barriers

Perhaps the most often mentioned barrier to LEED certification is the Cost Barrier. LEED buildings tend to have higher upfront costs. These costs include the additional material and labor costs of the actual implementation, but there are also higher costs for consultants, commissioning authorities, and documentation for the certification process. Conversation with TSMC indicated that 40% of the premium for its LEED-Gold fab came from these additional consulting fees. Many of these costs are not well understood and can be difficult to quantify, and it is often hard to obtain accurate cost information for planning purposes. Often higher costs result from the additional time needed for research and planning because the LEED process is not well understood by building owners.

However, many of these upfront costs are only perceived costs and a closer look reveals that they can be mitigated through proper planning and analysis. A well-known study by Davis Langdon (Langdon, 2007) analyzed a total of 221 buildings with similar program goals, 83 of which had a goal of LEED certification and 138 of which did not. This study concluded that, on average, there was no significant cost difference between LEED and non-LEED buildings. It was possible to avoid added cost by pursuing the simpler, more cost effective strategies rather than the more advanced, expensive strategies for certification. As shown in Figure 2-1, for LEED certified laboratory buildings there was no statistical difference between the cost of LEED and non-LEED buildings. The study concluded, "there are low cost and high cost green buildings...(and) there are low cost and high cost non-green buildings" (Langdon, 2007). According to a report by the State of CA Sustainable Building Task Force, "if the stakeholder is committed at the project conception and the design and construction team has moderate sustainable design and construction experience, a LEED Certified building can be achieved on a conventional building budget" (Syphers, Baum, Bouton, & Sullens, 2003).

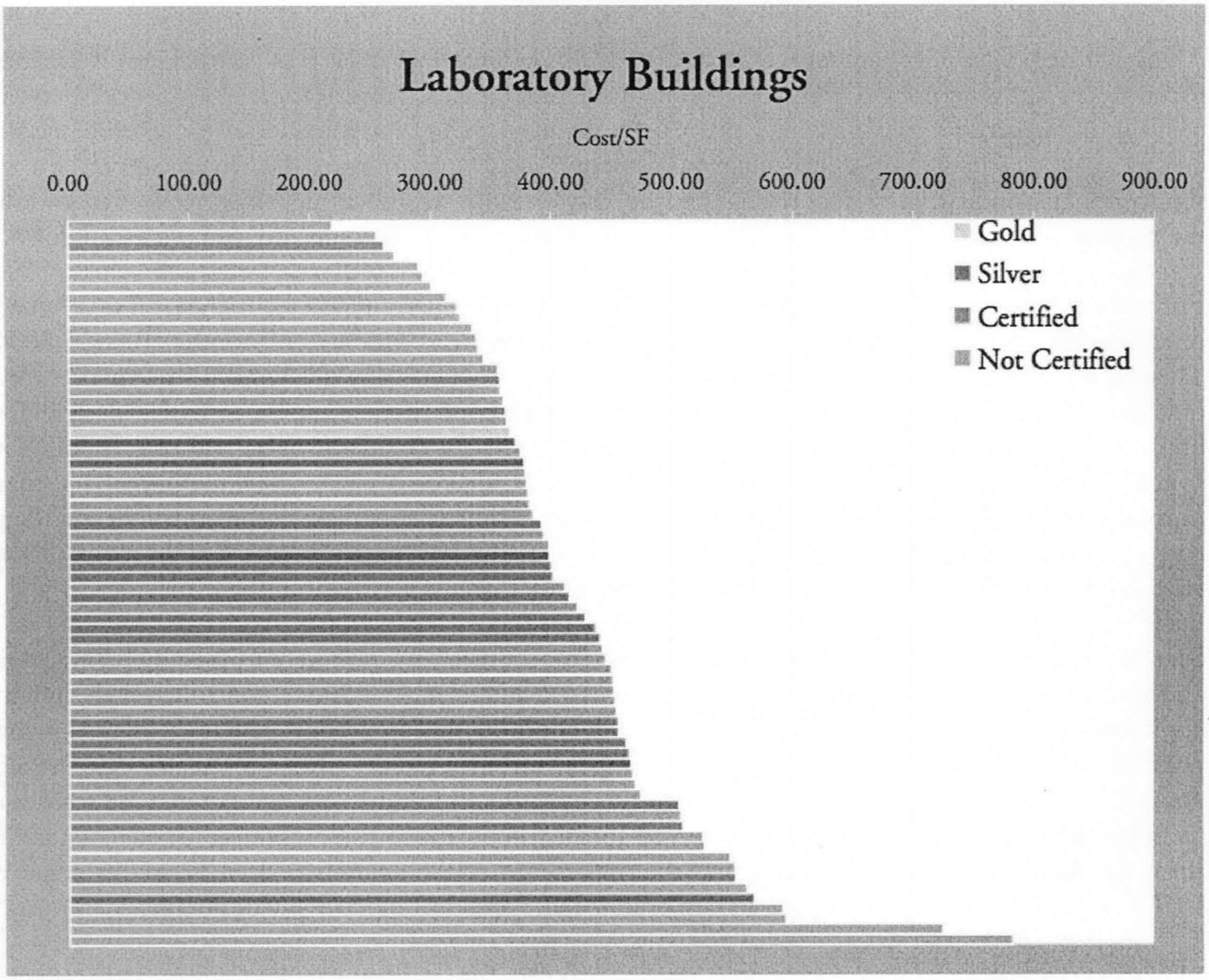

Figure 2-1: Cost of LEED versus non-LEED buildings for laboratories (Langdon, 2007)

The most effective way to overcome the Cost Barrier is to align the budget with the program early in the design process. It is important to have an accurate financial model that reflects an adequate understanding of where all of the costs lie. The analysis should include not only the upfront costs, but also all of the benefits that are anticipated over the lifecycle of the building that are likely to result from LEED certification. These benefits include lower operating costs, increased productivity, and federal and local tax incentives. As discussed in the TI and TSMC case studies above, when the operational savings were included in the analysis, the additional costs to implement LEED in both projects had payback periods of less than six months. Another important factor in the analysis is understanding and quantifying the value of LEED to the brand and image of the organization. For example, if Intel concluded that LEED certification was worth $500,000 to its brand appeal, this benefit should be included in the financial model. For companies that are risk

Project Team: It is critical to select a team that has proper knowledge and experience of the details of how LEED works. If the project team is internal to the company, in-house training should be conducted. If the project team is external to the company, external consultants and contractors that have experience with LEED should be selected.

Documentation: Contract documents, including scopes of work, drawings, and specifications, must be updated to incorporate LEED goals and criteria. All construction documentation must reflect the level of certification and the documentation that is necessary to achieve that level of certification.

2.4 Acceptance Barriers

Perhaps the most important and difficult barrier to overcome is the Acceptance Barrier. This barrier can affect all aspects of the team and project. This barrier manifests itself when members of the team do not believe in the value of LEED. Some may question the environmental value of LEED and the motives of their organization. They may see LEED as "green washing" or a fad that management promotes today but will not necessarily be a priority later. Members of the team may not have the resources or availability and therefore place it on the back burner. The team may not accept the inevitability of LEED and therefore are not fully committed to it.

The Acceptance Barrier is often the most difficult barrier to overcome, especially when dealing with a large organization such as Intel, because it requires a strong force to counter the inertia of "business as usual." The most strategic way to overcome this barrier is to have a clear, consistent message from upper management that LEED certification is a priority for the organization. This message should be repeated often and should be framed in a way that speaks directly to the values of the organization. For example, for some organizations it makes strategic sense to speak about the environmental benefits of LEED; for others it makes strategic sense to frame the problem from the economic benefits and promote the cost savings that will result from LEED certification. For Intel, the message must clearly show how LEED certification is aligned with its overall strategic objective of "building new business by tackling big problems" (Intel Corporation, 2009). According to a recent study that analyzed effective marketing strategies for building public support for environmental protection, effective communication around a topic such as LEED begins "by recognizing the core ideals, goals, and values that motivate the audience, and to come back to those ideals throughout the conversation" (Pike & Herr, 2009).

Another effective strategy to counter the Acceptance Barrier is to organize and devote considerable resources to a large-scale "kick-off" event, preferably in a remote location, with key stakeholders of the organization. For example, TSMC brought key stakeholders to visit TI's LEED certified fab at the very beginning of the project to build support and enthusiasm for LEED. This type of activity can counter the myth that LEED is not a priority for management and forces the team to accept its inevitability.

2.5 Alignment Barriers

Finally, lack of alignment presents a barrier to LEED certification for many organizations. Design and construction of a LEED building requires cooperation and integration between many different building disciplines, including architects, engineers, consultants, contractors, and building owners.

