The Chemical Company

Submission for Verification of Eco-efficiency Analysis Under NSF Protocol P352, Part B

Synthetic Turf, Eco-Efficiency Analysis Final Report – August 2010

Submitted by:

BASF Corporation
Product Stewardship
100 Campus Drive, Florham Park, NJ, 07932

Prepared by:

Bruce Uhlman, Senior Sustainability Specialist

Mubaraka Diwan, Sustainability Specialist

Mark Dobson, Business Director

Randall Sferrazza, Product Manager

Paul Songer, Account Manager

Table of Contents

1. Purpose and Intent of this Submission

1.1. The purpose of this submission is to provide a written report of the methods and findings of BASF Corporation's "Synthetic Turf, Eco-Efficiency Analysis", with the intent of having it verified under the requirements of NSF Protocol P352, Part B: Verification of Eco-Efficiency Analysis Studies.

1.2. The Synthetic Turf, Eco-Efficiency Analysis was performed by BASF according to the methodology validated by NSF International under the requirements of Protocol P352. More information on BASF's methodology and the NSF validation can be obtained at http://www.nsf.org/info/eco_efficiency.

2. Content of this Submission

2.1. This submission outlines the study goals, procedures, and results for the Synthetic Turf, Eco-Efficiency Analysis (EEA) study, which was conducted in accordance with BASF Corporation's EEA (BASF EEA) methodology. This submission will provide a discussion of the basis of the eco-analysis preparation and verification work.

2.2. As required under NSF P352 Part B, along with this document, BASF is submitting the final computerized model programmed in Microsoft® Excel. The computerized model, together with this document, will aid in the final review and ensure that the data and critical review findings have been satisfactorily addressed.

3. BASF's EEA Methodology

3.1. Overview:

BASF EEA involves measuring the life cycle environmental impacts and life cycle costs for product alternatives for a defined level of output. At a minimum, BASF EEA evaluates the environmental impact of the production, use, and disposal of a product or process in the areas of energy and resource consumption, emissions, toxicity and risk potential, and land use. The EEA also evaluates the life cycle costs associated with the product or process by calculating the costs related to, at a minimum, materials, labor, manufacturing, waste disposal, and energy.

3.2. Preconditions:

The basic preconditions of this eco-efficiency analysis are that all alternatives that are being evaluated are being compared against a common functional unit or customer benefit. This allows for an objective comparison between the various alternatives. The scoping and definition of the customer benefit are aligned with the goals and objectives of the study. Data gathering and constructing the system boundaries are consistent with the functional unit and consider both the environmental and economic impacts of each alternative over their life cycle in order to achieve the specified customer benefit. An overview of the scope of the environmental and economic assessment carried out is defined below.

3.2.1. Environmental Burden Metrics:

For BASF EEA environmental burden is characterized using eleven categories, at a minimum, including: primary energy consumption, raw material consumption, greenhouse gas emissions (GHG), ozone depletion potential (ODP), acidification potential (AP), photochemical ozone creation potential (POCP), water emissions, solid waste emissions, toxicity potential, risk potential (occupational illnesses and accidents), and land use. These are shown below in Figure 1. Metrics shown in yellow represent the six main categories of environmental burden that are used to construct the environmental fingerprint, burdens in blue represent all elements of the emissions category, and green show air emissions.

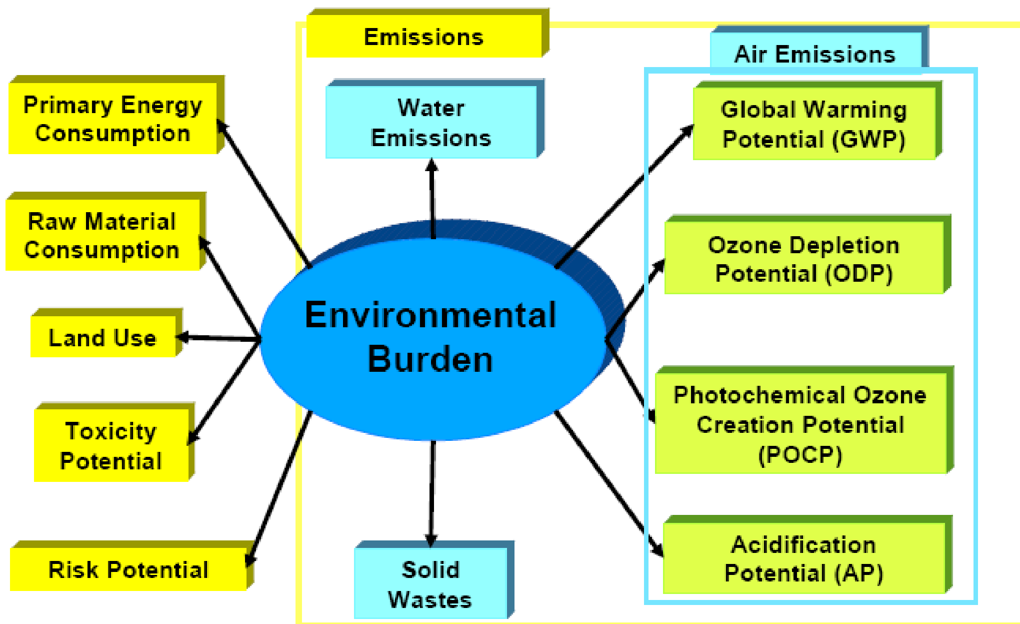

Figure 1. Environmental Impact categories

3.2.2 Economic Metrics:

It is the intent of the BASF EEA methodology to assess the economics of products or processes over their life cycle and to determine an overall total cost of ownership for the defined customer benefit ($/CB). The approaches for calculating costs vary from study to study. When chemical products of manufacturing are being compared, the sale price paid by the customer is predominately used. When different production methods are compared, the relevant costs include the purchase and installation of capital equipment, depreciation, and operating costs. The costs incurred are summed and combined in appropriate units (e.g. dollar or EURO) without additional weighting of individual financial amounts. The BASF EEA methodology will incorporate:

- the real costs that occur in the process of creating and delivering the product to the consumer;
- the subsequent costs which may occur in the future with appropriate consideration for the time value of money; and
- costs having an ecological aspect, such as the costs involved to treat wastewater generated during a manufacturing process.

3.3 Work Flow:

A representative flowchart of the overall process steps and calculations conducted for this eco-efficiency analysis is summarized in Figure 2 below.

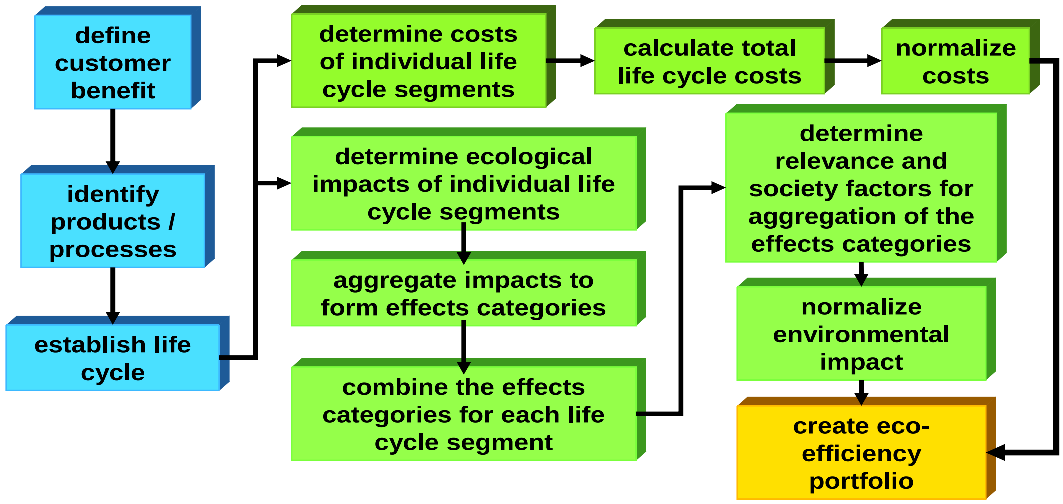

Figure 2: Overall process flow for Residential Insulation EEA study

4. Study Goals, Decision Criteria and Target Audience

4.1. *Study Goals*: The specific goal defined for the Synthetic Turf, Eco-Efficiency Analysis was to quantify the differences in life cycle environmental impacts and total life cycle costs of a multi-purpose sports recreational field that could be installed by municipalities or school districts in the United States.

The study specifically compares three different kind of synthetic turf fields versus a professionally installed and maintained natural turf grass field. The study considered the full life cycle so the production, installation, use and end-of-life of the various fields were evaluated and compared. The study considered application of these recreational fields across the United States as a whole with no specific focus on one region (e.g. Northeast, Southwest). Thus average national data was used for key study input parameters such as field availability, durability for the synthetic turf fields, maintenance requirements for the natural turf grass field and costs for the installation and maintenance of the fields over their respective life cycles.

One of the key performance attributes that clearly differentiates the alternatives considered is the ability for each alternative to meet the increasing demand to hold recreational events year round while balancing consideration for the long-term condition and quality of the field. Because of its inherent ability to handle a higher frequency of events as well accommodate events over a longer time frame during the calendar year without adversely affecting the quality of the field, synthetic fields have a higher availability than their natural grass counterparts. Thus the availability of a field is defined (specific for this study) as the ability to support a recreational or sporting event without adversely affecting the long-term quality and condition of the field. The exact extent of this increased availability can be influenced by many factors such as climate, the intensity & frequency of the events held on the field, the type of fields installed and the quality of the on-going maintenance activities etc. Thus, to present an objective comparison between the two alternatives (synthetic & natural turf grass), a broad range of natural grass availabilities were considered which brackets the highest and lowest expected availability data for natural grass relative to the baseline synthetic turf data. This will allow stakeholders who review the report to interpret the results in the context of their specific requirements & experiences with synthetic and natural turf grass.

The study will also help quantify in a comprehensive manner some of the key criteria evaluated in the decision making process associated with selecting the appropriate kind of turf for a recreational sports fields. Some examples of this information include the environmental impact associated with the production of a synthetic turf field, the on-going impact of maintaining a natural turf grass field, how does availability of the field affects its eco-efficiency and finally how do the relative life cycle costs of a synthetic field compare relative to natural turf grass.

Results will be used to help articulate in an objective and science based manner the relative eco-efficiency or sustainability of synthetic turf over its product life cycle when compared to natural turf grass. These results will provide the necessary life cycle environmental and cost data to key stakeholders in the sports turf value chain who are challenged with making decisions related to comparing the relative sustainability of synthetic turf and natural turf grass fields.

4.2. *Decision Criteria*: The context of this EEA study compared the life cycle for three unique synthetic turf fields (nylon fiber, polyethylene fiber and a nylon/polyethylene blended fiber) and natural turf grass in a commercial market at a regional level over the course of an entire life cycle. The study was technology driven and required supplier and customer engagement. The study goals, target audience, and context for decision criteria used in this study are displayed in Figure 3.

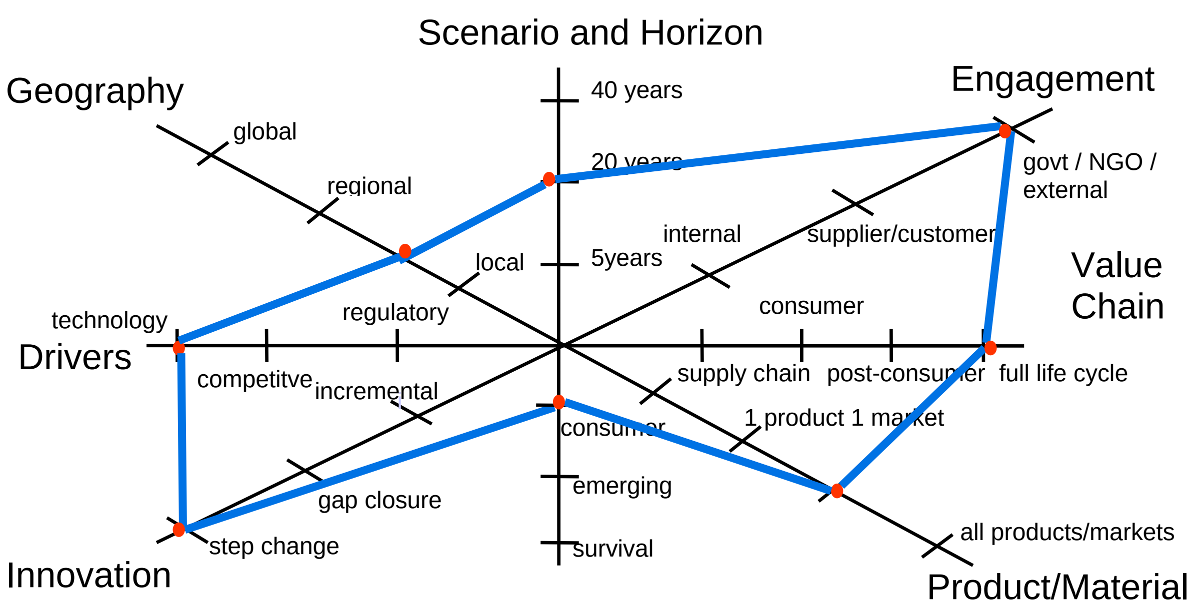

Figure 3. Diagram of study goals, target audience, and context for decision criteria for the Synthetic Turf Eco-efficiency Analysis.

4.3. *Target Audience*: Target audience for the results are state and local government agencies/municipalities, school boards, customers and trade associations. Results will be shared with key stakeholders in the sports turf value chain, published in marketing material and presented at conferences.

5. Customer Benefit, Alternatives and System Boundaries

5.1. *Customer Benefit*: The base case Customer Benefit is defined to be the Production, Installation, Use and Disposal of a multi-purpose recreational sport field of 75,000 ft^2 with the ability to support 600 hours/year of event activity in an average residential town over a 20 year time frame.

The 600 hours was based on the ability to handle two hundred unique 3 hour events, a reasonable utilization of a field in an active community supporting activities 3 - 4 seasons out of the year. Six hundred hours of event activity a year is at the upper end of the recommended activity for a natural turf grass field but well below that possible for synthetic turf which can sustain up to 3,000 hours of activity/yr. without "rest"[13]. Twenty years was a significant enough time period to fully capture the durability and replacement impacts related to the synthetic turf field as well as to allow an effective evaluation of the long-term financial commitment communities make with regards to their recreational fields.

5.2. *Alternatives*: The product alternatives compared are summarized in Table 1, and consisted of a nylon synthetic turf field, a polyethylene synthetic turf field, a nylon & polyethylene blend synthetic turf field and several natural grass alternatives based on their relative availabilities (hours of events/year). All the synthetic turf fields considered are manufactured by AstroTurf® and represent a reasonable sampling of available synthetic turf fields on the market. All the natural grass fields were based on the same natural turf grass with sand cap design. All the synthetic turf fields included the supporting base and underground drainage system. Industry studies and reports as well as the field experiences and expert judgment of the team were used to determine the range of availabilities for the synthetic turf (base line) and natural grass fields[1, 2, 3]. The natural grass field alternatives were evaluated at five different usage points ranging from 150 hrs./yr. to 600 hrs./yr. However, the application rate of inputs on all the natural grass alternatives will remain the same regardless of the field's usage rate.

Table 1: Summary of study alternatives.