Understanding and balancing the needs of these various stakeholders is critical. Within a large organization especially, it is not always easy to know who the stakeholders are.

There are two main strategies for overcoming these barriers. First, a "LEED champion", internal to the organization, must be selected at the earliest stage of the project. This champion should be someone who has authority over all of the disciplines discussed above. This person must be willing and able to communicate a uniform and coherent message throughout the project and act as the program manager throughout the project duration.

Second, it is essential to conduct an "eco-charrette" early in the design process. An eco-charrette is defined as "an intensely focused activity intended to build consensus among participants, develop specific design goals and solutions for a project, and motivate participants and stakeholders to be committed to reaching those goals. Participants represent all those who can influence the project design decisions" (Lindsey, Todd, & Jayter, 2003). The goal of an eco-charrette is to gather key stakeholders and experts to develop and agree to the program goals and specific strategies to achieved LEED certification. The majority of successful LEED projects have completed this design step and it is considered critical to the success of the project (Yudelson, 2009). The eco-charrette will be expanded upon later in this report.

3 Methodology

The following sections outline the methodology used for the analysis to determine which individual LEED credits it makes the most strategic sense for Intel to pursue. First, the LEED criteria were applied to Intel's existing design and construction practices to determine which points Intel was already achieving. Second, the remaining credits were analyzed for their costs and risk to determine which credits Intel should pursue to reach the Silver certification level. Finally, the analysis determined how Intel must update its current design and construction practices to successfully achieve those credits.

3.1 Applying LEED Criteria to Existing Fab

The first step in the analysis was to apply the LEED criteria to Intel's current design and construction policies: which credits was Intel already achieving, which were possible but required an increase in cost and/or risk, and which were completely impossible to pursue. This preliminary analysis helped to focus the detailed cost/benefit and risk analysis that followed. The methodology for this initial analysis is shown in Figure 3-1. Each individual LEED credit was classified in one of three "bins". The classification scheme consisted of the following:

SECURE: Intel currently practices this LEED criterion in its design/construction practices.

POSSIBLE: Intel currently does not practice this LEED criterion, but can meet this criterion at a relatively low level of cost and risk. Potential changes to the design and/or construction processes will be required if this credit is implemented. The credits that fall within this category will be evaluated in more detail for their costs, benefits, and risks as described in the following sections.

NOT VIABLE: Intel will not be able to meet these criteria either because of physical constraints, policy constraints, or because the credit will negatively impact Intel's existing technology processes.

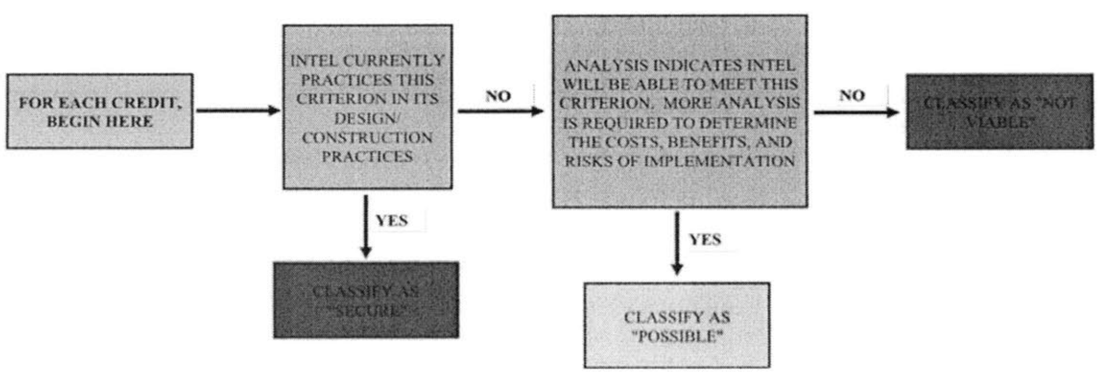

Figure 3-1: Methodology for Applying LEED to Existing Fab

3.2 Cost/Benefit and Risk Analyses

The second step in the analysis was to evaluate the credits within the "possible" category and determine the cost, benefits, and risks of implementing each credit. The cost/benefit and risk analyses are described in the following two sections.

3.2.1 Cost/Benefit Analysis

This analysis included all of the costs and benefits to implement the credits classified as "possible". The following costs and benefits were considered: upfront capital costs, additional LEED consulting costs, LEED certification fees, operational cost savings, productivity savings, local Oregon tax incentives, and value of LEED for Intel's brand. These costs and benefits were used to calculate the Net Present Value (NPV) to implement LEED-Silver certification for a 10-year period and a discount rate of 15%. These costs and benefits are described in more detail below; results of the cost/benefit analysis are presented in Section 4-3.

<u>Upfront Capital Costs</u>

Upfront capital costs include the incremental cost of materials, labor, design and construction to implement each individual credit. These costs were determined on a per credit basis. Cost data were taken from three relevant case studies. These case studies were based on actual LEED projects, in which the incremental cost of each individual credit was determined after the building was completed. The case studies represent three different building types – a federal courthouse (Steven Winter Associates, 2004), a laboratory building (Haxton & Beckstead, 2008), and a hospital (Department of Health and Human Services, 2006).

These costs were determined on a square footage basis, and were scaled up for this analysis based on the square footage of the fab. While a semiconductor facility is different from these types of buildings, it is important to note that the majority of LEED credits (76%) have nothing to do with the function of the building and are therefore scalable for different types of building. Many of these credits are cosmetic changes to the building (i.e., use of low-emitting paint) that have nothing to do with the underlying function of the building. Those credits that depend heavily on the function of the building, including credits related to the optimization of energy performance and on-site renewable energy generation, are treated differently and their costs were scaled both by square footage and by energy use.

<u>Additional LEED Consulting Costs</u>

LEED certification will involve additional costs associated with hiring LEED specialists, who provide guidance and advice, documentation services, energy modeling, and commissioning activities. According to conversations with TSMC[3], these consulting fees comprised approximately 40% ($400,000) of the cost premium for LEED certification for their LEED-Gold fab in Taiwan.

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[3] Based on personal conversation with Tony Chin, TSMC Taiwan (November 24, 2009)

LEED Registration Fees

Every LEED-certified project must pay mandatory registration and certification fees. According to the USGBC website (USGBC, 2009), the registration fee for a new building is $1,200 and the fee for a combined design and construction review for certification for a facility greater than 500,000 square feet is $27,500. Therefore the combined fees for registration and certification are $28,700.

Operational Cost Savings

Operational cost savings include the utility savings that result from energy efficient improvements or on-site renewable energy generation. These are based on the percentage reduction of total energy use of the facility or the percentage of renewable energy generated. Savings associated with LEED water efficiency improvements, which involve efficient plumbing fixtures and landscaping, are considered negligible and are neglected. Operational cost savings are calculated as an on-going yearly benefit.

Productivity Savings

As discussed above, several studies have indicated LEED certification carries significant productivity benefits. These benefits stem from improved working conditions for employees, including better air quality, thermal comfort, and access to natural light, which increase employee productivity and reduce illness and absenteeism. While these benefits are not always easy to quantify, they can be estimated as a percentage of the total overhead costs of employees working in a fab. A study by California's Sustainable Building Task Force (Katz, 2003) found several attributes associated with green building design have been positively and significant correlated with increased productivity. The study attributes a 1% productivity and health gain to LEED Certified and Silver buildings and a 1.5% gain to LEED Gold and Platinum buildings.

Value of LEED to Intel's Brand

LEED certification could add significant benefit to Intel's brand. Intel's commitment to sustainability has helped it to attract and retain talented employees and to become a trusted business partner to its suppliers and customers. This marketing benefit, while not easy to quantify, must be included in the cost/benefit analysis because it carries significant strategic value.

3.2.2 Risk Analysis

This analysis included an evaluation of all of the known risks to implement the credits classified as "possible". As discussed above, understanding the specifics risks of LEED is an important barrier that must be overcome. For the purpose of this analysis, risk is defined as anything that causes the project to not meet expectations, to be delayed, or to cost more than planned. Nine risk categories were identified for the analysis, including:

- **Availability of materials:** Many credits depend of the availability of specific materials, such as certified wood, and lack of availability would make these credits unobtainable.