Turf	Description	Availability
PureGrass®	Nylon yarn + pigment	600 hrs/year
GameDay Grass™ MT 41	Polyethylene yarn + pigment	600 hrs/year
GameDay Grass™ 3D 52	70% Polyethylene/30% Nylon yarn + pigment	600 hrs/year
(Natural) Grass – 600 hrs.	Same availability as synthetic turf; sports turf grass with sand cap	600 hrs/year
(Natural) Grass – 432 hrs.	28% reduced availability relative to syn turf	432 hrs/year
(Natural) Grass – 360 hrs.	40% reduced availability relative to syn turf	360 hrs/year
(Natural) Grass – 300 hrs.	50% reduced availability relative to syn turf	300 hrs/year
(Natural) Grass – 200 hrs.	67% reduced availability relative to syn turf	200 hrs/year
(Natural) Grass – 150 hrs.	75% reduced availability relative to syn turf	150 hrs/year

Representative schematics of the cross-sections of the two general alternatives considered (synthetic and natural grass) are presented below in Figures 4 & 5. These cross-sections generally reflect the material components that will be considered during the various stages of the field's life cycle (e.g. material production, installation, replacement and maintenance, disposal etc.). However, some representations are not incorporated in this study for example there will be no inlaid lines for the synthetic field and an all weather synthetic track is not pertinent to the scope and goals of this study. Likewise, no drain tiles are included in the natural grass option. Specific to the painting requirements for both alternatives, the frequency of painting required will be dependent on the type of field but the type, color and amount of paint required for painting the field will be fixed the same for all alternatives. The assumptions are quantified in Tables 5 and 8 below.

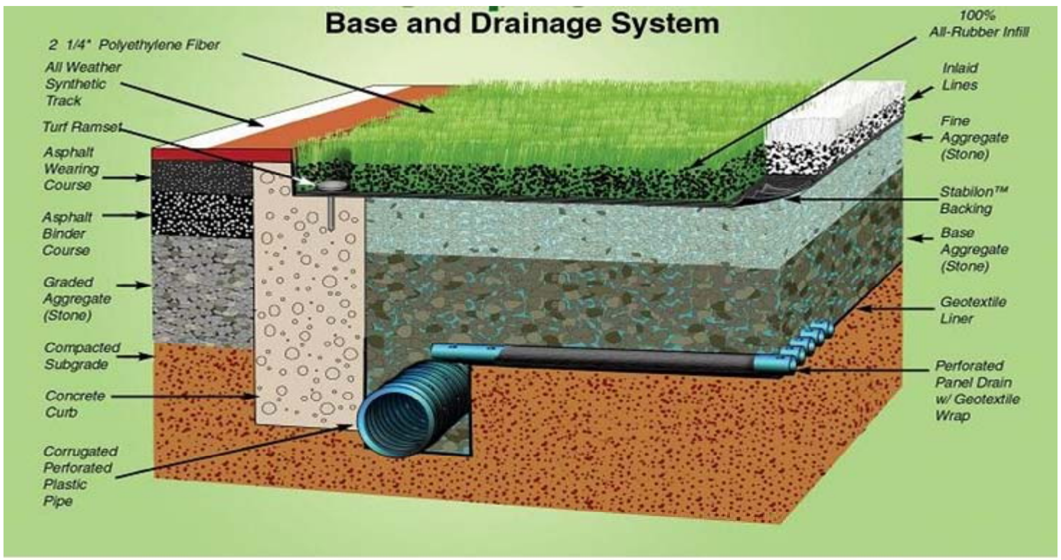

Figure 4: Typical Cross-section Synthetic Turf Athletic Field[13]

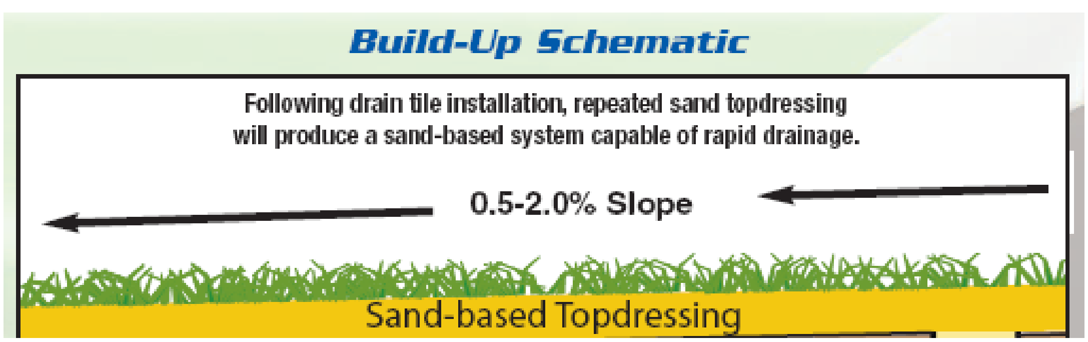

Figure 5: Typical Schematic of Natural Grass and Sand Cap Field[14]

5.3. *System Boundaries*: The system boundaries define the specific elements of the life cycle (production, use, and disposal phases) that are considered as part of the analysis. The system boundaries for the alternatives evaluated in the Synthetic Turf study are shown in Figures 6 and 7.

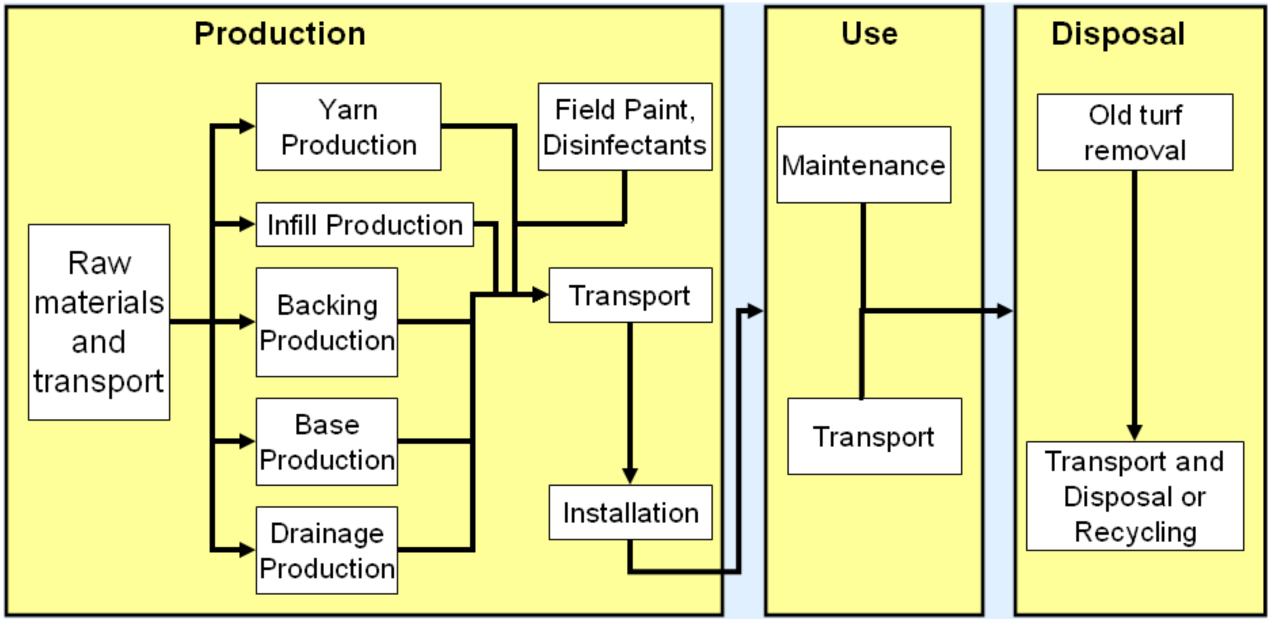

Figure 6. System boundaries for Synthetic Turf

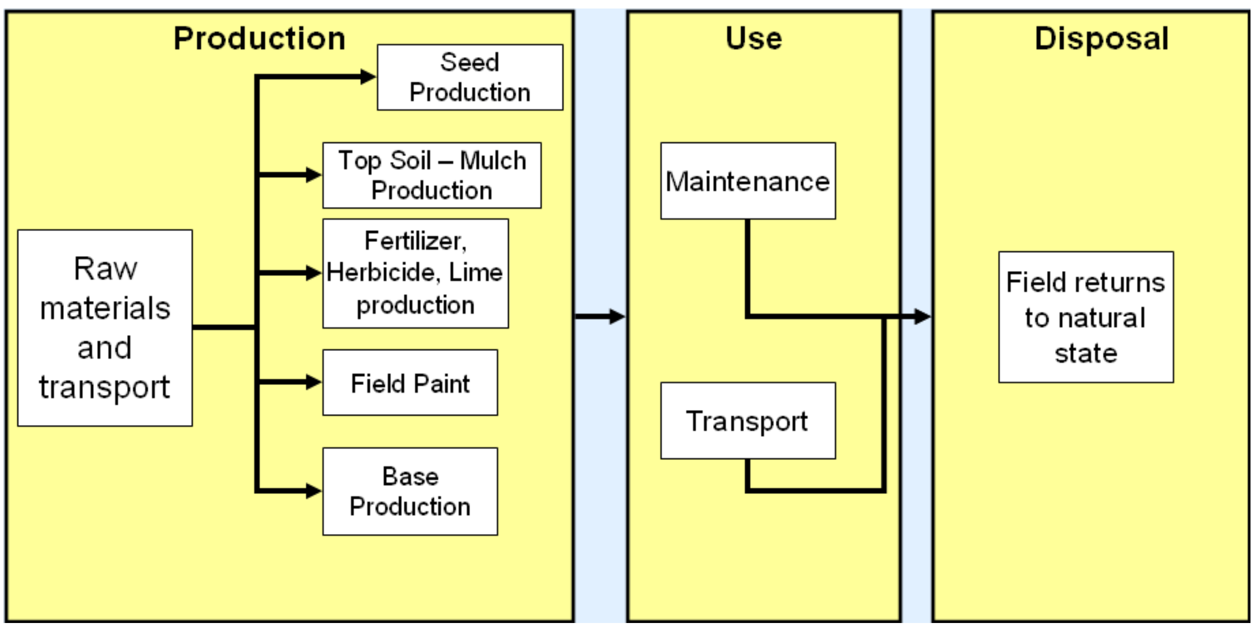

Figure 7. System boundaries for Natural Turf Grass

5.4. *Scenario Analysis*: In addition to the base case analysis, several additional scenarios were evaluated to determine the sensitivity of the study's final conclusions and results to key input parameters as well as to help focus the interpretation of the study results. Results will be presented and discussed along with the base case in section 8.

5.4.1. *Scenario #1*: Comparison of the synthetic field alternatives with natural turf grass alternatives reflecting availabilities between 300 – 360 hrs/year

5.4.2. *Scenario #2*: Reduction in the maintenance costs for a natural grass field by 40% (reference section 6.2.1.2 for base case maintenance costs)

5.4.3. Scenario #3: Reduction in recommended maintenance activities for natural grass by 25% (as defined in Table 8 below)

5.4.4. *Scenario #4*: Comparison of only the synthetic turf fields

5.4.5. Scenario #5: Increase in durability of the synthetic field alternatives by 10% (accomplished by adding 10% to values defined in section 6.3.2)

5.4.6. *Scenario #6*: Elimination of the land emissions impacts and credits for all natural turf grass alternatives

6. Input Parameters and Assumptions

6.1. *Input Parameters*: A comprehensive list of input parameters were included for this study and considered all relevant material and operational characteristics for the alternatives. The general data sources included Astroturf®, University of Tennessee Institute of Agriculture, the Sports Turf Managers Association (STMA), various individual material manufacturers as well as BASF internal data. Input parameters utilized in the analysis were absolute values and not relative values.

6.1.1. Synthetic Turf Field:

The generic material composition of the synthetic yarn as well as the overall material requirements for the production & installation of the synthetic turf field, as reflected in Figure 4 and considering the specific replacement requirements defined for each alternative (based on respective durability data defined in section 6.3.2), are shown below in Tables 2 through 4. Unless specifically noted, the three alternatives differ mostly in the relative amounts of materials required and not in the nature of materials used. For example, the infill material, primary backing material, antimicrobial etc. are identical in their composition, only the amount required for each alternative is different.

PureGrass®		**GameDay Grass™ MT 41**		**GameDay Grass™ 3D 52**	
Component	**% wt**		**% wt**	**Component**	**% wt**
Nylon	92	Polyethylene	95	Polyethylene	66.5
Pigment	8	Pigment	5	Nylon	27.6
				Pigment	5.9
Total	**100**	**Total**	**100**	**Total**	**100**

Table 2: Synthetic Yarn Composition

Yarn			PureGrass®	GameDay Grass™ MT 41	GameDay Grass™ 3D 52
	pile ribbon face weight	oz/yd²	56	41	52
		oz/CB	933,333	854,167	962,963
		kg/CB	26,460	24,216	27,300
	synthetic yarn	kg/CB	24,343	23,005	25,689
	pigment weight	kg/CB	2,117	1,211	1,611
Infill					
	infill density	lb_m/ft^2	-	3.4	2.7
	infill weight	kg/CB	-	289,165	204,117
Primary Backing					
	Woven Polyester	oz/yd²	6	8	8
		oz/CB	100,000	166,667	148,148
		kg/CB	2,835	4,725	4,200
Secondary Backing					
	Polurethane precoat	oz/yd²	22	26	26
		oz/CB	366,667	541,667	481,481
		kg/CB	10,395	15,356	13,650
Backing					
	Antimicrobial	kg/CB	529	484	546
	Urethane Adhesive	ft²/gal	70	70	70
		gal/CB	2,143	1,071	1,071
		lb/CB	18,429	9,214	9,214
		kg/CB	8,357	4,179	4,179

Table 3: Synthetic Field – General Input Data: Field

		PureGrass®	GameDay Grass™ MT 41	GameDay Grass™ 3D 52
Base		DOES NOT NEED TO BE REPLACED DURING STUDY LIFE CYCLE		
Geotextile Lining	oz/yd2	5	5	5
	oz/CB	33,871	33,871	33,871
	kg/CB	960	960	960
Aggregate Base	short ton	1,900	1,900	1,900
	kg/CB	1,390,065	1,390,065	1,390,065
Aggregate finish course	short ton	980	980	980
	kg/CB	716,981	716,981	716,981
Wood Nailer	Board ft (ft2*in)	800	800	800
	kg/CB	1,053	1,053	1,053
Perimeter Concrete Curbing	yd3	22.2	22.2	22.2
	kg/CB	31,786	31,786	31,786
Sub grade	kg/CB	0	0	0
Drainage		DOES NOT NEED TO BE REPLACED DURING STUDY LIFE CYCLE		
Drainage Stone				
1" Flat Drain	lnft	3,600	3,600	3,600
	kg/CB	286	286	286
8" HDPE Collector Pipe	lnft	400	400	400
	kg/CB	197	197	197
12" HDPE Collector Pipe	lnft	1,200	1,200	1,200
	kg/CB	1,097	1,097	1,097
Fasteners - Screws	kg/CB	136	136	136

Table 4: Synthetic Field – General Input Data: Base and Drainage System

While there are significantly less maintenance requirements for synthetic turf fields than with natural grass fields, some activities and materials are required to ensure the synthetic field continues to perform at the required performance level and desired playability while maintaining its desired level of appearance. Frequent activities normally included in field maintenance programs include sweeping or vacuuming to remove dirt and debris, brushing or raking in order to lift the turf fibers and prevent matting, aerating to minimize compaction of the in-fill, repainting the field lines and the application of cleaning and anti-static agents. Other maintenance activities that will occur less frequently over the year include inspection and repairing of seams and repairs to the base. The economic and environmental impacts of these activities for each synthetic field alternative were considered. Cost impacts are itemized in Table 9 while material requirements for maintaining the synthetic field are identified in Table 5 below.