- **Commodity price volatility:** The price of building material commodities, such as steel, can affect the viability of many credits.
- **Performance Issues:** Several credits require monitoring and verification after the building is constructed; if standards are not met, potentially costly corrective action must be taken.
- **Increased Design/Construction Complexity:** While many credits require relatively simple changes (i.e., specifying the use of low-VOC paint in specifications), others require design and construction changes that can be costly and resource intensive.
- **Design Changes to Facilities Systems:** Intel is risk averse when it comes to changes to its facilities equipment, including its HVAC systems, due to the strictly controlled environment of the cleanroom. Credits that involve changes to facilities equipment face much higher hurdles for approval than other credits.
- **Supply Chain Challenges:** Some credits place specific requirements on sourcing decisions. For example, multiple credits place limits on the distance from which its construction materials can be sourced in order to limit transportation-related emissions.
- **Space Constraints:** Many credits require a certain amount of open outdoor space for implementation; depending on the final master plan, which has not yet been approved, this space may or may not be available.
- **"Attractiveness":** Certain credits require used of certain materials or plants that may not be considered "attractive" for an Intel facility and hence would not be pursued.
- **Changes to Green Building Code:** Potential updates to LEED in the near future may have a significant impact on the viability of multiple credits, and hence this risk should be considered.

Each of these risk categories was analyzed to determine both its *impact* and its *likelihood*. Impact was defined the percentage of "possible" credits that would not be viable if the risk was realized. Likelihood was determined through interviews and surveys of construction experts familiar with LEED construction (Feigin, 2009). The overall risk profile for LEED certification can then be obtained by plotting the impact and likelihood (both scaled on a range from 0 to 10) of each risk category on a graph, an example of which is which is shown in Figure 3-2.

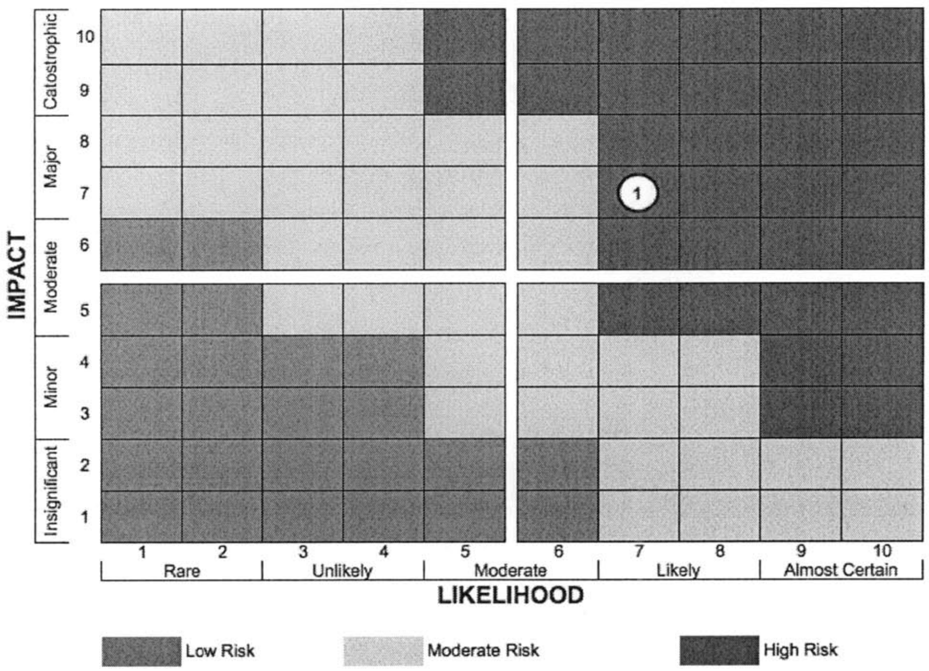

Figure 3-2: Example of Risk Profile for Risk Analysis

The individual risk of each risk category was quantified as the product of impact and likelihood, scored on a scale of 0 to 100. The overall risk for LEED certification was quantified as the summation of the individual risks of all of risk categories. Pursuing credits that minimize this quantity mitigates the overall risk of LEED certification. Results of the risk analysis are presented in Section 4-3.

3.3 Developing a Portfolio Planning Model

Having identified and quantified the cost, benefits, and risks of implementing the credits classified as "possible", a framework was then developed in order to determine which of these credits it made the most strategic sense for Intel to pursue. Many of the credits with higher costs tended to carry lower risks and vice versa. Hence the decision of which credits to pursue would be a tradeoff between cost and risk.

This decision was viewed as a "portfolio planning" problem because (1) it involved choosing a certain number of options from a pool of options, and (2) the decision was a tradeoff between cost and risk. This is similar to modern portfolio theory in which an investor chooses from a group of assets with the goal of maximizing return and minimizing risk. Planning for LEED is similar to this concept, except the goal is to minimize cost instead of maximizing return. Modern portfolio theory is demonstrated in Figure 3-3. Each point on the graph represents a combination of assets (i.e., stocks and bonds) and each combination has a unique set of risks and rewards. In some cases, the decision between two portfolios is straightforward. For example, in Figure 3-3, investors would choose the 50/50 stock and bond portfolio over the 100% bond portfolio because both portfolios carry the same risk but the 50/50 portfolio yields a higher return. The goal is to choose the investment that maximizes return for a given level of risk.

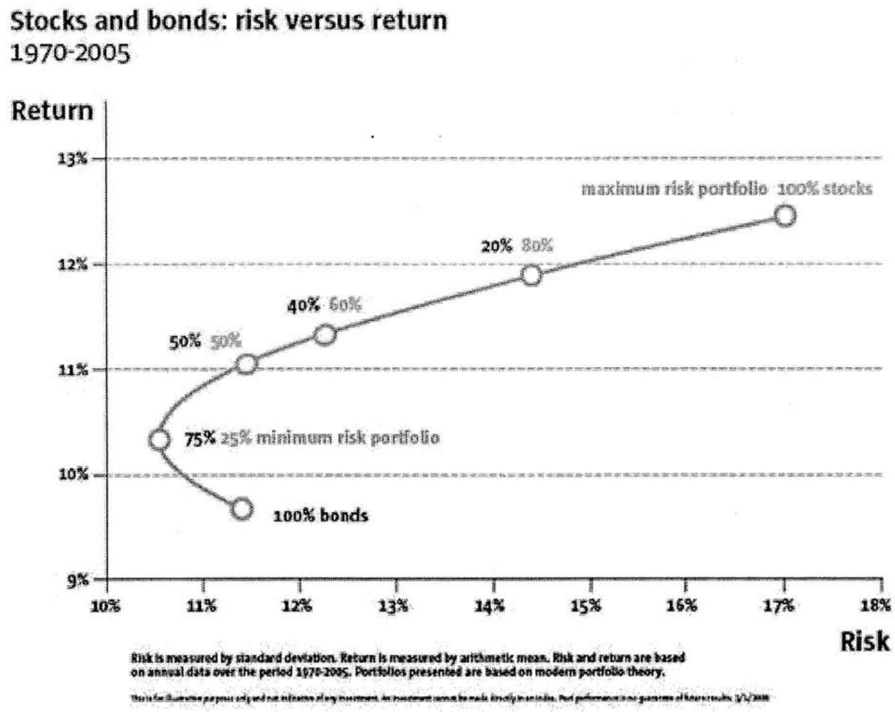

Figure 3-3: Example of Portfolio Theory (Capital at Work, 2009)

Therefore looking at LEED from a portfolio planning theory perspective can effectively assess the tradeoffs between cost and risk. The analysis was then used to identify multiple scenarios, each consisting of a different combination of credits and each carrying a unique set of cost and risk. This approach was then used to optimize the solution – for example, one scenario could be optimized to minimize the overall project risk, while another could be optimized to minimize the overall project cost. The results of portfolio planning model and optimization are presented in Section 4-4.

3.4 Evaluating Process Improvements for Implementing LEED

In addition to evaluating the costs and risks, it will be equally important to understand how Intel's planning, design, and construction processes will have to change in order to implement LEED certification. The following aspects of process improvement were analyzed:

- **Schedule:** What is the current design and construction timeline when Intel decides to build a new fab, and what milestones must be integrated into the timeline to implement LEED successfully?

- **Contract Documents:** Numerous contract documents and deliverables are created during the planning, design, and construction process, including Requests for Qualifications

(RFQs), Requests for Proposals (RFPs), drawings, specifications, and submittals. How must these documents be modified to meet the objectives of LEED?

- **Key Personnel:** Who must be involved in the process of LEED certification and who should take ownership of the various LEED credits?

Recommendations for key process improvements are described in Section 4-5.

3.5 Data needs and data collection

The analyses described above required a significant amount of data and internal documentation. Where data was not available or inaccessible due to Intellectual Property concerns, it was estimated from literature or reasonable assumptions were made with the assistance of Intel personnel.