		PureGrass®	GameDay Grass™ MT 41	GameDay Grass™ 3D 52
Water-weekly	gal/1000ft2*year	131	131	131
	kg/year	1	% of Turfgrass requirement	
	kg/CB	742,833	742,833	742,833
Field Painting	gal/1000 sq ft	0.25	0.25	0.25
	# applications/year	8	8	8
	kg/CB	14,288	14,288	14,288
Disinfectant	gal/field/year	20	20	20
	kg/CB	1,506	1,506	1,506
Fabric Softener	gal/field/year	9	9	9
	kg/CB	678	678	678
Crumb Rubber	lbm/field/lifetime		10,000	10,000
	kg/CB		11,340	10,080

Table 5: Synthetic Field – Maintenance Requirements

Other than for PureGrass®, the other synthetic fields require in-fill in order to help keep the fiber upright and to provide for shock absorbency. The nylon yarn in PureGrass® does not require infill in order to keep it upright. This study assumed that the infill for the GameDay Grass™ alternatives was derived from recycled tires. Manufacturing data and equipment literature were used to calculate the environmental impact, mostly energy requirement, associated with making the crumb rubber infill from recycled tires. Table 6 shows the specific energy requirements for crumb rubber infill. Finally, the antimicrobial material integrated into the backing material of the synthetic field as well as used during the maintenance and cleaning operations of the field is based on organosilane chemistry. The concentration of the active ingredient is less than 2% in water. Usage amounts for the fabric softener (antistatic agent) and disinfectant were obtained from STMA literature which cited actual maintenance data for a similar synthetic turf field[15] to the one being modeled in this analysis.

Crumb Rubber Manufacturing		
Electricity	MJ/lbm	1.53
Diesel Fuel	MJ/lbm	1.56

Table 6: Energy Requirements for crumb rubber manufacturing

6.1.2. Natural turf grass Field

Turf grass faculty at the University of Tennessee Knoxville was consulted as well as their publications referenced[4] in order to define the requirements to establish and maintain a high quality natural grass sports field. Specific requirements to establish and maintain a professional turf grass field as defined by the study's customer benefit (75,000 ft^2 and able to support 200 events/yr. for 20 yrs.) are summarized in Tables 7 and 8. Mowing, fertilization and irrigation are the primary maintenance practices most often needed to keep natural turf fields healthy. Mowing maintains uniform grass height and suppresses weeds. Turf grass fields are fertilized to provide nutrients that would otherwise limit plant growth. An application of lime may be necessary to neutralize soil acids and supply plants with calcium and magnesium. Actively growing turf grasses often contain more than 70% water and require from 1/10" to 3/10" of water per day. Turfs are irrigated to prevent severe drought stress and activate fertilizers, herbicides and insecticides. With regards to the water inputs identified for natural grass in Table 8, the effects of rainfall on meeting these recommended watering requirements was not incorporated into this analysis.

Sometimes, turfs benefit from supplementary maintenance practices such as dethatching, mechanical aeration, topdressing and rolling. Turfs are dethatched to lift and remove excess organic matter from the soil surface. Core aerification loosens soil and speeds the flow of water into the turf grass root zone. Broadcasting a shallow layer of soil or compost over a turf after core aerifying may smooth the surface and improve the soil's biological activity.

The economic and environmental impacts of these activities for each turf grass alternative were considered. The frequency and type of all maintenance activities including their associated costs were applied equally to all turf grass alternatives regardless of its usage (availability). Material impacts for both the core and supplementary maintenance requirements are itemized in Table 8 while the cost impacts for these items are discussed and identified in section 6.2.1.2 below.

Grass Seed (KBG)	lbm/1000ft2	2.0
	kg/CB	68
Topsoil	yd3/1000ft2	12.5
	kg/CB	1,148,157
Mulch	lbs/1000ft2	50.0
	kg/CB	1,701.0
Sand Cap Base	inches	4.0
	kg/CB	1,259,980
Water- Initial	gal/1000ft2	112.0
	kg/day	31,694.2
	kg/CB	665,578.4
Water-regular	gal/1000ft2	300.0
	kg/day	84,895.2
	kg/CB	764,056.8

Table 7: Natural Turf Grass Field – Establishment requirements

Water-weekly	gal/1000ft2*year	13,125
	kg/year	3,714,165
	kg/CB	74,283,300
Nitrogen Fertilizer	lbs/1000ft2/year	4.0
	Nitrogen ratio in Fertilizer	2.2
	kg/CB	5,986
P_2O_5 Fertilizer	lbs/1000ft2/year	1.5
	P2O5 ratio in Fertilizer	5.0
	kg/CB	5,102
K_2O Fertilizer	lbs/1000ft2/year	1.5
	K2O ratio in Fertilizer	1.7
	kg/CB	1,704
Lime	lbm/1000ft2/year	25
	kg/CB	17,010
Top Dressing- Peat	yd3/1000ft2/year	0.8
	kg/CB	73,482
Over seeding	lbm/1000ft2/year	20
	kg/CB	13,608
Herbicide	oz/1000 ft	4.77
	gal/yr	2.79
	kg/CB	242
Insecticide	gal/acre	1
	kg/yr	6.5
	kg/CB	130
Fungicide	lbs/1000ft2	3
	kg/CB	102
Mowing	times/year/field	62
	times/CB	1,240
	Gasoline Usage - gal/mow	2.0
	Gasoline - MJ/CB	316,386
Sand replacement	inches/year	0.25
	kg/CB	1,574,975
Field Painting	gal/1000 sq ft	0.25
	# applications/year	12
	kg/CB	20,412

Table 8: Natural Turf Grass Maintenance Requirements

6.2. Costs

6.2.1. User costs were evaluated for each alternative. Costs were entered based on the installation, maintenance and disposal of the required field area to support the required amount of activity over a lifetime of 20 years (4000 total events @ 3 hrs. each) to the same level of performance and appearance.

6.2.1.1. Installation and Replacement

Costs specific to the synthetic turf alternatives, installation and replacement were provided by the manufacturer, AstroTurf®. These costs were also reviewed and compared against industry average data as reported by the Sports Turf Managers Association (STMA)[5]. The STMA literature was also used to estimate the installation costs for natural turf and sand cap grass field. Applicable labor costs were included.

6.2.1.2. Maintenance Costs

AstroTurf® provided the details on the maintenance costs associated with the various synthetic alternatives and are itemized in Table 9.

		PureGrass®	GameDay Grass™ MT 41	GameDay Grass™ 3D 52
All inclusive	$/ft2			
Maintenance Plan	$/year	$5,000	$5,000	$5,000
Seam and Inlay Repairs	$/year	$2,000	$2,000	$2,000
Grooming	$/year	$2,400	$2,400	$2,400
Base Repairs	$/year	$1,300	$1,300	$1,300
Infill	$/year		$1,516	$1,347
Painting	$/year	$1,000	$1,000	$1,000
Total	$/year	$11,700	$13,216	$12,047

Table 9: Maintenance Costs for Synthetic Turf Sports Field

Maintenance costs associated with the maintaining a high quality natural grass field with the maintenance activities identified in Table 8 were estimated at $0.35/ft^2. This puts the annual cost in the range of $25,000 - $30,000 which was deemed reasonable by the project team as well as supported by several external studies and reports[6,10] . Since the level and consistency of the maintenance activities for natural grass may vary based on the region, climate, level and type of activity, cost implications etc. a sensitivity analysis will be performed around this key assumption.

6.2.1.3. Disposal

It was assumed that the synthetic turf field would be removed at the end of the 20 year life cycle and the field returned back to its natural state. STMA literature[5] was referenced for the average cost to remove and dispose of a synthetic turf field. A cost of $3.00 /ft^2 was assumed for this study and includes a cost to provide back-fill and sod over the base and drainage system. A 10% credit in the removal and disposal cost only was given to the PureGrass® alternative due to it not having infill. Credit was based on the estimated cost to remove and dispose of the infill separately. No additional disposal costs were allocated to the natural grass field. Specific to the disposal of the field materials, though it was assumed that all material were taken off-site, materials that could be recycled (e.g. plastic) or reused were not sent to landfill. An assumption was made that the required reuse/recycling infrastructure was available for use. Thus only a small portion of the synthetic turf field was ever disposed of in a landfill. No direct credit was given for recycling or reusing materials only an off-set of not requiring material to go to landfill was applied. Transport was provided by a truck powered by diesel fuel.

Fuel price and the landfill disposal fee were based on a national average.

6.3. Study Assumptions

6.3.1. Transportation

Establishment and Maintenance of both the synthetic turf and natural turf recreational fields over the 20 year life cycle require a significant amount of materials to be transported. The environmental impact associated with the transport of these materials are significant and have an impact in determining the overall environmental impact for each alternative. For this study the transport distance of materials to the field during installation was assumed at 250 km and the transportation of materials to and from the field during the use, maintenance and end-of-life of the field were determined to be 100 km. Truck transport was the method of transportation with a diesel fuel efficiency of 2.7 MJ/ton/km.

6.3.2. Durability

A key differentiator between the synthetic turf alternatives are their relative durability. Manufacturer data was used to determine a representative “national average” durability of the synthetic fields. They were established as following:

- PureGrass® (nylon): 10 years
- GameDay Grass™ MT 41 (PE): 8 years
- GameDay Grass™ 3D 52 (blend): 9 years

These values were also consistent with the range reported by the STMA.

After high usage of natural turf grass, fields may require significant rehabilitation including soil profile improvements, re-grading and turf replacement after approximately 10 years. However for this study, it was assumed that the maintenance plan identified for the natural turf grass was sufficient to maintain the field at a high quality of appearance and performance while meeting the respective availability targets identified so no additional replacement/installation of turf was required over the lifetime of the field.

6.3.3. Field Emissions & Sequestration of CO_2 by natural turf grass

Natural grass, unlike synthetic turf, has the ability to sequester CO_2 and thus has an ecological advantage to synthetic turf in this perspective. Turf Grass sequestration capacity was taken from an externally published life cycle study[7]. However, off setting this benefit are the air (direct & indirect) and water emissions related to the use of Nitrogen based fertilizers. Values for these emissions benefits and impacts are identified in Table 10.

Turf Grass Carbon Sequestration	mtons $CO_2e/1000\ ft^2$/year	0.032
Direct/Indirect - Fertilizer Use		
N_2O to Air	% of application	1.5%
N to Water	% of application	10%

Table 10: Land Emissions credits – impacts for Natural Grass

Specific for this study, emissions to air from the use of Nitrogen based fertilizers were estimated from literature[8] as 1% direct emissions of N_2O and 0.5% total indirect emissions due to volatilization of the fertilizer and leaching of the fertilizer, with subsequent conversion to N_2O.

Though emissions to water are strongly dependent on the climate, a nominal value of 10% of applied N landing in the ground water was assumed.

For this analysis, the potential impacts of phosphate emissions into the water (from the use of P based fertilizers) as an eutrophicant was not directly considered.

7. Data Sources

7.1. The environmental impacts for the production, use, and disposal of the four alternatives (3 synthetic turfs and natural grass) were calculated from eco-profiles (a.k.a. life cycle inventories) for the individual components and for fuel usage and material disposal. Life cycle inventory data for these eco-profiles were from several data sources, including BASF specific production sites, and the quality of this data was considered medium-high to high. None of the eco-profile data was considered to be of low data quality. A summary of the eco-profiles is provided in Table 11.

Table 11: Summary of eco-profiles used in this EEA.

Eco-Profile	Source, Year	Comments
Polyethylene	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
HDPE	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Nylon	1996	BASF Internal Data
Turf Green Pigment	2009	Americhem. Mfg. data
Polyester Fiber	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Polyurethane Pre-coat	2009	Universal Textile Technologies. Mfg. data
Antimicrobial	2009	External mfg. data / patent; Boustead database[9]
Adhesive	2009	Synthetic Surfaces Inc.
Geotextile Liner	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Aggregate	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Cement	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Wood	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Topsoil, Biomass, Peat	U.S. Avg., 1996	Most reliable profiles available; Boustead database[9]
Fertilizers (N-P-K)	German Avg. 1996	Most reliable profiles available; Boustead database[9]
Sand	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Lime	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Herbicide	1997	Most reliable profile available; Boustead database[9]
Fungicide	2007	Most reliable profile available; Boustead database[9]
Insecticide	2007	External mfg data; Boustead database[9]
Antioxidant	2009	BASF (Ciba) internal data
Field Paint	2009	External mfg data; Boustead database[9]
Disinfectant	2009	External mfg data; Boustead database[9]
Fabric Softener	2009	External mfg data / patent; Boustead database[9]
UV Stabilizer	2009	BASF (Ciba) internal data
Truck Transport	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Electricity	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Gasoline Usage	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Diesel Use – US	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
Solid Waste to Landfill	U.S. Avg., 1996	Most reliable profile available; Boustead database[9]
BASF data sources are internal data, while the others are external to BASF. Internal data is confidential to BASF; however, full disclosure was provided to NSF International for verification purposes.		

8. Eco-efficiency Analysis Results and Discussion

8.1. *Environmental Impact Results*: The environmental impact results for the Synthetic Turf EEA reflecting the base case scenario only are generated as defined in Section 6 of the BASF EEA methodology and presented below.

8.1.1. *Primary energy consumption*: Energy consumption, measured over the entire life cycle, shows that natural grass alternative with the ability to support 600 hrs of activity per year (or 200 3 hr. events) has the lowest energy consumption of all the alternatives. The remaining natural turf grass alternatives have a corresponding higher relative energy consumption which is proportional to their reduced availabilities and thus larger field requirements. Amongst the Synthetic Turf alternatives, the PureGrass® has the lowest energy consumption (15% - 25% less) mostly attributed to the fact it has the highest durability and thus requires less resources over the 20 year life cycle and more importantly the nylon yarn used in PureGrass® does not require in-fill which consumes a significant amount of energy in order to recycle tires into crumb rubber. Energy impacts of the crumb rubber used for the infill are accounted for in terms of both the initial installation of the GameDay Grass™ alternatives and the routine replacement of the infill. Specific to the yarns, the nylon yarn requires more energy to produce than the polyethylene or polyethylene blended yarn but as mentioned before this is off-set by its ability to contribute to increased durability. Overall, it can be seen from Figure 8 that one of the key drivers for energy consumption for each alternative is the transportation in the production phase and in the use phase for the natural turf grass alternatives with the lower availabilities. Energy (fuel) consumption is high in the production phase due to the significant quantities (weight) of materials that are required to be transported. Finally, the large quantities of materials required to maintain the natural turf grass as well as the fuel required to mow the grass, contribute to the maintenance activities having a significant impact on energy consumption for the natural grass alternatives.

In general the energy consumption of the synthetic field lies in the range of the natural grass alternatives which have 300 – 432 hrs./year of availability, with the PureGrass® (600 hrs/year) being almost equivalent to the natural grass alternative which can support 432 hrs/year of event activity.

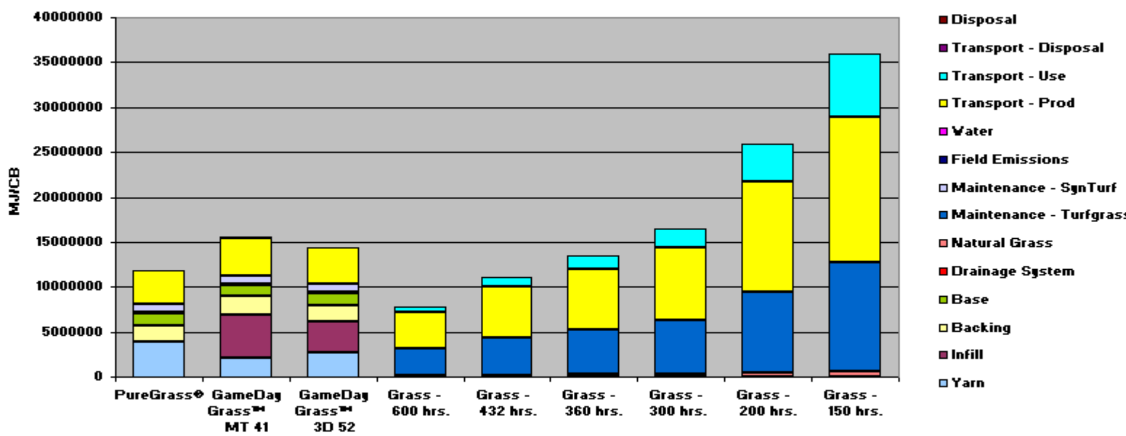

Figure 8. Primary energy consumption.

8.1.2. *Raw material consumption*: It is clear from Figures 9 and 10 that the synthetic turf alternatives consume the lowest amount of resources over the defined life cycle than any of the natural grass alternatives. Even the best natural grass alternative (Natural grass 600 hrs of activity/year) uses about twice the amount of resources than any of the synthetic turf fields. Per the EEA methodology, weighting factors are applied to the raw materials based on their available reserves and current consumption rate. Oil, water, top soil, sand and zinc are the key resources consumed by the natural grass fields.