The preliminary assessment of LEED credits described in Section 3-1 required access to existing internal Plan of Record (POR) documents. This information included specifications, as-built drawings, submittals and local zoning ordinances related the design and construction of Intel's most recently constructed fab. The following information was required for the preliminary assessment:

1. Roofing drawings and specifications
2. Plumbing drawings and specifications
3. Mechanical drawings and specifications for chiller water and HVAC systems
4. Landscaping and irrigation as-built drawings
5. Outdoor lighting plans
6. Fab interior finishing specifications
7. Local zoning ordinances for parking capacity
8. Number of fab full time employees (FTE)
9. Overall fab water and energy use
10. Overall fab construction costs

The analyses described in Section 3-2 through 3-5 (cost/benefit analysis, risk analysis, and process improvements) relied mainly on case studies in which LEED or specific energy efficiencies measures have been implemented. These analyses also relied on interviews with construction experts at Intel and TSMC, as well as documentation that is publically available from the state of Oregon and the USGBC.

4 Results

The following sections outline the results of the analyses described in the previous sections. First, some of the assumptions that are implicit in the analysis are discussed. Second, the results of the initial LEED assessment are presented, which indicated how many LEED points Intel is already achieving with its current design and construction practices. Third, the results of the cost/benefit and risk analyses, including the "portfolio" planning model are discussed. Finally, recommendations for process improvements to Intel's current design and construction practices are outlined.

4.1 Assumptions

The following assumptions were made in the analysis. Some of the assumptions were made because accurate data were not available; others were made to simplify the scale of the analysis. The assumptions from the analysis include the following:

1. **LEED Prerequisites**: LEED contains several prerequisites, or mandatory requirements that must be fulfilled at a minimum but for which no points are awarded. The analysis assumed that the new fab has already achieved these minimum prerequisites and hence they do not carry any incremental cost or risk. This assumption is accurate for Intel based on its existing POR; however it may not be applicable to a different fab that is designed and constructed to different standards.

2. **Credit Synergies:** Multiple LEED credits have synergies with each other. Certain solutions satisfy the requirements of more than one credit, and therefore may have lower cost than different solutions that satisfy each credit individually. For example, the use of native plants satisfies credits related to both site development and water efficient landscaping (because native plants do not require irrigation). This solution is less expensive than it would be to use non-native plants and recycle rainwater for irrigation. For the purpose of the cost/benefit and risk analyses, the synergies of credits are neglected. This is a conservative assumption, as any synergies would reduce both the cost and risk. This assumption was made because the cost data were compiled on a per credit basis, and the inclusion of synergies would make the model too complex to be useful for practical purposes.

3. **Description of Fab:** The analysis assumed the size of the new fab is approximately 800,000 square feet, or equivalent to the size of the most recent fab that was constructed at Intel. This assumption was necessary to scale the cost data for the cost/benefit analysis. A typical wafer fab configuration consists of 4 floors. The first floor consists of a dirty subfab, the second floor consists of a clean subfab, the third floor consists of the cleanroom, and the fourth floor consists of the air supply plenum.

4. **Energy Assumptions:** The analysis assumed the total annual energy consumption of the fab was 170,000 MWh (Westbrook, 2007) and a cost of electricity of \$0.05/kWh. This assumption was necessary to scale the cost data for the cost/benefit analysis of the energy credits, as discussed above.

5. **Net Present Value (NPV) Calculations:** All NPV calculations assume a discount rate of 15% and a 10-year investment with zero terminal value.

4.2 Results: Applying LEED criteria to Existing Fab

As discussed above, the first step of the analysis was to apply the LEED criteria to one of Intel's existing fabs, in order to assess how close Intel's current practices come to achieving LEED certification. The analysis indicated that 30 credits out of 110 are classified as "secure" within Intel's current POR. Since the minimum threshold to achieve LEED-Silver certification is 50 points, Intel must achieve a minimum of 20 additional points in order to become certified at the Silver level. Of the remaining 80 credits, 14 were classified as "not viable" due to existing physical or policy constraints, and 66 were classified as "possible" measures that could be achieved at an additional cost and/or risk.

In this section, each LEED credit is described in detail, and then classified as "secure", "possible", or "not viable", based on Intel's existing POR and information from the two case studies (TI and TSMC). The results are summarized in Figure 4-1. In the following section (Section 4-3), the credits classified as "possible" were analyzed in more detail to determine their costs and risks of implementation. It is important to note that these results are specific to Intel's site in Oregon, and facilities in different locations must be evaluated accordingly.

No.	Credit Name	Likelihood	Points
P1	Construction Activity Pollution Prevention	secure	0
SS1	Site Selection	secure	1
SS2	Community Connectivity	secure	5
SS3	Brownfield Redevelopment	not viable	2
SS4.1	Public Transportation Access	secure	6
SS4.2	Bicycle Storage and Changing Rooms	secure	1
SS4.3	Low-Emitting and Fuel-Efficient Vehicles	secure	3
SS4.4	Parking Capacity	secure	2
SS5.1	Protect or Restore Habitat	possible	2
SS5.2	Maximize Open Space	possible	1
SS6.1	Stormwater Design—Quantity Control	secure	1
SS6.2	Stormwater Design—Quality Control	secure	1
SS7.1	Heat Island Effect—Nonroof	secure	1
SS7.2	Heat Island Effect—Roof	possible	1
SS8	Light Pollution Reduction	possible	1
P1	Water Use Reduction	secure	0
WE1	Water Efficient Landscaping (Reduce 50%)	possible	2
WE1	Water Efficient Landscaping (Reduce 100%)	possible	2
WE2	Innovative Wastewater Technologies	possible	3
WE3	Water Use Reduction (Reduce 30%)	possible	2

No.	Credit Name	Likelihood	Points
EA1	Optimize Energy Performance (42%)	possible	1
EA1	Optimize Energy Performance (44%)	possible	1
EA1	Optimize Energy Performance (46%)	possible	1
EA1	Optimize Energy Performance (48%)	possible	1
EA2	On-site Renewable Energy (1%)	possible	1
EA2	On-site Renewable Energy (3%)	possible	1
EA2	On-site Renewable Energy (5%)	possible	1
EA2	On-site Renewable Energy (7%)	possible	1
EA2	On-site Renewable Energy (9%)	possible	1
EA2	On-site Renewable Energy (11%)	possible	1
EA2	On-site Renewable Energy (13%)	possible	1
EA3	Enhanced Commissioning	secure	2
EA4	Enhanced Refrigerant Management	secure	2
EA5	Measurement and Verification	possible	3
EA6	Green Power	possible	2
P1	Storage and Collection of Recyclables	secure	0
MR1.1	Maintain Existing Walls, Floors and Roof (55%)	not viable	1
MR1.1	Maintain Existing Walls, Floors and Roof (75%)	not viable	1
MR1.1	Maintain Existing Walls, Floors and Roof (95%)	not viable	1
MR1.2	Maintain Interior Nonstructural Elements	not viable	1

No.	Credit Name	Likelihood	Points
IEQ5	Indoor Chemical and Pollutant Source Control	possible	1
IEQ6.1	Controllability of Systems— Lighting	not viable	1
IEQ6.2	Controllability of Systems—Thermal Comfort	not viable	1
IEQ7.1	Thermal Comfort—Design	possible	1
IEQ7.2	Thermal Comfort—Verification	possible	1
IEQ8.1	Daylight and Views—Daylight	not viable	1
IEQ8.2	Daylight and Views—Views	not viable	1

WE3	Water Use Reduction (Reduce 35%)	possible	1	MR2	Construction Waste Management (50% recycled)	secure	1
WE3	Water Use Reduction (Reduce 40%)	possible	1	MR2	Construction Waste Management (75% recycled)	secure	1
P1	Fundamental Commissioning of Building Energy Systems	secure	0	MR3	Materials Reuse (5% reused)	not viable	1
P2	Minimum Energy Performance	secure	0	MR3	Materials Reuse (10% reused)	not viable	1
P3	Fundamental Refrigerant Management	secure	0	MR4	Recycled Content (10% content)	possible	1
EA1	Optimize Energy Performance (12%)	possible	1	MR4	Recycled Content (20% content)	possible	1
EA1	Optimize Energy Performance (14%)	possible	1	MR5	Regional Materials (10%)	possible	1
EA1	Optimize Energy Performance (16%)	possible	1	MR5	Regional Materials (20%)	possible	1
EA1	Optimize Energy Performance (18%)	possible	1	MR6	Rapidly Renewable Materials	not viable	1
EA1	Optimize Energy Performance (20%)	possible	1	MR7	Certified Wood	possible	2
EA1	Optimize Energy Performance (22%)	possible	1	P1	Minimum Indoor Air Quality Performance	secure	0
EA1	Optimize Energy Performance (24%)	possible	1	P2	Environmental Tobacco Smoke (ETS) Control	secure	0
EA1	Optimize Energy Performance (26%)	possible	1	IEQ1	Outdoor Air Delivery Monitoring	possible	1
EA1	Optimize Energy Performance (28%)	possible	1	IEQ2	Increased Ventilation	not viable	1
EA1	Optimize Energy Performance (30%)	possible	1	IEQ3.1	Construction Indoor Air Quality Management Plan—During Construction	secure	1
EA1	Optimize Energy Performance (32%)	possible	1	IEQ3.2	Construction Indoor Air Quality Management Plan—Before Occupancy	secure	1
EA1	Optimize Energy Performance (34%)	possible	1	IEQ4.1	Low-Emitting Materials—Adhesives and Sealants	possible	1
EA1	Optimize Energy Performance (36%)	possible	1	IEQ4.2	Low-Emitting Materials—Paints and Coatings	possible	1
EA1	Optimize Energy Performance (38%)	possible	1	IEQ4.3	Low-Emitting Materials—Flooring Systems	possible	1
EA1	Optimize Energy Performance (40%)	possible	1	IEQ4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	possible	1