Even considering its low resource weighting, water becomes a significant resource consumed during irrigation of the natural turf grass with a consumption of around 13,000 gallons/1000ft^2/year or almost 1 million gallons of water per standard 75,000 ft^2 field. As mentioned previously, the impact of precipitation on water resource consumption was not considered. Resource consumption is the most relevant environmental impact category for this study (see Figure 33 section 10.1) and thus has the most significant impact in determining the overall environmental impact for each alternative.

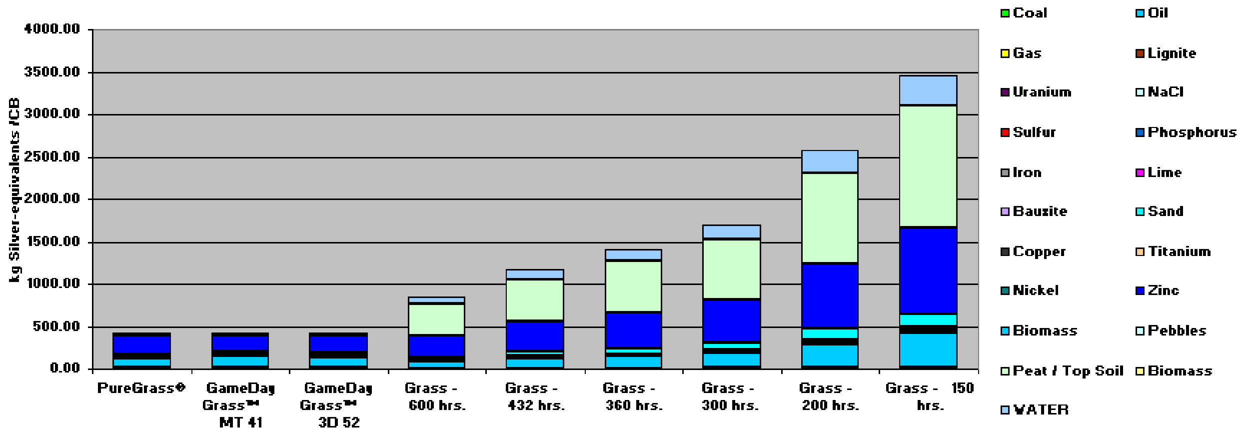

Figure 9. Resource Consumption: Materials

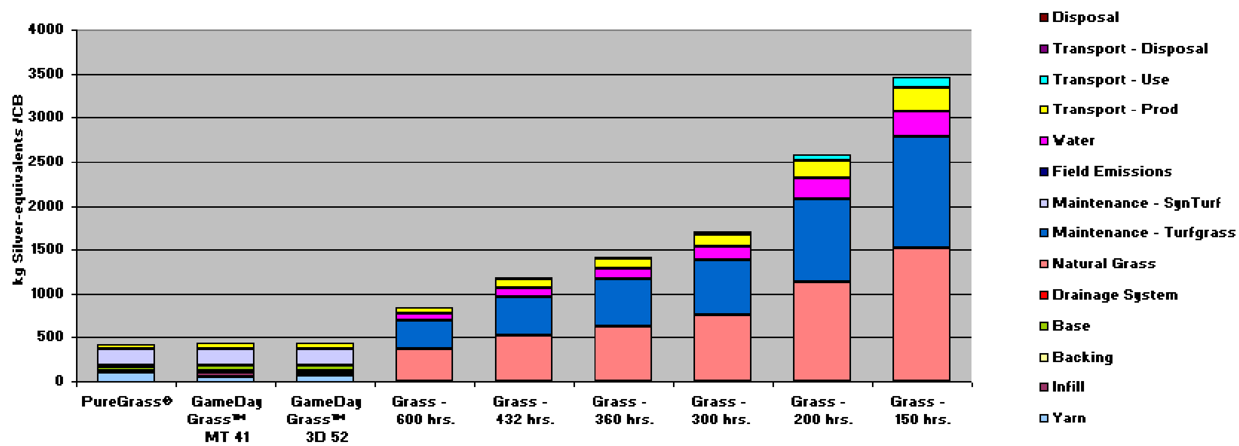

Figure 10. Resource consumption: Modules

8.1.3. *Air Emissions*:

8.1.3.1. *Greenhouse Gases (GHG)*: As expected, results for greenhouse gas emissions (Figure 11) are similar to the energy consumption chart but slightly more pronounced for the synthetic turf fields as they do not benefit from the carbon sequestration capability offered by the natural turf grass. In fact, the ability of the natural turf to sequester CO_2 leads to an overall reduction in greenhouse gas emissions for the natural grass alternatives of around 10% over the defined life cycle. The GHG emissions for the natural grass alternatives does include the global warming impact of the N_2O emissions to air from the fertilizer usage. For the synthetic turf alternatives, PureGrass®

has the lowest carbon footprint but the nylon yarn component has a significantly higher GHG emission than the other yarns. Lower durability and a higher in-fill requirement (25% higher than GameDay Grass™ 3D 52) cause the polyethylene based synthetic turf field to have the highest carbon footprint of the synthetic fields. The GHG emissions for the synthetic fields over their life cycle lie approximately around the natural grass turf alternative that supports 300 hrs of activity/year.

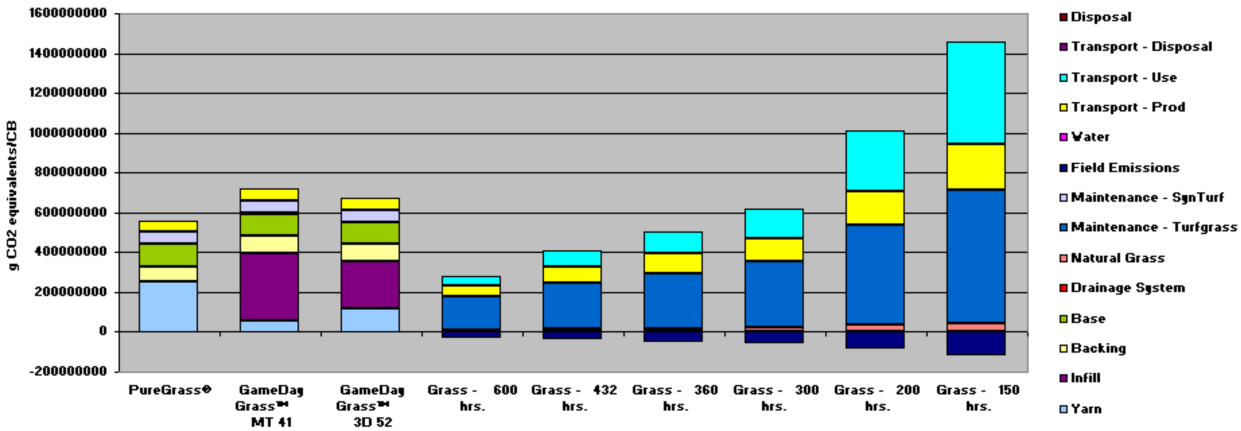

Figure 11. Greenhouse Gas (GHG) emissions.

8.1.3.2. *Photochemical ozone creation potential (smog)*: The lowest emissions for ground level ozone formation potential (POCP) occurs in the PureGrass® alternative. Figure 12 indicates that the maintenance and transportation activities are the largest contributors for all alternatives. POCP is mostly attributed to the hydrocarbon and VOC emissions related to the use of diesel fuel and gasoline. Alternatives that require larger amounts of materials to be produced and transported will have corresponding higher impacts. The N_2O emissions from the fertilizer application were included in the POCP calculation for the natural turf grass alternatives, though the effect was insignificant.

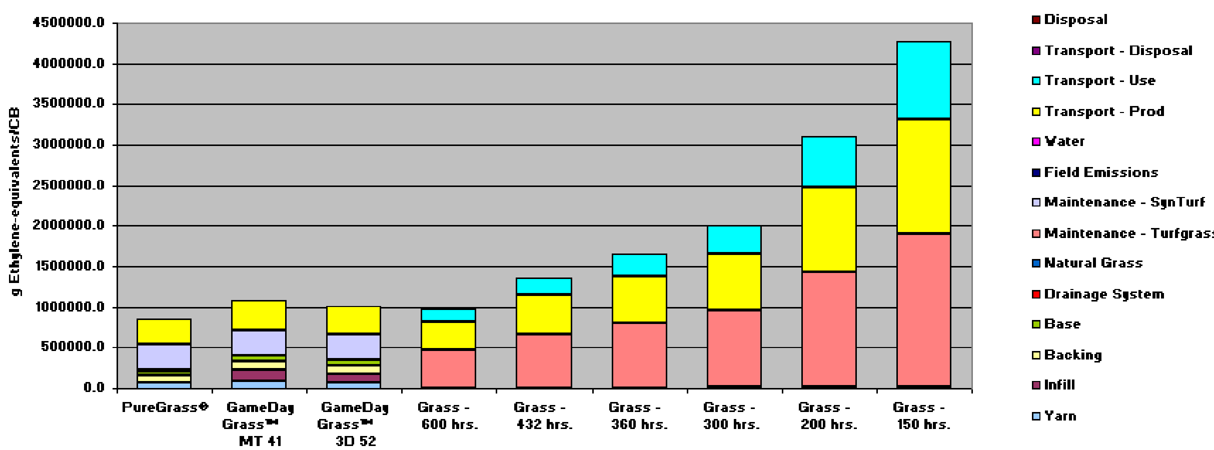

Figure 12. Photochemical ozone creation potential.

8.1.3.3. *Ozone depletion potential (ODP)*: As depicted in Figure 13, all of the alternatives result in a very minimal ODP, measured at between 100 - 260 g CFC equivalents per CB for the synthetic fields and around 1 – 4 g CFC equivalents for the natural turf fields. Put into context with the other environmental impacts being measured, the ODP levels contribute < 1% to the total environmental impact of the fields over their life cycle.

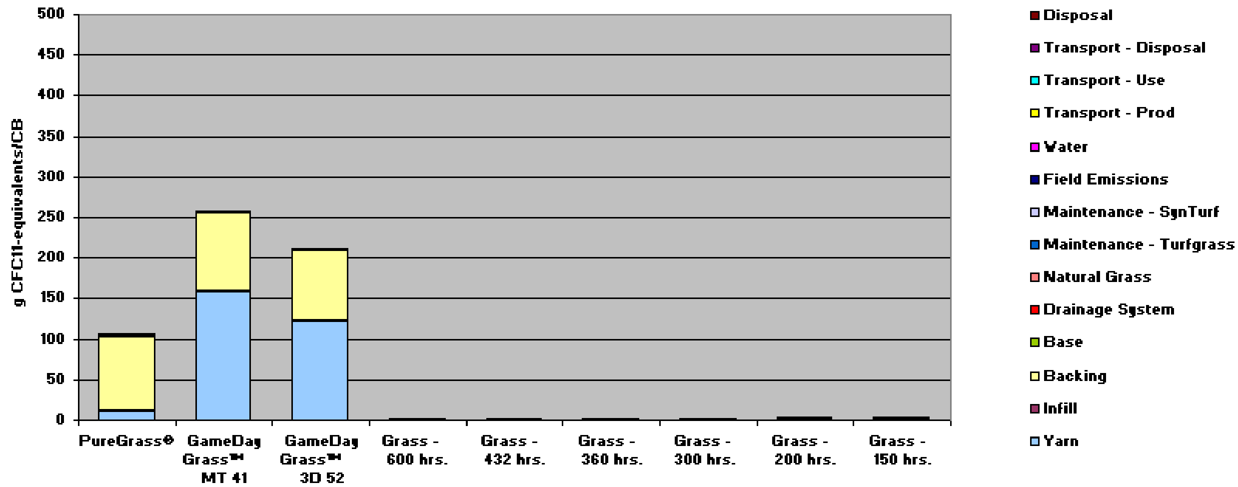

Figure 13. Ozone depletion potential.

8.1.3.4. *Acidification potential (AP)*: It can be seen from Figure 14 that overall, the major contributors to AP are the fuel & electricity consumption required to make the in-fill for the Gameday Grass™ synthetic turf fields as well as from the materials required to maintain the natural turf grass and the subsequent emissions from the fuels used to transport these materials to the site. Overall, the synthetic turf field's acidification potential lies in the range of the natural grass alternatives that have a 360 – 240 hrs. of availability/year. PureGrass® has a 30 – 40% lower acidification potential than the other synthetic turf fields. The N_2O emissions from the fertilizer application were included in the AP calculation for the natural turf grass alternatives.

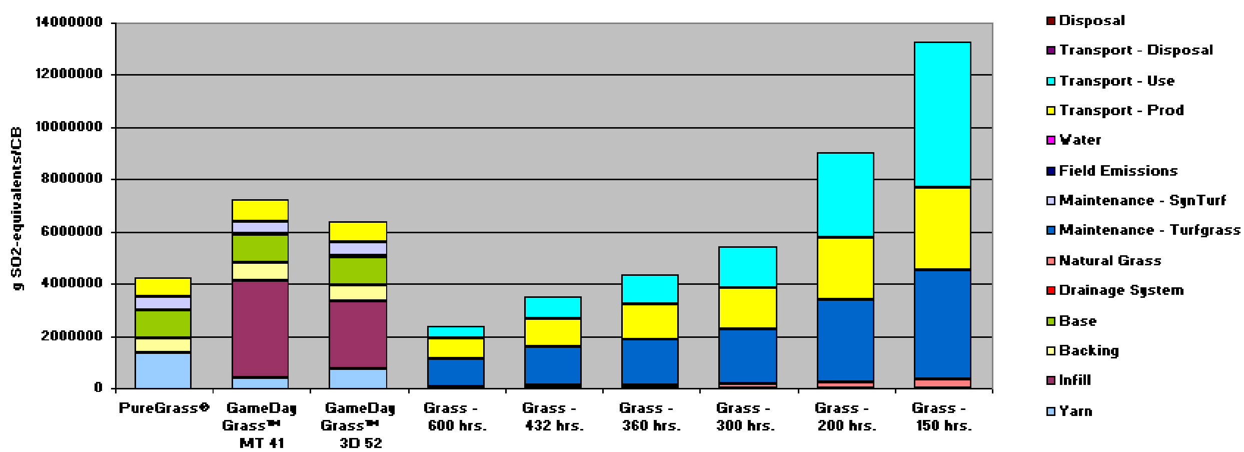

Figure 14. Acidification potential.

Utilizing the calculation factors shown in Figure 35, Figure 15 shows the normalized and weighted impacts for the four air emissions categories (GWP, AP, POCP and ODP) for each alternative. Air emissions from the synthetic turf fields lie in the range of the natural grass alternatives which support between 300 – 432 hrs/year of activity.