Figure 4-1: Summary of Initial Assessment of LEED credits based on Intel current POR

4.2.1 Sustainable Site Credits

The purpose of the Sustainable Site category is to encourage site development practices that reduce negative impacts on the existing ecosystem. Points are awarded to practices that encourage connectivity to existing infrastructure, protection of the original ecology, and avoidance of developing environmentally sensitive land. Many of the points in this category are achieved simply through the physical location of the development and therefore careful attention to site selection is essential.

SS Credit 1: Site Selection: This credit can be achieved by avoiding the development of any "inappropriate" sites, which include wetlands and native habitats for endangered species. This credit is assumed to be SECURE.

SS Credit 2: Development Density and Community Connectivity: This credit can be achieved through one of two options: (1) choosing a site located within ½ mile of 10 existing basic services (i.e., banks, supermarkets, restaurants, etc.), or (2) developing an existing site with a minimum building density of 60,000 square feet per acre. Assume this credit could be SECURE.

SS Credit 3: Brownfield Redevelopment: This credit can be achieved by redeveloping a contaminated site that is classified as a "brownfield." This credit is classified as NOT VIABLE.

SS Credit 4.1: Alternative Transportation – Public Transportation: This credit can be achieved through one of two options: (1) choosing a site that is within ½ mile of a light rail station (or providing a shuttle service to that station), or (2) choosing a site that is within ¼ mile of two or more bus lines. Therefore this credit is assumed to be SECURE.

SS Credit 4.2: Alternative Transportation – Bicycle Storage: This credit can be achieved by providing bicycle storage for 5% of the building users and changing rooms and showers to 0.5% of building users. Intel currently provides these amenities to its building users and therefore this credit is classified as **SECURE**.

SS Credit 4.3: Alternative Transportation – Low Emitting Vehicles: This credit can be achieved by providing preferred parking for fuel efficient vehicles for 5% of the total vehicle parking capacity. Currently Intel does not practice this policy, but this credit is readily achieved at very low cost and therefore is classified as **SECURE**.

SS Credit 4.4: Alternative Transportation – Parking Capacity: This credit can be achieved by limiting the number of parking spaces to meet but not exceed the minimum local zoning requirements, and by providing preferred parking for carpools for 5% of the total parking spaces. Intel does not have a policy on parking capacity for new facilities, and therefore this credit can easily be met by meeting the local zoning requirements for parking. This credit is classified as **SECURE**.

SS Credit 5.1: Site Development – Protect or Restore Habitat: This credit can be achieved by protecting or restoring 50% of the site (excluding building footprint) or 20% of the site (including building footprint), whichever is greater, with native or adaptive vegetation. There is no current policy concerning this credit, and there may be space constraint to achieve this credit; therefore this credit is classified as **POSSIBLE**.

SS Credit 5.2: Site Development – Maximize Open Space: This credit can be achieved by providing open space equal to 20% of the total project area. As described above, there is no current policy concerning this credit, and there may be space constraint to achieve this credit; therefore this credit is classified as **POSSIBLE**.

SS Credit 6.1: Stormwater Design – Quantity Control: This credit can be achieved by implementing stormwater management techniques that result in 25% decrease in stormwater runoff based on the 2-year, 24-hour design storm. Intel's stormwater management plans require all surface runoff to be diverted to a series of retention ponds located within vegetative corridors along the perimeter of the campus. This policy enables this credit to be achieved at no additional cost or risk, and therefore this credit is classified as **SECURE**.

SS Credit 6.2: Stormwater Design – Quality Control: This credit can be achieved by implementing a stormwater management plan that reduces impervious cover, promotes infiltration and captures and treats the stormwater runoff from 90% of the average annual rainfall using acceptable best management practices. As described above, the requirement to divert all surface runoff to detention ponds will promote infiltration, and therefore this credit is classified as **SECURE**.

SS Credit 7.1: Heat Island Effect – Nonroof: This credit can be achieved through one of two options: (1) using shade, pervious pavement, and reflective hardscape for 50% of the site hardscape (including roads, sidewalks, courtyards and parking lots), or (2) placing a minimum of 50% of parking spaces under cover. Intel would likely plan to provide a parking structure; therefore this credit is classified as **SECURE**.

SS Credit 7.2: Heat Island Effect – Roof: This credit can be achieved through one of two options: (1) using roofing materials with a solar reflectance index greater than 78 for a minimum of 75% of the roof surface, or (2) installing a vegetated roof that covers at least 50% of the roof area. There is no current Intel policy concerning either of these options, and therefore this credit is classified as **POSSIBLE**.

SS Credit 8: Light Pollution Reduction: This credit can be achieved through the following: (1) for interior lighting, reducing lighting with a direct line of sight to any openings during night hours, or providing shielding to all openings in the envelope, and (2) for exterior lighting, power densities must not exceed ANSI/ASHRAE/IESNA Standard 90.1-2007. There is no current Intel policy concerning this credit, and therefore this credit is classified as **POSSIBLE**.

4.2.2 Water Efficiency Credits

The purpose of the Water Efficiency category is to encourage practices that reduce consumption of potable water and wastewater through efficient fixtures, and recycling and reusing water for non-potable water uses such as irrigation. It is important to note, as discussed previously, that this category does not include any process water that is used in a fab. The focus of this category is for landscaping, and domestic and commercial water consumption. While this type of water can be significant for a residential or commercial building, it represents only a fraction of the overall water use in a wafer fab because it does not include process water.

It seems reasonable that Intel's sustainability objectives would require it to exceed LEED limits because LEED covers only a small fraction of a fab's overall water use. As shown above with TI and TSMC, innovative water efficiency measures were economically integrated into construction. Process water efficiency represents a significant potential savings for Intel. Therefore it is essential that Intel reduce water consumption beyond what is required by LEED in order to achieve its sustainability objectives.

WE Credit 1: Water Efficient Landscaping: This credit can be achieved by reducing potable water consumption for irrigation by a minimum 50% using one or more of the following options: (1) using native plants that do not require irrigation, (2) using water efficient landscaping techniques, or (3) using recycled water for landscaping. Additional points are awarded for reducing consumption beyond 50%. There is no current Intel policy concerning this credit, and therefore this credit is classified as **POSSIBLE**.

WE Credit 2: Innovative Wastewater Technologies: This credit can be achieved by reducing potable water use for building sewage conveyance by 50% through the use of water-conserving fixtures (e.g., high efficiency water closets and urinals) or the use of nonpotable water. There is no current Intel policy concerning this credit, and therefore this credit is classified as **POSSIBLE**.

WE 3: Water Use Reduction: This credit can be achieved by reducing water consumption for commercial fixtures (lavatory fixtures, faucets, showers, etc.) by 30%. This is generally accomplished by using high efficiency fixtures. Additional points are awarded for reducing consumption beyond 50%. There is no current Intel policy concerning this credit, and therefore this credit is classified as **POSSIBLE**.

4.2.3 Energy and Atmosphere Credits

The purpose of the Energy and Atmosphere category is to encourage practices that reduce consumption of energy and the resulting greenhouse gases that contribute to global climate change. LEED buildings can reduce greenhouse gas emissions by incorporating techniques that both reduce the amount of energy required for the building's operation and using more benign sources of energy, including solar and wind power. As discussed above, the credits in this category would be particularly challenging for Intel, given the high-energy consumption of its wafer fabs, compared to a typical office building. However, there could still be multiple opportunities for improvement, as shown through the case studies of TI and TSMC.

EA 1: Optimize Energy Performance: This credit can be achieved by demonstrating improvement in the energy use of a new building by 12% compared with the baseline performance. Additional points are awarded for energy improvements beyond 12%. TI and TSMC achieved multiple points in this category though a number of strategies including: variable flow control for chilled water, warm water, HVAC fans, and exhaust fans; heat recovery; optimization of the temperature control of the cooling tower; use of high efficiency lighting fixtures. Therefore this credit is classified as **POSSIBLE**.