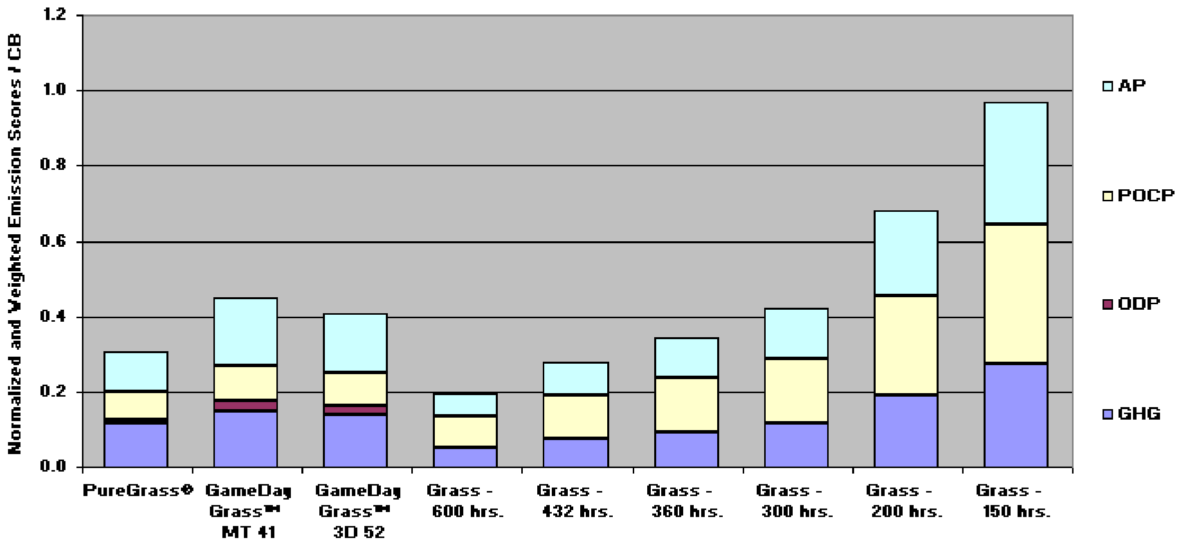

Figure 15. Overall Air Emissions

8.1.4. *Water emissions*: Figure 16 shows that the main contributor to the water emissions for the synthetic turf fields are the polyurethane chemistries related to the backing material and adhesive. For the natural grass alternatives, field emissions of nitrogen from the use of nitrogen based fertilizers is the major contributor. Overall, relative to the other environmental impact categories, water emissions contribute less than 2% to the overall environmental impact.

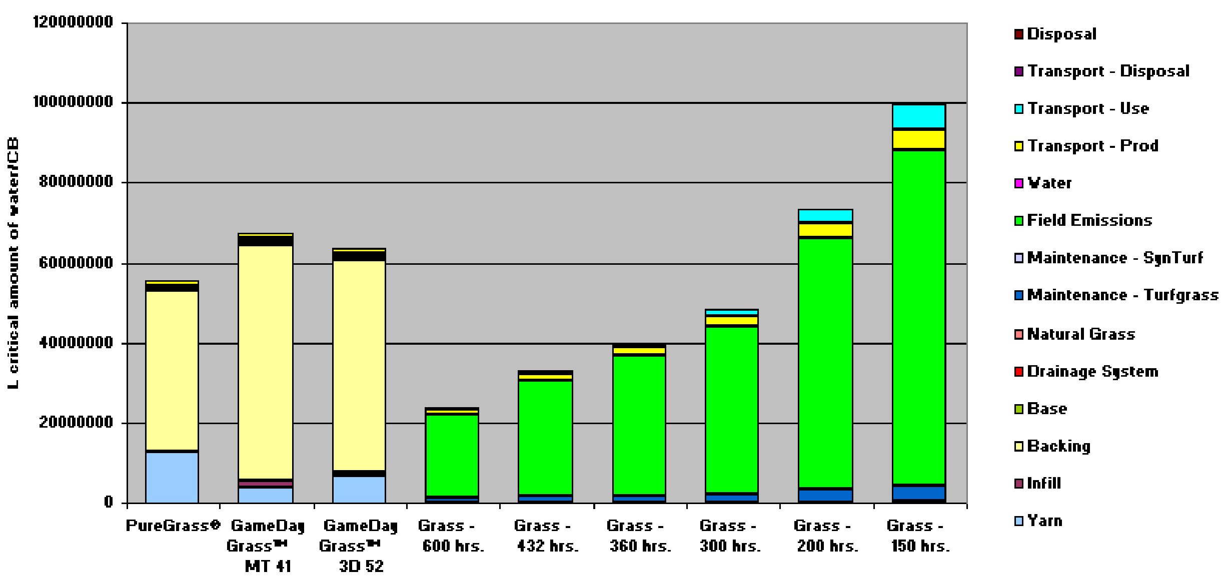

Figure 16. Water emissions.

8.1.5. *Solid waste generation*: As depicted in Figure 17, the Gameday Grass™ synthetic turf alternatives generates the least amount of waste due to the credit it receives for utilizing tires in the infill that would normally be sent to the landfill. For the synthetic turf alternatives the largest contributor to solid waste generation is the end of life disposal of the field materials that cannot be recycled. Solid waste generation for the natural grass fields comes from the indirect solid waste emissions related to the production, use and transportation of the raw materials used to install and maintain the field. For the PureGrass® synthetic field (no infill), the solid waste generation is equivalent to the natural grass alternative which supports 300 hrs/year of activity.

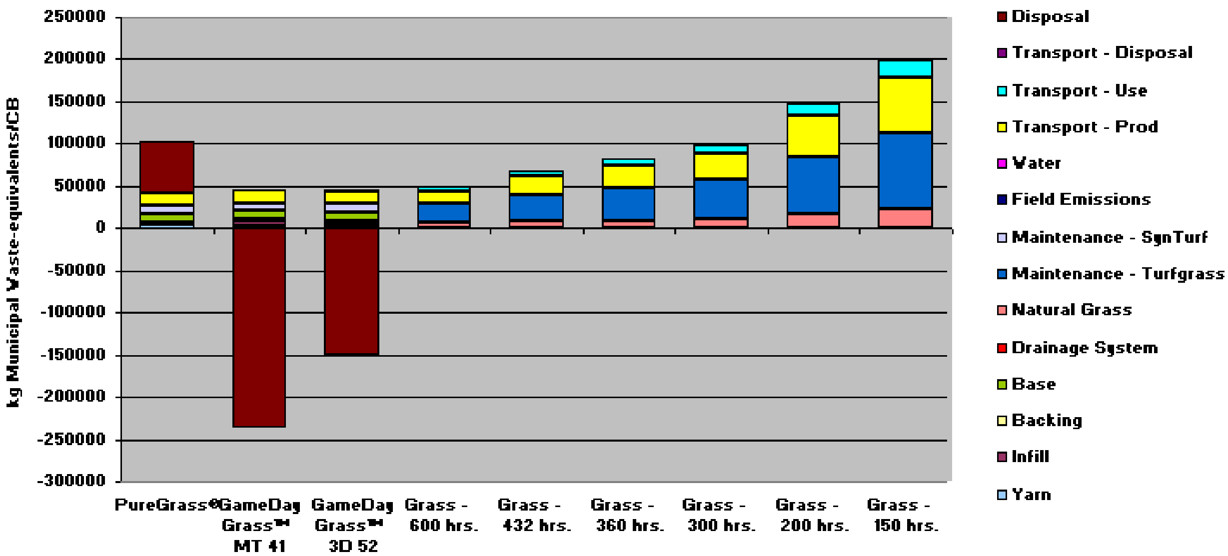

Figure 17. Solid waste generation.

Utilizing the calculation factors shown in Figure 35, a composite of the cumulative impact of the three main emission areas of air, water and solid waste is derived. Figure 18 below shows the relative weighted impacts for the three main emissions categories for each of the alternatives considered. GameDay Grass™ MT 41 (polyethylene yarn) has the lowest overall life cycle emissions of all the alternatives considered.

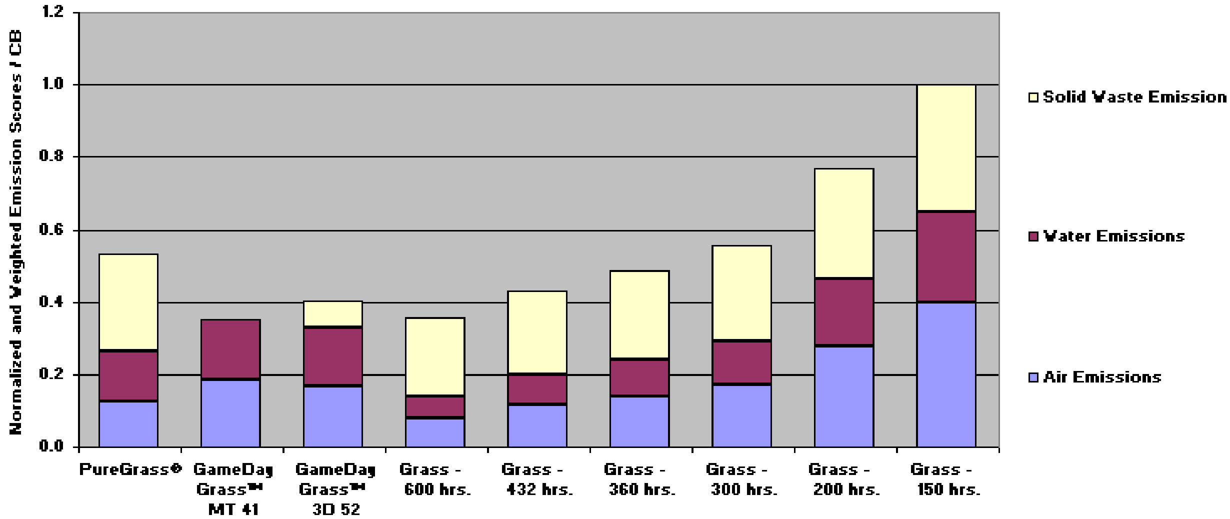

Figure 18. Overall Emissions.

8.1.6. *Land use*: As displayed in Figure 19, the synthetic fields, specifically PureGrass®, have the lowest impact on land use. Fuel use during the production and use phases of the life cycle, mostly as a result of transportation related activities, is the single largest contributor. Activities related to the production (quarrying) and delivery of the sand for the natural grass fields is also a major individual contributor to land use.

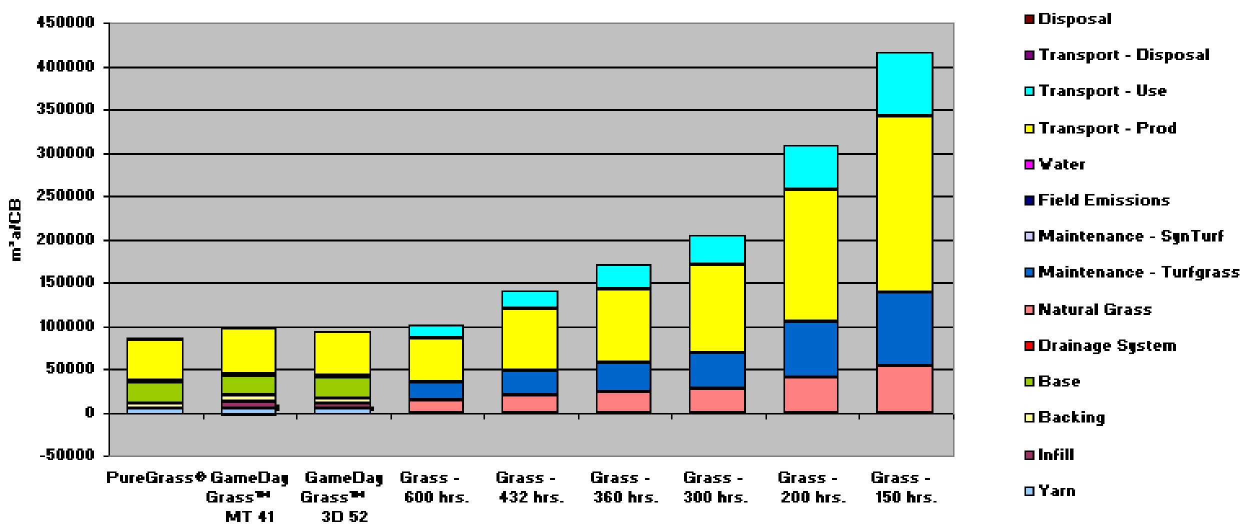

Figure 19. Land use.

8.1.7 *Toxicity potential*: The toxicity potential of the individual components for the various recreational field alternatives was analyzed for the production, use and disposal phases of their respective life cycles. For the production phase, not only were the final products considered but the entire pre-chain of chemicals required to manufacture the products were considered as well. Human health impact potential in the use phase consisted mainly of the maintenance activities and material applications associated with maintaining the sport fields. Toxicity potential in the disposal phase comes from the removal and transport of the materials to a landfill or other end-of-life destination (e.g. recycling). Nanoparticles were not included in the chemical inputs of any of the alternatives

Inventories of all relevant materials were quantified for the three life cycle stages (production, use and disposal). Consistent with our methodology's approach for assessing the human health impact of these materials (ref. Section 6.8 of Part A submittal), a detailed scoring table was developed for each alternative broken down per life cycle stage. This scoring table with all relevant material quantities considered as well as their R-phrase and pre-chain toxicity potential scores were provided to NSF International as part of the EEA model which was submitted as part of this verification. Figure 20 shows how each module contributed to the overall toxicity potential score for each alternative. The values have been normalized and weighted. The toxicity potential weightings for the individual life cycle phases were production (20%), use (70%) and disposal (10%). These standard values were not modified for this study from our standard weightings.

As to be expected because of the large weight of materials (volume of material x density) that were installed for each alternative and also transported to the site to maintain the fields over their 20 year life cycle (more relevant for the natural turf grass alternatives) the human health impact of the emissions from the fuel consumed during transport was the largest contributor to toxicity potential. In addition, the emissions from the gasoline used to mow the natural turf grass in the use phase (highest relative weighting of life cycle stages) was a significant contributor to the overall toxicity potential score, especially considering the higher weighting placed on the potential exposure to the field maintenance workers during the use phase. There were no great differences between the synthetic turf fields as the materials and field components are quite similar.

Figure 21 shows how the scoring is distributed across the life cycle stages. Consistent with the discussion above, the use phase is the most significant, followed by the production and the final disposal. A high safety standard was assumed for the manufacturing processes for the raw materials. For the use phase, an allowance was made to take into consideration the open nature of the application process. Finally, no reduction in the scores based on exposure conditions was applied for the disposal phase of the materials as the potential for human contact during removal and disposal/recycling of the synthetic field materials is high.

Many studies have been conducted on synthetic fields based on potential chemical exposure or allergies related to materials present in the synthetic materials, specifically the crumb rubber in-fill or the pigment. Recent studies[1,11] which have included reviewing available data as well as specific research work, have concluded that for new or replacement synthetic fields, generally no specific public health concerns or risks exist. Conclusions from data available and reviewed by the NYSHOD (NY State Dept of Health)[1], also show that outdoor or indoor synthetic turf surfaces are no more likely to harbor infectious agents than other surfaces in those same environments.