EA 2: On-site Renewable Energy: This credit can be achieved by generating 1% of the building's annual energy usage from on-site renewable energy systems. Additional points are awarded for renewable energy generation beyond 1%. This credit is likely too expensive for a high-energy use fab to achieve, and therefore this credit is classified as **NOT VIABLE**.

EA 3: Enhanced Commissioning: This credit can be achieved by performing commissioning activities, including hiring an independent commissioning authority to review design and documentation, develop systems manual, verify training of personnel, and review operation after completion. This credit is already part of Intel's POR, and therefore this credit is classifies at **SECURE**.

EA 4: Enhanced Refrigerant Management: This credit can be achieved by not using refrigerants that contribute to ozone depletion in any HVAC or refrigeration equipment. This credit is already part of Intel's POR, and therefore this credit is classifies at **SECURE**.

EA 5: Measurement and Verification: This credit can be achieved by developing and implementing a measurement and verification plan to confirm that energy savings are being achieved. This credit requires a process for corrective action if energy savings are not being achieved. While Intel does currently monitor its energy usage, this credit places an additional burden of requiring corrective action, and therefore will add considerable cost and risk for its implementation. Therefore this credit is classified as **POSSIBLE**.

EA 6: Green Power: This credit can be achieved by engaging in a 2-year renewable energy contract to provide at least 35% of the building's electricity from renewable sources. The high-energy consumption of fabs makes this credit difficult to achieve; therefore this credit is classified as **POSSIBLE**.

4.2.4 Material and Resources Credits

The purpose of the Material and Resources category is to encourage the use of environmentally friendly materials and sourcing practices. Points are awarded for recycled and reused materials, as well as sourcing from local suppliers. As shown below, many of these credits are not achievable because reuse of building material for advanced manufacturing facilities is limited.

MR 1: Building Reuse: This credit can be achieved by maintaining a minimum of 50% of the existing building. This credit generally applies only to the reuse or refurbishment of existing buildings and therefore is classified as **NOT VIABLE**.

MR 2: Construction Waste Management: This credit can be achieved by recycling and/or salvaging a minimum of 50% of construction and demolition debris. Additional points are awarded for 75% recycled rate. This credit is assumed to be **SECURE**.

MR 3: Materials Reuse: This credit can be achieved by using salvaged, refurbished or reused materials, the sum of which constitutes at least 5% of the total value of materials on the project. The total project cost of TI's LEED Certified fab was approximately $150 Million (Westbrook, 2007). Additional points are awarded for 10% reuse. This credit is very difficult to achieve based on high first cost of a fab, and therefore is classified as **NOT VIABLE**.

MR 4: Recycled Content: This credit can be achieved by using materials with recycled content such that the sum of constitutes at least 10% of the total value of the materials in the project. Additional points are awarded for 20% recycled content. It is likely that this credit could be achieved due to the high content of structural steel that is typical in a fab. This credit is classified as **POSSIBLE**.

MR 5: Regional Materials: This credit can be achieved by using building materials that have been extracted and manufactured within 500 miles of the project site for a minimum of 10% of the total materials value. Additional points are awarded for 20% regional materials. This credit will depend on the location of Intel's suppliers and therefore is classified as **POSSIBLE**.

MR 6: Rapidly Renewable Materials: This credit can be achieved by using rapidly renewable building materials and products for 2.5% of the total value of all building materials and products used in the project. This credit is very difficult to achieve based on high costs of a fab, and therefore is classified as **NOT VIABLE**.

MR 7: Certified Wood: This credit can be achieved by using a minimum of 50% of wood-based materials and products that are certified in accordance with the Forest Stewardship Council's principles. There is minimal wood used in fab construction so this credit would be a minimal cost increase. Therefore this credit is classified as **POSSIBLE**.

4.2.5 Indoor Environmental Quality Credits

The purpose of the Indoor Environmental Quality category is to encourage strategies that promote the health and well being of the building's occupants. These credits decrease the occurrence of airborne illnesses and contaminants, provide access to natural lighting, and give building occupants more control over individual lighting and thermal comfort. Many of these credits are not achievable because the strictly controlled environment of the cleanroom precludes their implementation.

IEQ 1: Outdoor Air Delivery Monitoring: This credit can be achieved by installing permanent monitoring systems to ensure that ventilation systems maintain design minimum requirements. This credit is classified as **POSSIBLE**.

IEQ 2: Increased Ventilation: This credit can be achieved by increasing breathing zone outdoor air ventilation rates to all occupied spaces by at least 30% above the minimum prerequisite values. Due to the strict ventilation requirements of the fab's cleanroom, this credit is assumed to be not achievable. Therefore this credit is classified as **NOT VIABLE**.

IEQ 3: Construction Indoor Air Quality Management Plan: This credit can be achieved by developing and implementing an Indoor Air Quality management plan for the construction and preoccupancy phases of the building. Intel already practices this criterion and therefore this credit is classified as **SECURE**.

IEQ 4: Low-Emitting Materials: These credits can be achieved by using materials that comply with VOC limits for all adhesive, sealants, paints, coatings, and flooring systems. This credit is classified as **POSSIBLE**.

IEQ 5: Indoor Chemical and Pollutant Source Control: This credit can be achieved by employing strategies to minimize and control the entry of pollutants into buildings, including long entryways into building and exhaust space for hazardous chemicals. These credits are classified as **POSSIBLE**.

IEQ 6: Controllability of Systems: These credits can be achieved by providing individual lighting and thermal comfort controls for a minimum 50% of building occupants to enable adjustments to suit individual task needs and preferences. Due to the strict temperature and humidity requirements of the cleanroom, this credit is not achievable and classified as **NOT VIABLE**.

IEQ 7: Thermal Comfort: These credits can be achieved by designing HVAC systems and providing monitoring systems to meet minimum ASHRAE standards. These criteria are classified as **POSSIBLE**.

IEQ 8: Daylight and Views: These credits can be achieved by providing access to natural sunlight and views to building occupants. The controlled environment of the cleanroom eliminates the ability to achieve these credits and therefore they are classified as **NOT VIABLE**.

4.3 Results of Cost/Benefit and Risk Analyses

The second step in the analysis was to evaluate the credits within the "possible" category and determine the cost, benefits, and risks of implementing each credit. The results of these analyses are presented in this section. These results assume that Intel will pursue all of the credits in the "possible" category. In the following section (Section 4-4), the results of the "portfolio" planning model are discussed, in which only certain credits are pursued in order to minimize cost and/or risk.

4.3.1 Results of Cost/Benefit Analysis

As discussed above, the cost/benefit analysis evaluated all of the cost and benefits related to LEED certification, including upfront costs, additional consulting and certification fees, and operational and productivity benefits over the lifecycle of the project. The upfront costs for LEED certification are shown in Figure 4-4. This figure shows the cumulative costs of LEED certification plotted against the cumulative points achieved. Assuming the least expensive credits are pursued, the total "average" upfront cost for LEED certification at the Silver level (50 points) is $900,000, with a high and low cost of $2.3 Million and $160,000 respectively.

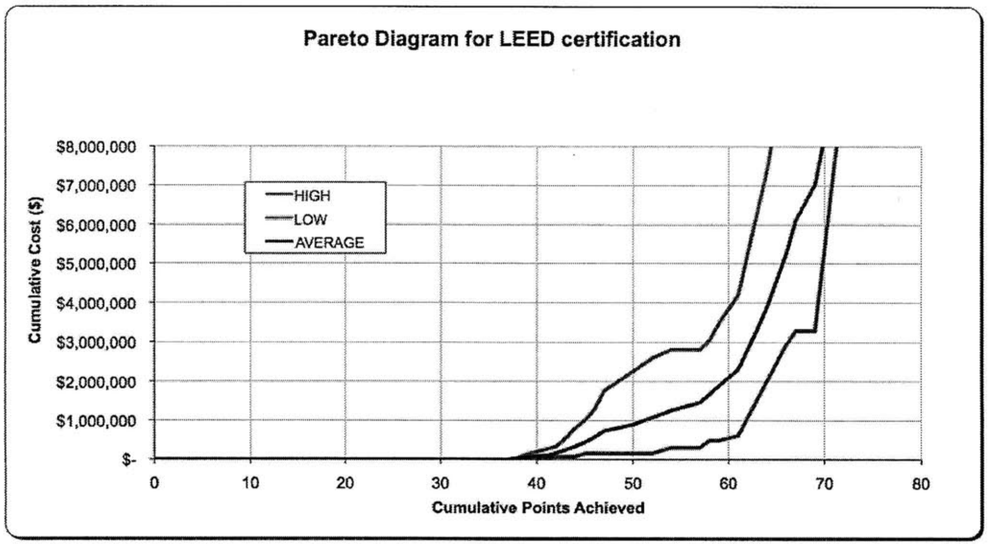

Figure 4-4: Cumulative Cost of LEED Certification (assuming all "possible" points are pursued)

The Net Present Value (NPV) of LEED certification considering all of the life cycle costs and benefits that were previously discussed is shown in Figure 4-5. Figure 4-5 shows that for the least expensive credits, LEED certification at the Silver level has a positive NPV of over $2 Million.

Certification Level	Certified	Silver	Gold	Platinum
Upfront capital costs (1)	($65,176)	($898,275)	($1,889,255)	($23,098,936)
Consulting Fees (2)	($400,000)	($400,000)	($400,000)	($400,000)
Certification Fees (3)	($17,500)	($17,500)	($17,500)	($17,500)
Operational Savings (4)	$340,000	$340,000	$340,000	$3,740,000
Productivity Savings (5)	$200,000	$200,000	$300,000	$300,000
Oregon Tax Incentives (6)	$0	$647,500	$907,240	$1,753,726
NPV (15%, 10 yr)	$2,227,459	$2,041,861	$1,812,497	($1,486,885)

Figure 4-5: Net Present Value Calculations for LEED Certification, assuming least expensive credits are pursued

4.3.2 Results of Risk Analysis

The cost/benefit analysis described in the previous section assumed that the least expensive credits were pursued. However, the actual credits that will be pursued depend not only on cost but also on the riskiness of the credits. For this analysis, as described in Section 4-3-2, the risks of pursuing all of the "possible" credits were evaluated and are shown in Figure 4-6. Figure 4-6 demonstrates that there are certain credits that carry a high amount of risk, and therefore there may be credits that Intel would choose not to pursue because they carry too high risk.

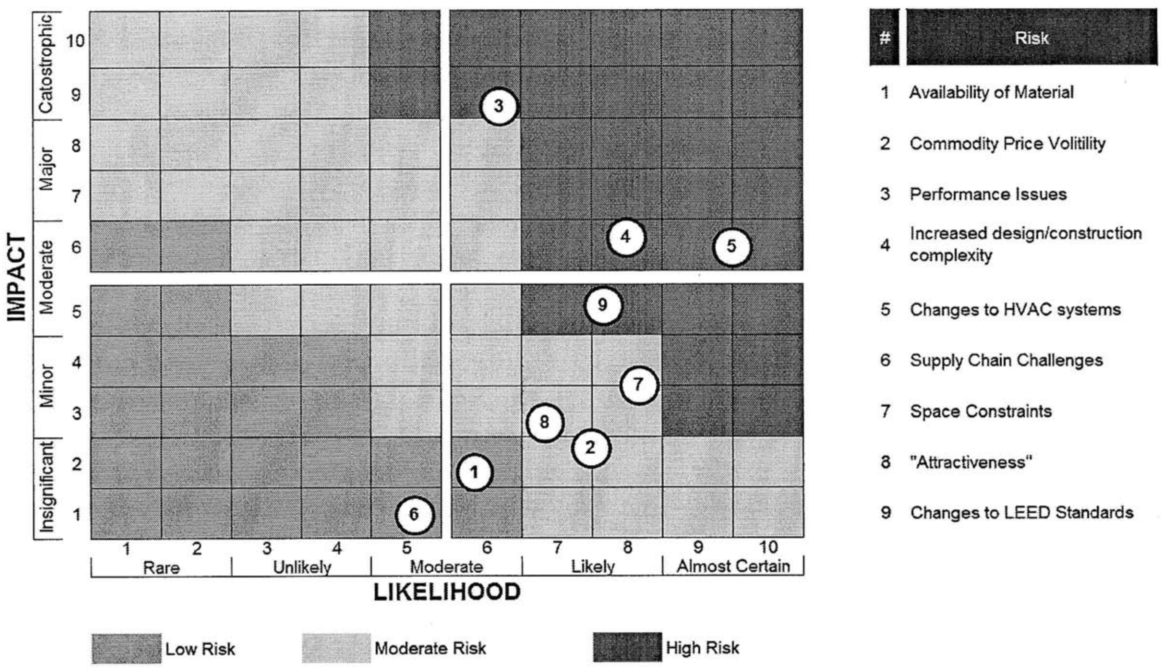

Figure 4-6: Risk Profile for LEED, assuming all "possible" credits are pursued

4.4 Results of Portfolio Planning Model

The cost/benefit and risk analyses were then combined to create a "portfolio planning" model as shown in Figure 4-7. The model input requires the user to choose 20 ("yes" or "no") out of the 66 "possible" credits to achieve LEED-Silver certification. The model output shows the cost curve and risk profile for that portfolio of 20 credits. The model can be used to analyze various scenarios, each with its unique individual costs and risks.

No.	Credit Name	Pursue Credit?	Points
SS5.1	Protect or Restore Habitat	yes	2
SS5.2	Maximize Open Space	yes	1
SS7.2	Heat Island Effect—Roof	yes	1
SS8	Light Pollution Reduction	yes	1
WE1	Water Efficient Landscaping (Reduce 50%)	yes	2
WE1	Water Efficient Landscaping (Reduce 100%)	no	2
WE2	Innovative Wastewater Technologies	yes	3
WE3	Water Use Reduction (Reduce 30%)	yes	2
WE3	Water Use Reduction (Reduce 35%)	no	1
WE3	Water Use Reduction (Reduce 40%)	no	1
EA1	Optimize Energy Performance (12%)	yes	1
EA1	Optimize Energy Performance (14%)	no	1

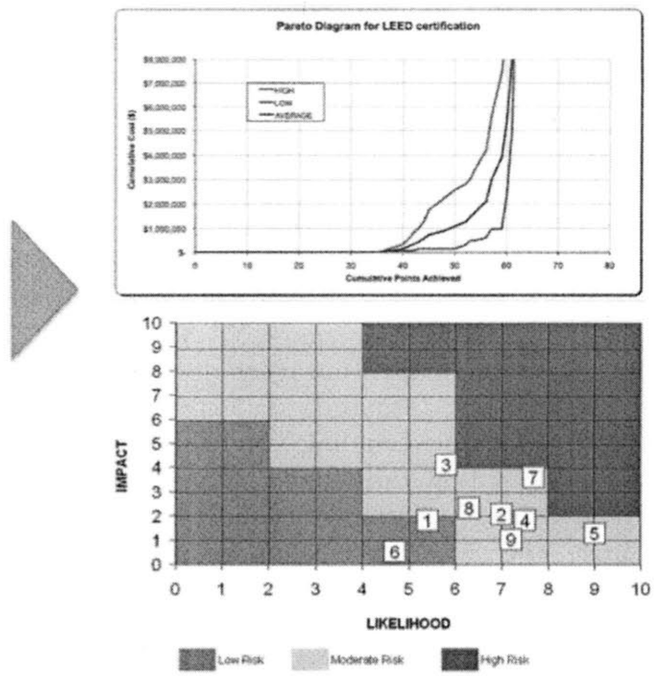

Figure 4-7: Portfolio Planning Model

The portfolio planning model was then used to optimize the solution to minimize risk. However, the true minimum risk situation gave a much higher upfront cost. The optimal situation was then determined by adding an additional constraint, which only considered credits that had a maximum upfront cost of less than $200,000. This modification determined a lower cost solution without signification increase in risk. The upfront cost constraint of $200,000 was determined through trial-and-error to achieve a solution with a positive NPV. The model allows this constraint to be modified by the user. The optimal can be achieved at an upfront cost of $1.1 Million and a positive NPV of $130,000 as shown in Figure 4-8.