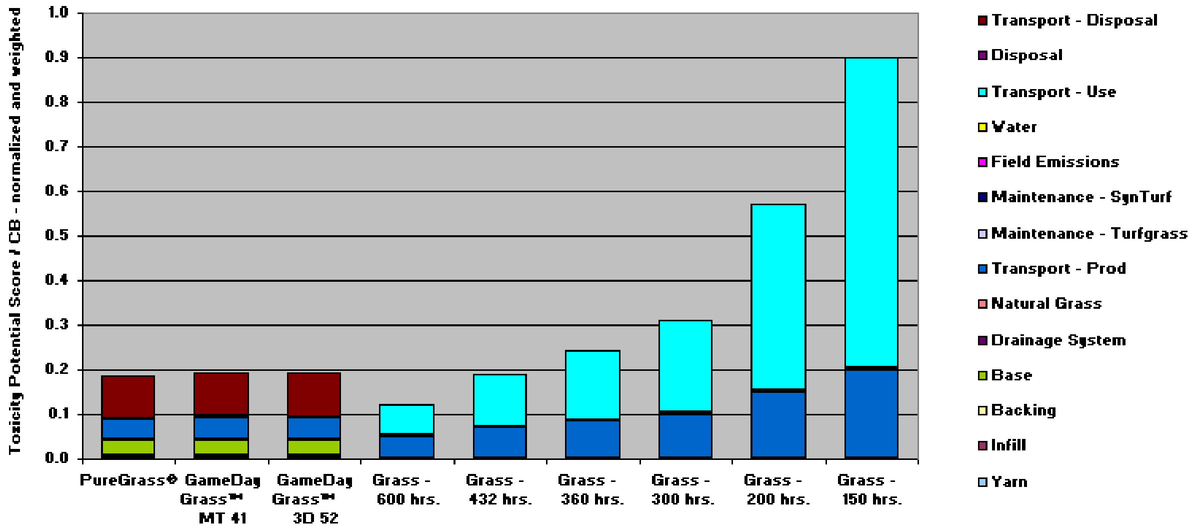

Figure 20. Toxicity Potential by Module

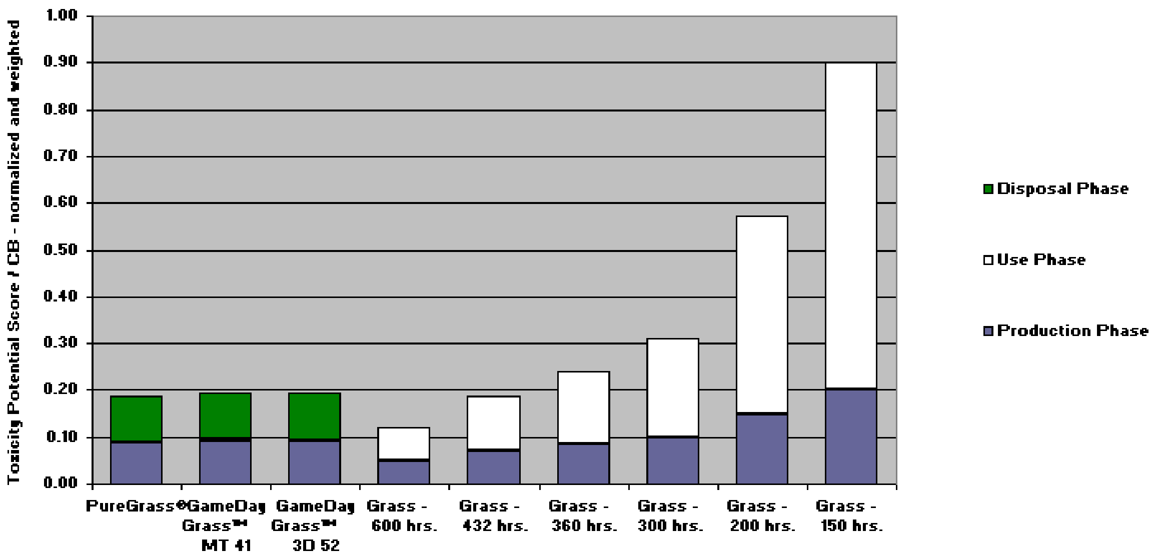

Figure 21. Toxicity Potential by Life Cycle Stage

8.1.8. *Risk potential (Occupational Illnesses and Working Accidents Potential):*
All the materials and activities accounted for in the various life cycle stages were assigned specific NACE codes. NACE (Nomenclature des Activities Economiques) is a European nomenclature which is very similar to the NAICS codes in North America. The NACE codes are utilized in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the business economy and is broken down by specific industries. Specific to this impact category, the NACE codes track, among other metrics, the number of working accidents, fatalities and illnesses and diseases associated with certain industries (e.g. chemical manufacturing, petroleum refinery, inorganics etc.) per defined unit of output. By applying these incident rates to the amount of materials required for each alternative, a quantitative assessment of risk is achieved.

In Figure 22, the greatest Occupational Illnesses and Accident potential occurs for the synthetic turf alternatives. The module which contributes to the highest risk potential for occupational illnesses and accidents is the aggregate, used for the base, and by far the largest single resource (by weight) used in the synthetic field alternatives. Activities related to the sand replacement and to a lesser degree the field painting activities contribute the largest amount to the occupational illnesses and accidents risks for the maintenance of the grass fields.

This study put a 25% weighting on additional risk categories specific to the materials, activities and issues considered by this study. These three categories covered the areas of the risk of injury, the risk of heat stress and the risks associated with maintenance activities not identified or captured elsewhere (e.g. mowing the grass). Figure 23 shows the overall risk category for each alternative with these additional impacts considered.   All alternatives were rated identically with regards to the risk of injury. Obviously, many factors contribute to the type, frequency and severity of injuries that can occur on both synthetic and natural grass fields. In general, the consensus findings from multiple studies have found that there are no consistent differences between the injury rates for natural and synthetic sport fields[1]. It's a fact that the field temperatures of synthetic fields, more specifically those with crumb rubber infill, can reach surface temperatures during hot summer days that far exceed the field temperatures of natural grass fields.   These higher levels can contribute to heat stress for those who are using the fields during those periods.   Thus for this risk category a maximum score of 5 was attribute to the synthetic fields with a corresponding lower value applied to the natural turf grass.

Overall, it can be seen from Figures 22 and 23 that the synthetic turf fields score higher in the risk category than any of the natural turf grass alternatives and significantly more than the turf grass fields with higher availabilities.

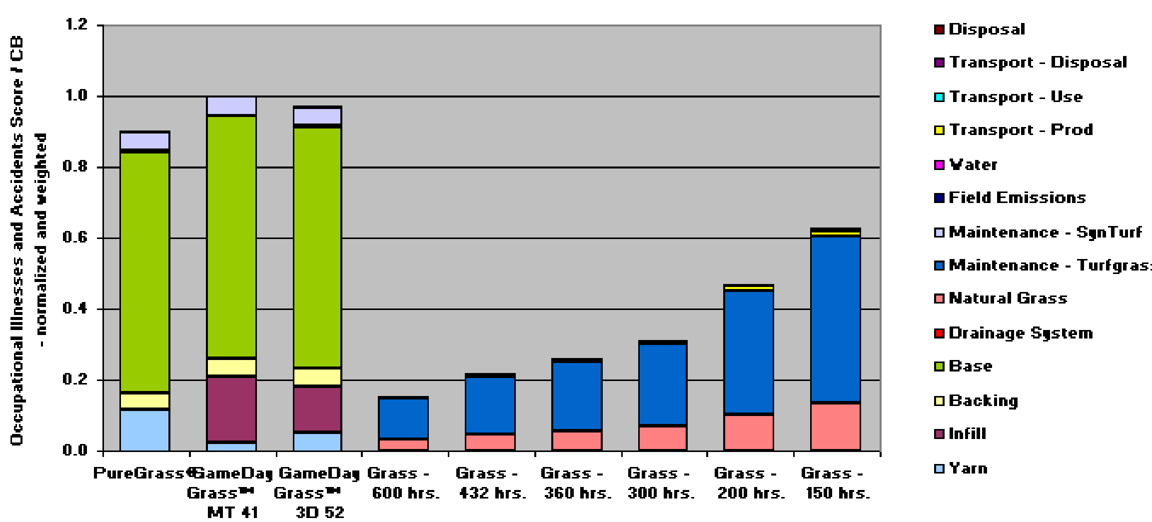

Figure 22. Occupational Illnesses and Working Accidents by Module

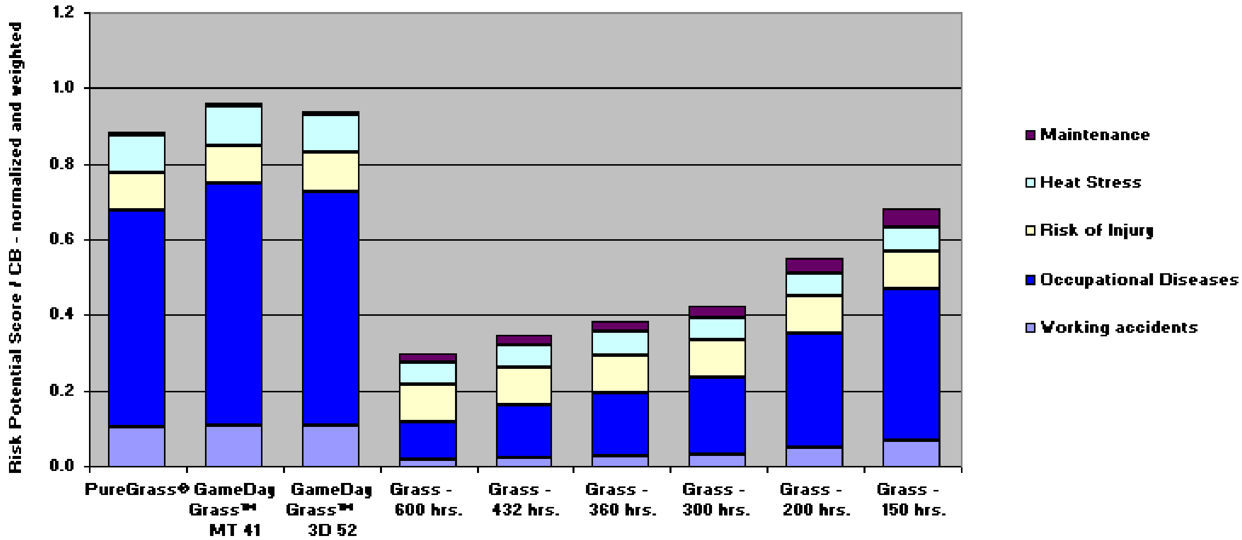

Figure 23. Risk Potential by Type

8.1.9. *Environmental fingerprint*: Following normalization, or normalization and weighting with regards to emissions, the relative impact for all six of the environmental categories for each alternative is depicted in the environmental fingerprint (Figure 24). PureGrass®, GameDay Grass™ MT 41 and GameDay Grass™ 3D 52 perform well in all categories except for occupational illnesses and accidents (risk). The natural grass alternatives have similar environmental profiles with the natural grass alternatives which have the lowest availability to hold events and thus requiring more land area to perform the same customer benefit having the higher impact. Conversely, the natural grass alternatives with availabilities similar to the synthetic turf fields show low environmental impact in all categories and in some cases having lower impact than the synthetic turf alternatives. Considering all alternatives (and thus the full range of availabilities for natural grass including an availability identical to synthetic turf, which by many expert opinions is not realistic), the leading alternative in the environmental impact areas of resource consumption (key impact for the study), emissions (air, water, solid waste) and land use was synthetic turf. In the impact areas of energy consumption, toxicity potential and risk, natural turf grass had the leading alternative. In summary, in order to have an equivalent overall environmental impact, it is not necessary for the natural grass alternative to achieve the same availability as the synthetic turf field. For the base case analysis, the synthetic turf fields have equivalent overall environmental impact (on a weighted basis) to a natural turf field that has approximately 420 hours of availability / year. Thus, if the natural turf field achieves an availability less than around 420 hrs/year the synthetic turf field would have a lower overall environmental impact and if the natural turf grass can achieve an availability greater than 420 hrs./year than it would have a lower overall environmental impact than the synthetic turf alternative.

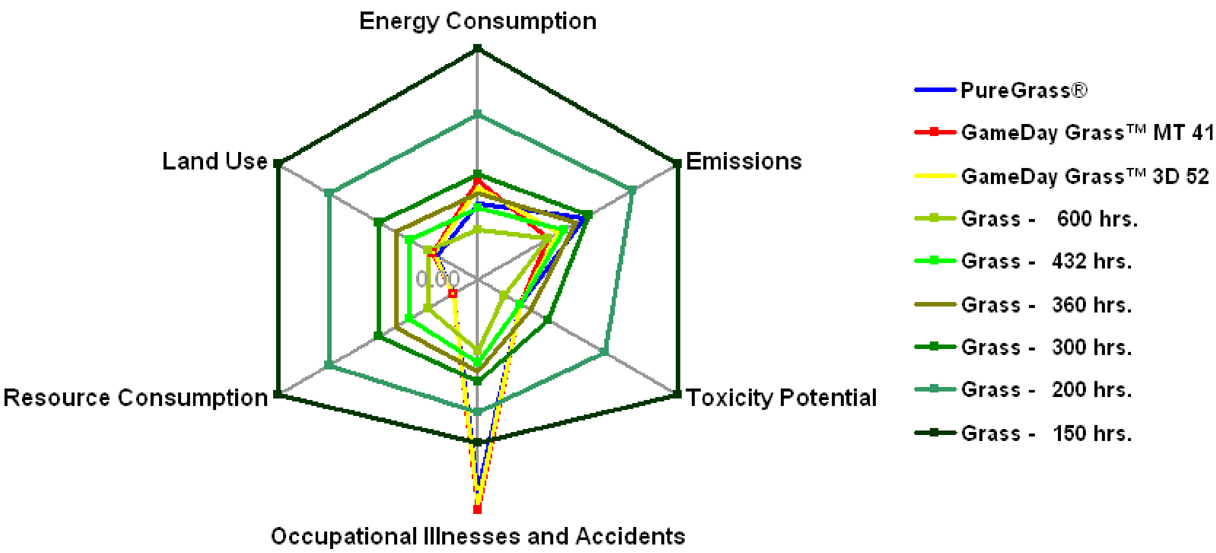

Figure 24. Environmental fingerprint.

8.2. *Economic Cost Results*: The life cycle cost data for the Synthetic Turf eco-efficiency analysis are generated as defined in Section 7 of the BASF EEA methodology. The results of the life cycle cost analysis, which was based on a "point in time analysis", found that the three synthetic field alternatives had quite similar life cycle costs with PureGrass® having the slightly lower cost. Presented in an often communicated metric for synthetic fields, cost per event, the range for the synthetic fields analyzed in this study was on average $380/event which compares favorably with historical data tracked by General Sports Venue, a subsidiary of AstroTurf®. The life cycle breakdown for synthetic turf is approximately 70% installation costs, and 15% each for maintenance and disposal costs. The installation costs defined in Table 13 do take into consideration the required re-installation of the synthetic fields as required by their respective life expectancies as defined in section 6.3.2 (field durability).

Obviously, the life cycle costs for the natural turf grass field will depend on the availability of the field. For the full range of availabilities considered the life cycle costs ranged from $240 - $980 / event. Looking at the midpoint value for the natural turf alternatives (300 – 360 hrs/year) which best reflects reasonable availability for turf grass that takes into consideration a wide range of regional as well as specific municipality/school system requirements, the average life cycle cost averaged around $440/event, over 15% higher than the corresponding synthetic turf alternatives. Reviewing the cost break down for the natural turf grass fields indicate that the installation and maintenance costs over the life cycle are much more similar than for the synthetic turf fields with the maintenance costs being the major contributor, almost 55% of the total cost. Table 12, Table 13 and Figure 25, summarize the life cycle cost contributors for the alternatives considered in this study.

Table 12: Life cycle costs for Synthetic Turf

LIFE CYCLE COSTS		PureGrass® 600 hrs.	GameDay Grass™ MT 41 600 hrs.	GameDay Grass™ 3D 52 600 hrs
Installation	$/CB	$1,012,500	$1,012,500	$1,054,167
Maintenance	$/CB	$234,000	$264,313	$240,944
Maintenance	$/year	$11,700	$13,216	$12,047
Transport & Fuel Cost	$/CB	$25,546	$28,927	$27,959
Disposal Total Landfill costs	$/CB	$210,000.00	$225,000.00	$225,000.00
TOTAL ($/CB)		$1,482,046	$1,530,740	$1,548,070
COST ($/event)		$371	$383	$387

Table 13: Life cycle costs for Natural Turf Grass

LIFE CYCLE COSTS		Natural Grass 600 hrs.	Natural Grass 432 hrs.	Natural Grass 360 hrs.	Natural Grass 300 hrs.	Natural Grass 200 hrs.	Natural Grass 150 hrs.
Installation	$/CB	$393,750	$546,875	$656,250	$787,500	$1,181,250	$1,575,000
Maintenance	$/CB	$525,000	$729,167	$875,000	$1,050,000	$1,575,000	$2,100,000
Maintenance	$/year	$26,250	$36,458	$43,750	$52,500	$78,750	$105,000
Transport & Fuel Cost	$/CB	$41,913	$61,639	$76,904	$96,514	$163,804	$243,783
Disposal Total Landfill costs	$/CB	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL ($/CB)		$960,663	$1,337,681	$1,608,154	$1,934,014	$2,920,054	$3,918,783
COST ($/event)		$240	$334	$402	$484	$730	$980

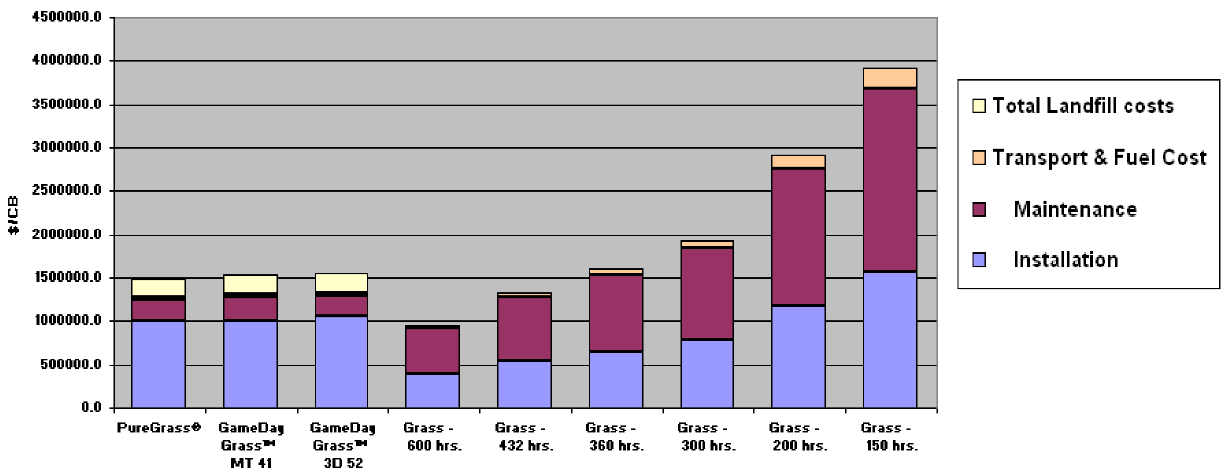

Figure 25. Life cycle costs.

8.3. *Eco-Efficiency Analysis Portfolio*: The eco-efficiency analysis portfolio for the Synthetic Turf eco-efficiency analysis has been generated as defined in Section 9.5 of the BASF EEA methodology. Utilizing regionally specific relevance factors and calculation factors, the relative importance of each of the individual environmental impact categories are used to determine and translate the fingerprint results (Figure 24) to the position on the environmental axis for each alternative shown. Figure 26 displays the eco-efficiency portfolio, which shows the results when all six individual environmental categories are combined into a single relative environmental impact and combined with the life cycle cost impact. Because environmental impact and cost are equally important, the most eco-efficient alterative is the one with the largest perpendicular distance above the diagonal line. The results from this study find that the natural turf grass alternative that can support 600 hrs/year of event activity (same availability as the synthetic turf alternatives) is the most eco-efficient alternative due to its combination of lower environmental burden and lowest life cycle cost. The natural turf grass alternative with the lowest availability (natural grass - 150 hrs/year of availability) is the least eco-efficient of the alternatives as it will require 4 times the amount of land and materials to achieve the customer benefit as the best natural turf grass alternative. The three synthetic turf alternatives are grouped together slightly behind the natural grass alternative that can support 432 hours/year of event activity and ahead of the natural turf grass alternative that can support 360 hrs./year of event activity.

Recreational Sports Field Eco-Efficiency Analysis

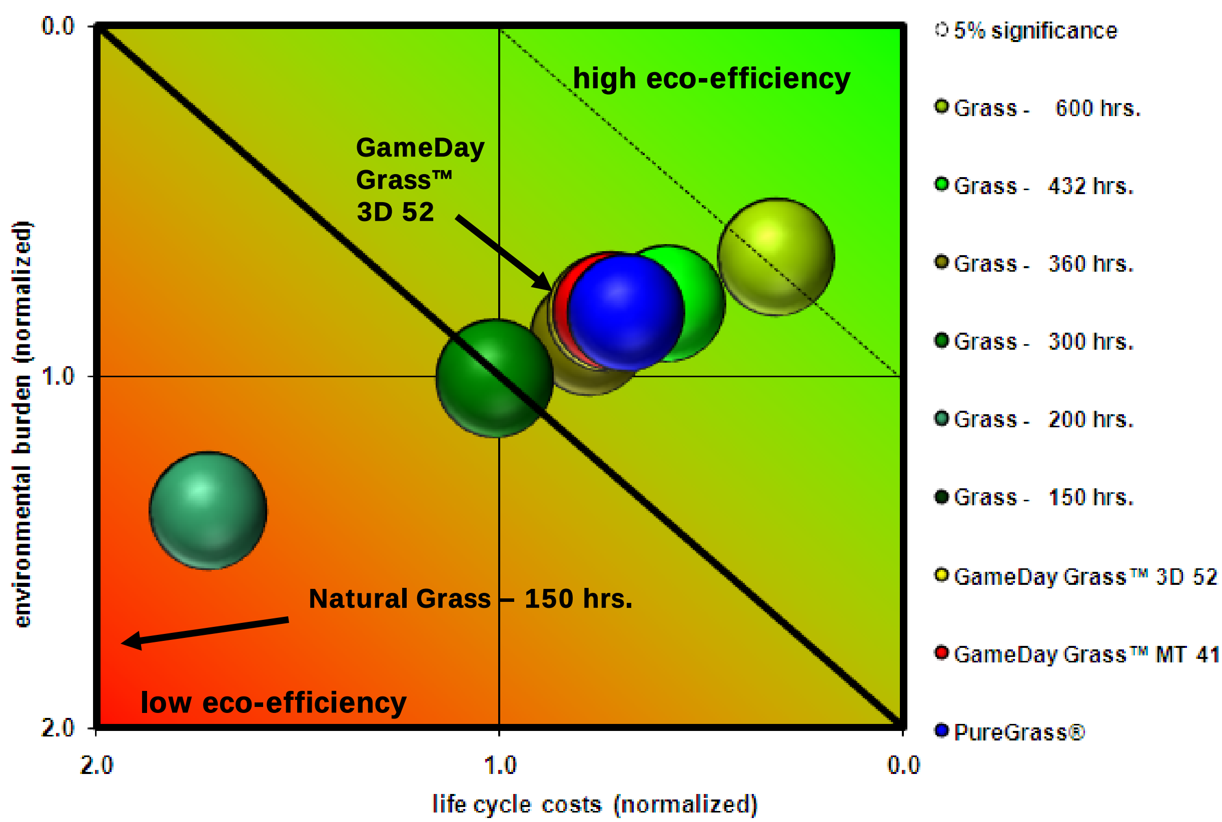

Figure 26. Eco-efficiency portfolio, base case analysis.

8.4. *Scenario Analyses*

8.4.1. Scenario #1: Comparison of synthetic turf fields vs. select natural grass alternatives

Though the broadest range of natural turf alternatives was presented in the base case analysis, the team felt based on their experiences and research that more realistic natural turf alternatives for comparison were the ones which can support between 200 – 360 hours of event activity/year relative to the synthetic turf basis of 600 hours/year. The results of this comparison is shown in Figure 27 and clearly shows for this comparison that the three synthetic turf alternatives are the most eco-efficient with PureGrass® (the best synthetic turf) having about a 20% advantage over the best natural turf grass alternative (360 hrs/year of availability). Clearly the synthetic turf alternatives have significantly reduced environmental impact over their life cycle along with lower life cycle costs when compared to the natural turf grass alternatives.

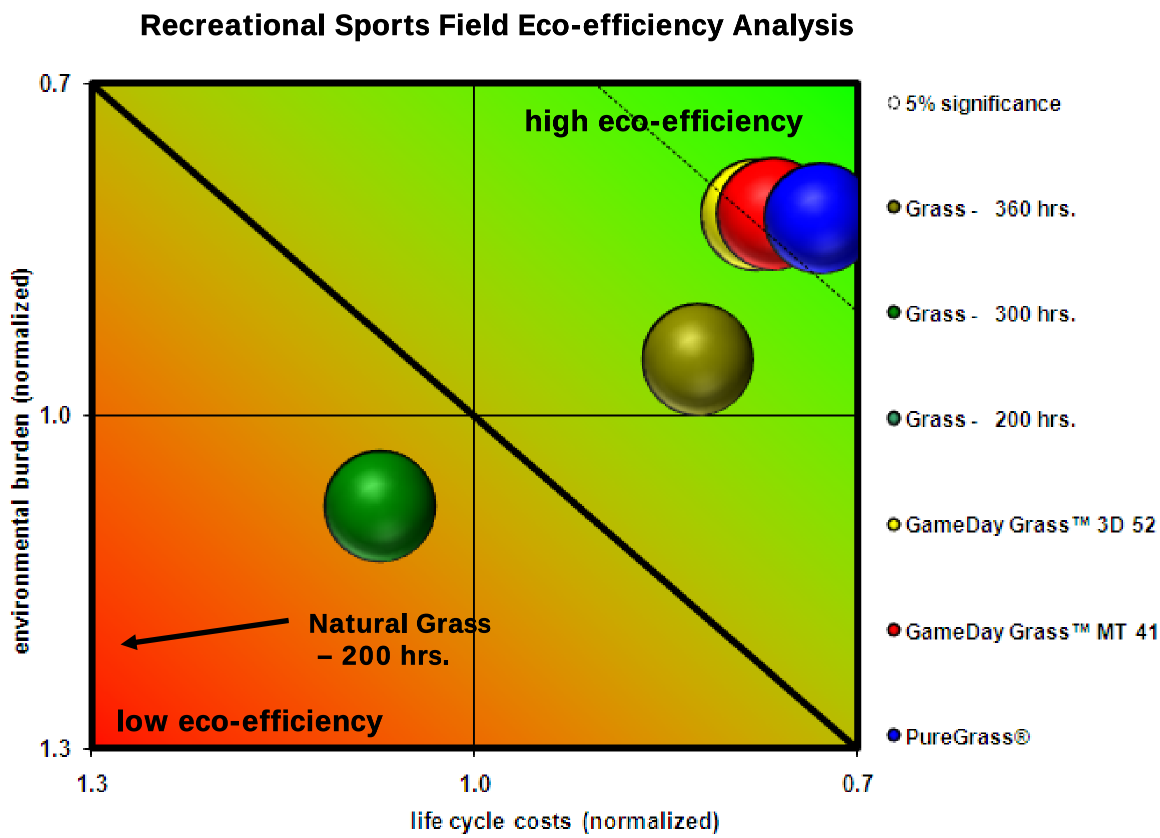

Figure 27. Scenario #1: Eco-efficiency portfolio for natural grass alternatives supporting 200 – 360 hrs/yr. of activity. (note scale change from base case analysis).

8.4.2. Scenario #2: Reduction in the maintenance costs for a natural grass field

As mentioned in section 6.2.1.2 (Maintenance costs) the base case assumption for maintenance costs for the natural grass alternatives was $0.35/ft^2. As maintenance costs can contribute significantly to the life cycle cost for a natural turf field, a sensitivity analysis was performed and an overall value of $0.20/ft^2 was used and was based on a University of Tennessee Extension publication[12]. As the field was only used for football, it can be expected that the costs, especially labor and materials, would be higher for a multi-purpose field that supported a significantly higher amount of events per year and would require more care and attention. The estimate was also based on 2004 costs and was not escalated to today's costs. Thus the figure was viewed as quite conservative.

As expected, and shown in Figure 28 below, with such a significant drop in the required maintenance costs, the natural grass alternatives improved their relative eco-efficiency by improving their life cycle costs. The synthetic turf alternatives eco-efficiencies lie between the 360 – 300 hrs/yr. of availability natural turf alternatives. The synthetic turf alternatives still have a lower environmental burden when compared to natural turf grass alternatives that support fewer than 400 hours of activity / year. Synthetic turf life cycle costs are equivalent to the natural grass alternative that supports 300 hours of activity per year.

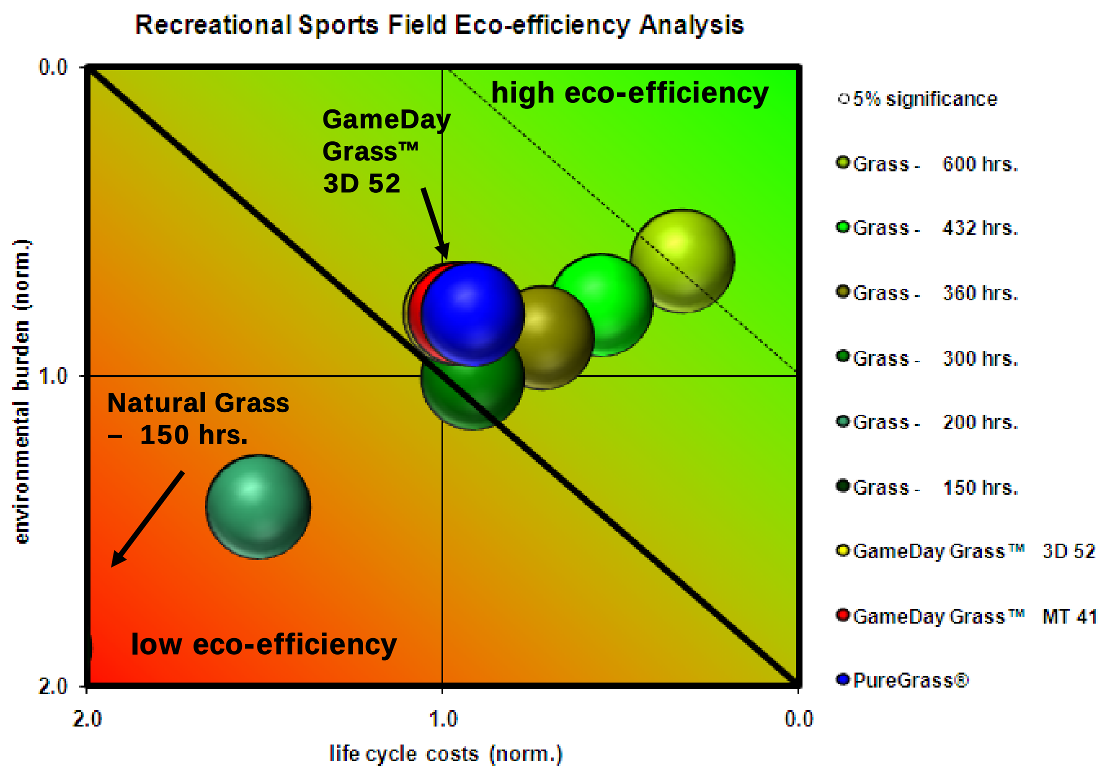

Figure 28. Scenario #2: Eco-efficiency portfolio for the reduction in natural grass maintenance costs to $0.20/ft^2

8.4.3. Scenario #3: Reduction in the recommended maintenance activities for natural grass

The recommended maintenance activities (as specified earlier in Table 8) for the natural turf grass alternatives were reduced by 25% and the results are depicted in Figure 29. This amount of change may affect the overall quality and performance of the field and thus the number of hours of activity that can be supported; however, for this analysis no adjustment was made to the base case assumptions related to availability. Compared to the base case, only a slight improvement was noticed for the natural turf alternatives. Based on the overall study findings of the important role hours of availability plays in the final results, if the reduction in maintenance activities were to have a negative effect on the hours of availability any small environmental benefit this yielded would be far outweighed by the increasing life cycle costs and environmental impact required to install and maintain a larger amount of recreational fields.