Certification Level	Silver
Upfront capital costs	($1,103,294)
Consulting Fees	($400,000)
Certification Fees	($17,500)
Operational Savings	$0
Productivity Savings	$200,000
Oregon Tax Incentives	$647,500
NPV (15%, 10 yr)	$130,460

Figure 4-8: Net Present Value Calculations for LEED-Silver Certification, assuming the optimized scenario

The optimal solution recommended that Intel pursue the following 20 points:

- SS5.1: Protect or Restore Habitat (2 points)
- SS5.2: Maximize Open Space (1 point)
- SS7.2: Heat Island Effect – Roof (1 point)
- SS8: Light Pollution Reduction (1 point)
- WE1: Water Efficient Landscaping – Reduce 50% (2 points)
- WE2: Innovative Wastewater Technologies (3 points)
- WE3: Water Use Reduction – Reduce 40% (4 points)
- MR4: Recycled Content – 10% (1 point)
- IEQ1: Outdoor Air Delivery Monitoring (1 point)
- IEQ 4.1: Low-Emitting Materials—Adhesives and Sealants (1 point)
- IEQ 4.2: Low-Emitting Materials—Paints and Coatings (1 point)
- IEQ 4.3: Low-Emitting Materials—Flooring Systems (1 point)
- IEQ 5: Indoor Chemical and Pollutant Source Control (1 point)

4.5 Recommended Process Considerations When Implementing LEED

This section presents recommendations for process improvements to successfully implement the 20 LEED credits outlined in the previous section, including process changes related to schedule, contract documents, and personnel. The majority of the key LEED milestones must happen within the first few months of Front End Planning. As discussed before, incorporating LEED goals early in the project is critical to its success. The key events and milestones include:

1. Registration with USGBC: The first step of the LEED process is registering the project with the USGBC. This should be done as early as possible to maximize the chances of success. Registration is not a commitment to certification; it is only an indication of intent. Registration formally opens contact with the USGBC and provides access to critical software, tools, and information necessary for planning purposes.

2. Set Programming Goal of LEED Certification: The goal of LEED-Silver certification should be explicitly written into all programming documentation.

3. Finalize Master Site Plan: The Master Site plan should be finalized and frozen in order to accommodate outdoor space requirements. Certain credits require a minimum amount of the site plan be designated as open space. There may be conflicts further down the road if this space is not designated at the beginning of the project.

4. Appoint LEED Champion: As early as possible, a LEED champion should be appointed in order to overcome the Alignment Barriers that were discussed in Chapter 2. This champion should be someone who has authority over all of the disciplines involved in the fab design. This person must be willing and able to communicate a uniform and coherent message throughout the project and act as the program manager throughout the project duration.

5. Kickoff Tour of LEED Facility: Most successful LEED projects commence with an official tour of a LEED-Certified facility for key stakeholders. Both TI and TSMC accomplished this and attribute their successes to this milestone (at least in part).

6. Conduct Eco-Charrette: As discussed earlier, an Eco-Charrette should be conducted at the beginning of the project. This workshop should include all of the key stakeholders that will be involved with LEED to establish the goals and objectives of the project and implement a coordinated and integrated design. According to the National Renewable Energy Laboratory's Charrette Handbook (Lindsey, Todd, & Jayter, 2003), there are numerous benefits to conducting a charrette at the early stage of the design process, including:

   - Providing a forum for those who can influence design decisions on a project to meet and begin planning the project
   - Helping establish a creative environment for identifying and incorporating design strategies to achieve LEED credits
   - Encouraging agreement on project goals
   - Kicking off the design process
   - Saving time and money by soliciting ideas, issues, and concerns for the project design to help avoid later iterative redesign activities and change orders
   - Promoting enthusiasm for a project
   - Helping teams design projects that minimize resource consumption, reduce life cycle costs, and maximize health and environmental performance across a wide range of measures in the five LEED credit areas

   At the conclusion of the Eco-Charrette, each LEED credit should be assigned a stakeholder, who will ultimately hold responsibility for that credit. Figure 4-9 outlines LEED credit stakeholders for the 20 points outlined in the previous section.

7. Develop "Green" Specifications: The majority of the credits chosen from the optimization model can be achieved by clearly stating their intent in contract documents. When developed, the specifications should identify all credits that will be targeted and outline the required submittals and templates necessary for certification. For example, the specifications should clearly state the specific brand and type of appliances. While a consulting company typically performs this task, it is important that Intel is also aware of it in order to meet specific LEED requirements. The specs should also describe the submittals that will be necessary to meet LEED documentation requirements.

8. RFPs and RFQs for LEED Experienced Contractors: Requests for Qualifications (RFQs) and Requests for Proposals (RFPs) are the standard documents that are meant to solicit bids from potential contractors. RFQs should require potential bidders to list their LEED experience and qualifications, and these qualifications should be an important factor in the selection process. RFPs should require acknowledgement of the specific LEED goals and the strategies that will be pursued to achieve those goals. Another potential strategy would be to consider using a "best value" bidding process, which sets a fixed budget and allows bidders to describe which credits can be included for that price (Syphers, Baum, Bouton, & Sullens, 2003).

9. Gather Proper Documentation: Proper documentation is required to prove to the USGBC that the credits pursued have actually met LEED requirements. This can often be an onerous task, and often requires having the contractor methodically keep track of all the materials used in the project. This is why it is very important that all of the required documentation be explicitly stated in the specifications as discussed above.

10. Certify Project with USGBC: The actual certification is awarded at the completion of the project, with a third party conducting a documentation review and inspection to confirm that that the facility has met the requirements to become certified.

	Architect	Landscape Architect	Mechanical Engineer	Electrical/Lighting Engineer	Plumbing Engineer	Construction Manager
SS5.1: Protect or Restore Habitat		◆				
SS5.2: Maximize Open Space		◆				
SS7.2: Heat Island Effect – Roof	◆					
SS8: Light Pollution Reduction				◆		
WE1: Water Efficient Landscaping		◆				
WE2: Innovative Wastewater Technologies					◆	
WE3: Water Use Reduction					◆	
MR4: Recycled Content						◆
IEQ1: Outdoor Air Delivery Monitoring			◆			
IEQ4: Low-Emitting Materials	◆					
IEQ 5: Chemical and Pollutant Control			◆			

Figure 4-9: LEED Credit Responsibilities

5 Discussion and Conclusion

The objective of this study was to develop a planning strategy to achieve LEED certification for the construction of a hypothetical new wafer fab. The study identified the main barriers to achieve LEED certification, analyzed the costs, benefits, and risks of pursuing LEED certification, and recommended process improvements to implement it. The final results indicated that for the optimized scenario, LEED-Silver certification could be achieved for a positive NPV of over $130,000.

The underlying assumption of this analysis was that LEED certification aligned with Intel's sustainability objectives, and in a broader sense, Intel's overall corporate objectives. It is worth discussing whether the goal of LEED certification really does, in fact, align with these objectives. Does LEED make sense given the considerable barriers to its implementation? Is LEED the appropriate environmental metric for Intel for the design and construction of its new facilities? Should LEED be an end goal in itself or should it merely be used as guide for incorporating environmentally friendly design decisions?

This is a difficult question to answer. One of Intel's core strategic objectives is to "build new businesses by tackling big problems" (Intel Corporation, 2009). Enviromental sustainability must be key to this objective. There could be inherent marketing value in promoting Intel's new fab as a LEED fab because the public is aware of and undertands the value of LEED certification. Marketing Intel's facilities as "green" could enhance Intel's brand and bring new opportunities to Intel by attracting and retaining customers and employees that value sustainability. There is now significant evidence that companies that pursue ambitious sustainability agendas see real financial benefits, including increased revenue and increased shareholder value (Coulter, 2008). This evidence points to the fact that there is considerable strategic advantage in pursuing sustainabilty as a corporate objective.

However, this report has also described the numerous barriers to LEED certification. Several of these barriers are associated with implementing change with a large, bureaucratic organization. Stakeholders may not see the value in pursuing LEED certification. They may question the very science behind the theory of climate change; they may view LEED as a fad that is popular today but is gone tomorrow; or they may not understand how LEED aligns with their business objectives. Implementing change in such a context is very challenging and can easily become derailed without strong leadership.

In addition, it is difficult to ignore the fact that the LEED criteria do not go far enough. The largest portions of Intel's environmental footprint are its water and energy consumption. The analysis from this report has demonstrated that it is entirely possible to achieve LEED certification without making any improvements to process water and energy consumption. As shown in the case studies, there are many energy and water improvements that can be implemented with proper planning that can lead to very quick paybacks. If not already implemented, Intel should consider implementing strategies beyond LEED, including some of the improvements that were completed by TI and TSMC, as outlined earlier in this report. These are strategies that Intel's competitors have proven successful, and therefore should not carry significant increase in cost and risk.

The paragraphs above argue that LEED may not in fact be an appropriate metric for new semiconductor fab construction, and instead a more holistic approach should be considered by all semiconductor companies. The goal should not be to "Design new facilities to a minimum LEED-Silver level" but to "Design high performance facilities that achieve X percent reduction in energy use and Y percent reduction in water use". LEED certification should not be the end goal but merely a guide for incorporating sustainable design and construction practices. Design teams, instead, should be focused on selecting the right engineering solutions for each individual facility. LEED points should still be tracked as an administrative task, while recognizing the high probably that LEED certification will be achieved if the goal of a "high performance building" is achieved. It is this more holistic approach that will enable Intel to successfully pursue sustainability programs that align with its corporate objectives, without becoming sidetracked by the many barriers that are specific to LEED.

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