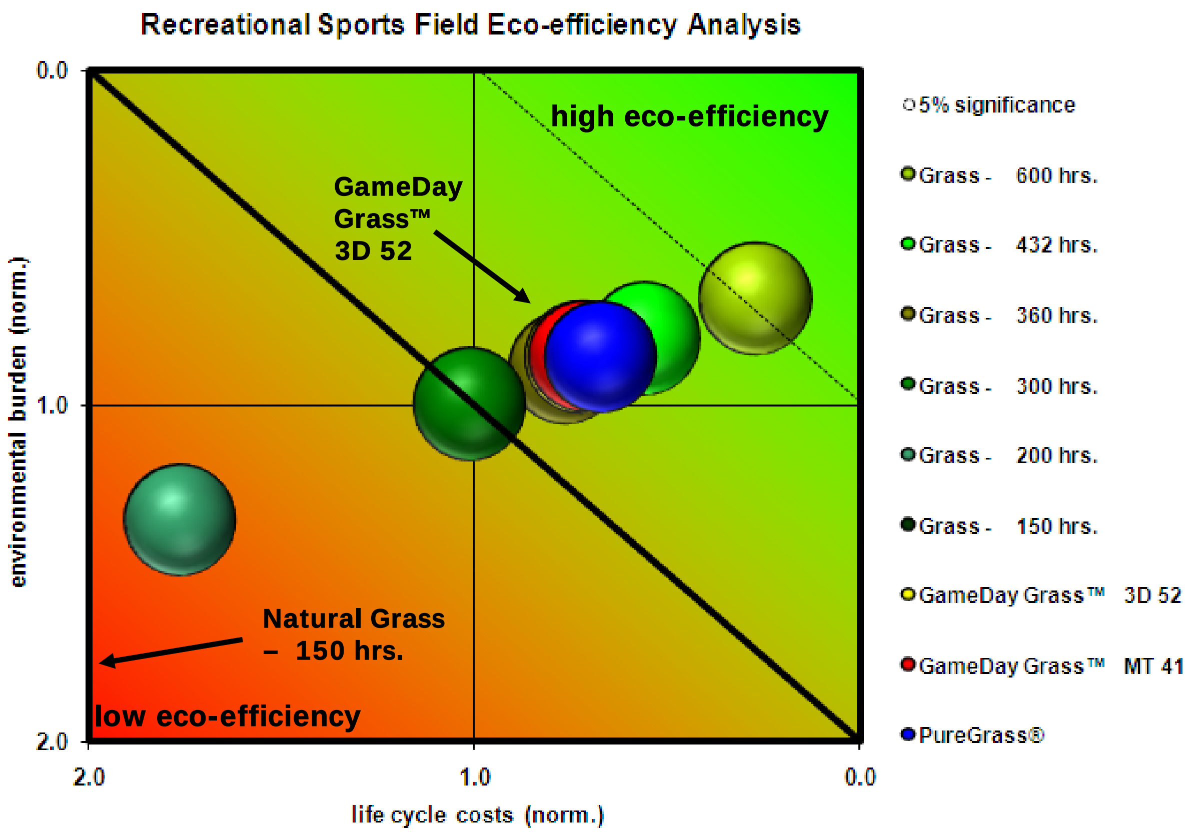

Figure 29. Scenario #3: Eco-efficiency portfolio for the reduction in natural grass maintenance requirements

8.4.4. Scenario #4: Comparison of only synthetic turf alternatives

Figure 30 depicts the eco-efficiency portfolio when only the synthetic field alternatives were considered. All alternatives lie within the 5% significance interval for the study so all alternatives would be viewed as having similar eco-efficiencies. PureGrass® despite its higher installation and replacement costs has about a 3% and 5% life cycle cost advantage relative to the GameDay Grass™ MT 41 and GameDay Grass™ 3D 52 alternatives respectively.

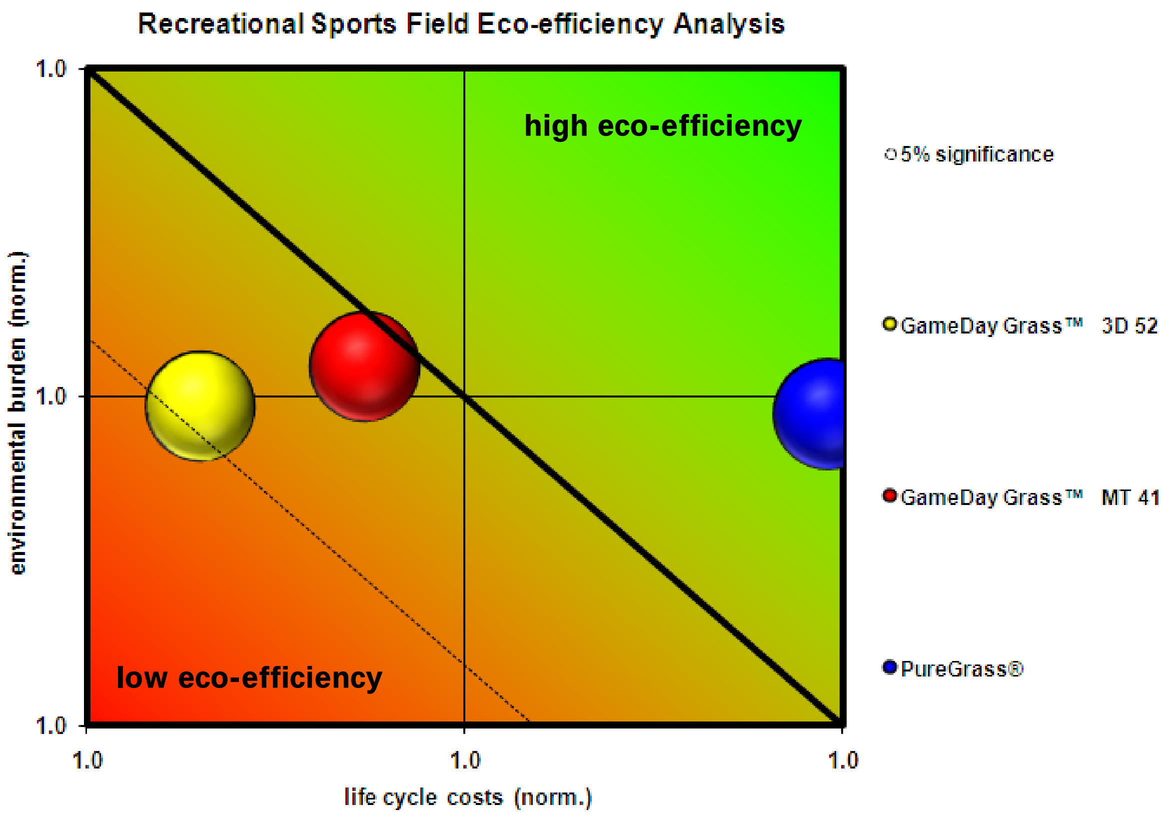

Figure 30. Scenario #4: Eco-efficiency portfolio for only synthetic turf alternatives. (note scale change from base case analysis)

8.4.5. Scenario #5: Increase in durability of synthetic turf fields by 10%

Increasing the standard durability of the synthetic turf fields, as established in section 6.3.2, will benefit these alternatives by not only reducing the overall life cycle cost (e.g. less replacements required over the 20 year lifetime considered) but also having an impact in reducing the overall environmental impact as fewer materials would be required in order to fulfill the defined customer benefit. Figure 31 shows that the relative eco-efficiency of the three synthetic field alternatives improves by approximately 10% when the durability is improved by a similar amount. The relative eco-efficiency of the synthetic field alternatives approaches the natural grass having 432 hrs/year of availability.

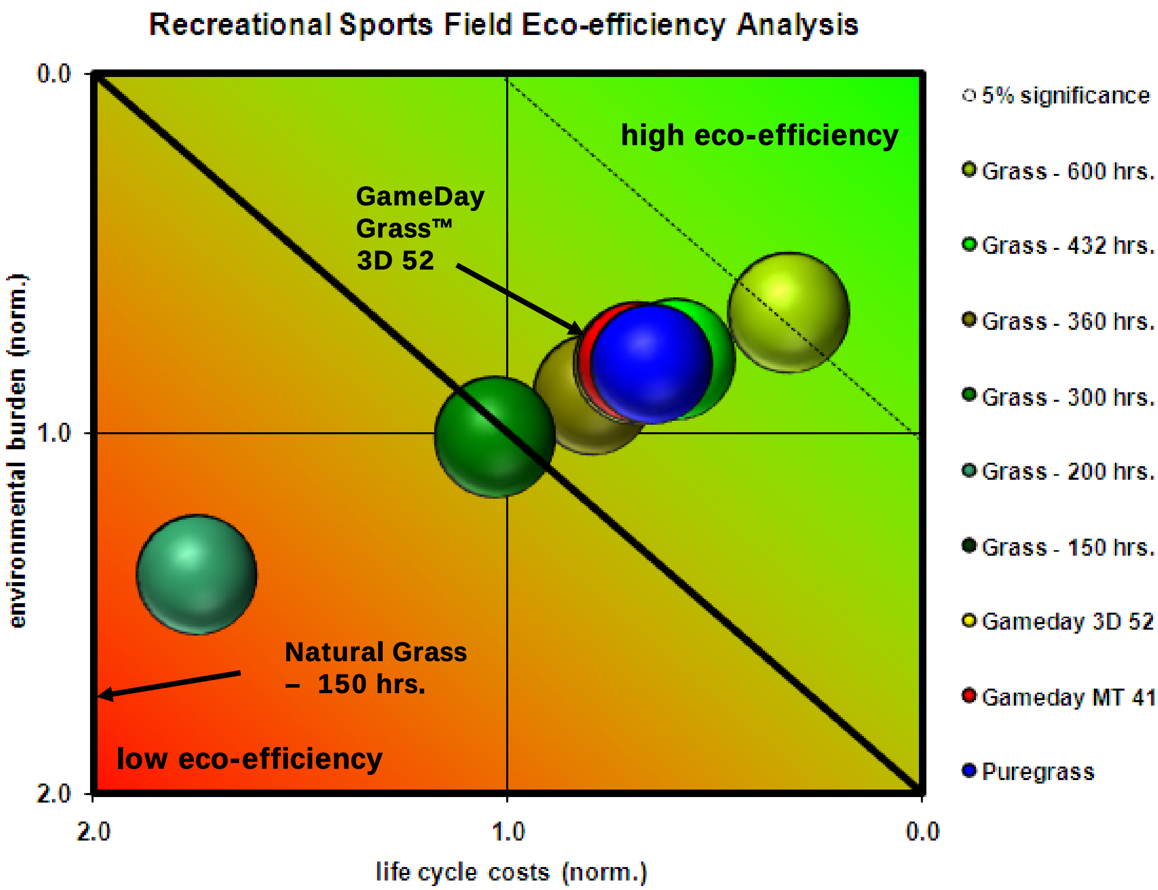

Figure 31. Scenario #5: Eco-efficiency portfolio for increased durability for synthetic turf

8.4.6. Scenario #6: Elimination of land emissions impacts and credits for natural grass

When the CO_2 sequestration benefit and the direct and indirect emissions to air and water resulting from the use of N-based fertilizers are removed from consideration for the natural grass alternatives, Figure 32 shows that the effect is only a slight eco-efficiency improvement for the natural turf grass alternatives. This indicates that the negative impact from the emissions related to the use of fertilizers is almost as significant as the benefits related to the ability of natural grass to reduce greenhouse gas emissions. The synthetic turf alternatives still maintain their same relative eco-efficiency position in comparison to the base case.

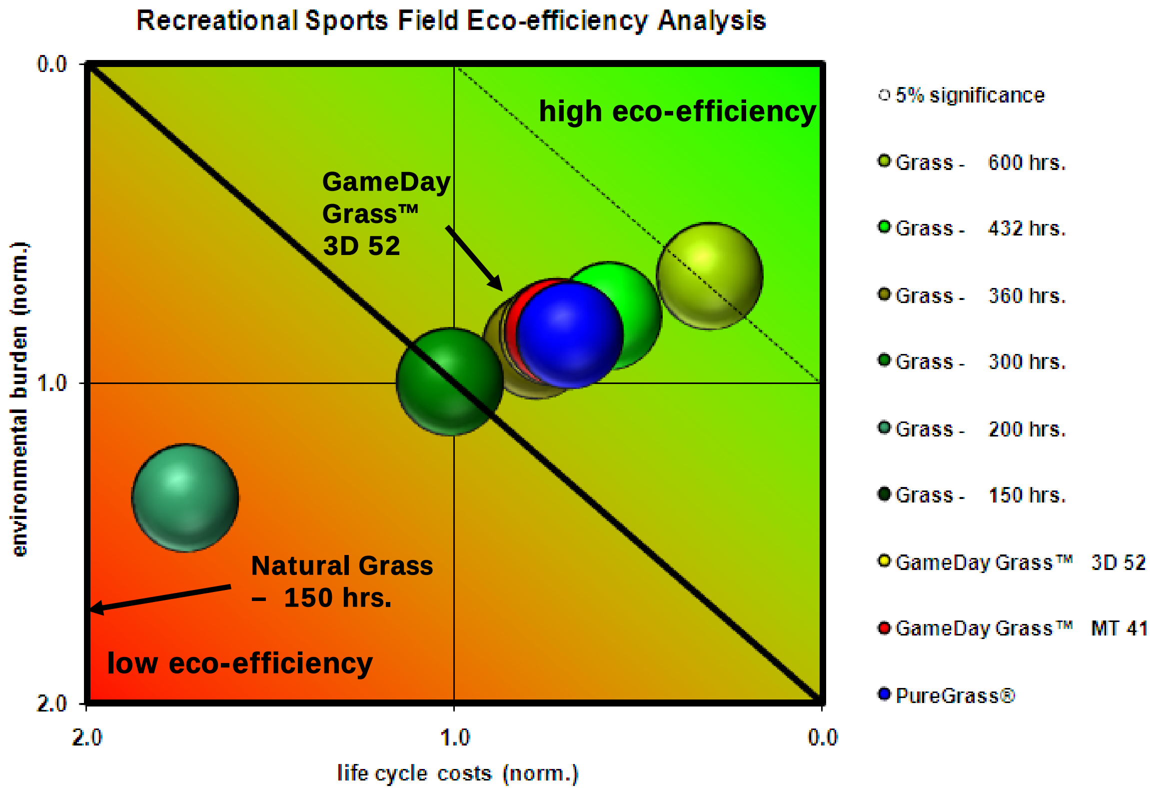

Figure 32: Scenario #6: Eco-efficiency portfolio reflecting no field emissions – credits for natural grass

9. Data Quality Assessment

9.1. *Data Quality Statement*: The data used for parameterization of the EEA was sufficient with most parameters of high or medium-high data quality, which means the data was specific to this study context and goals. Moderate data is where industry average values or assumptions pre-dominate the value. No critical uncertainties or significant data gaps were identified within the parameters and assumptions that could have a significant effect on the results and conclusions. The sensitivities analysis section addresses how moderate or reasonable changes to key project parameters and assumptions will affect the final results. Eco-profiles utilized were deemed of sufficient quality and appropriateness considering both the geographic specificity of the study as well as the time horizon considered. Table 14 provides a summary of the data quality for the eco-efficiency analysis.

Table 14: Data quality evaluation for EEA parameters.

Parameter	Quality Statement	Comments
Synthetic Field		
Material Composition	High	AstroTurf® & Material Suppliers
Amount of Materials	High	AstroTurf®
Durability	Med-High	AstroTurf® & Trade Association data
Maintenance Activities – Costs	Med-High	AstroTurf®
End-of-Life Impacts	Med-High	AstroTurf®
Crumb rubber mfg	Mod	Manufacturing & Trade Association data
Natural Grass		
Establishment data	High	The University of Tennessee Institute for Agriculture – Guidelines
Maintenance Requirements	High	The University of Tennessee Institute for Agriculture - Guidelines
Field Emissions data	Mod	Recommendations from IPCC and external articles
Costs	Mod	STMA literature; external articles / publications
Transportation Distances	Mod	Manufacturer data – team estimate

10. Sensitivity and Uncertainty Analysis

10.1.1. *Sensitivity and Uncertainty Considerations:* A sensitivity analysis of the results indicates that the impact with the highest environmental relevance (Figure 33) was resource consumption followed by toxicity potential. These results were expected and can be attributed to the type and large quantities of materials required to establish and maintain the fields over their life cycles. The calculation factors, which considers both the social weighting factors and the environmental relevance factors, and shown in Figure 35 indicate which environmental impact categories were having the largest affect on the outcome as reflected in the portfolio. The impacts with the highest calculation factors were the same as those with the highest environmental relevance factors, which is often the case. The input parameters that were related to these impact categories have sufficient data quality to support a conclusion that this study has a low uncertainty.

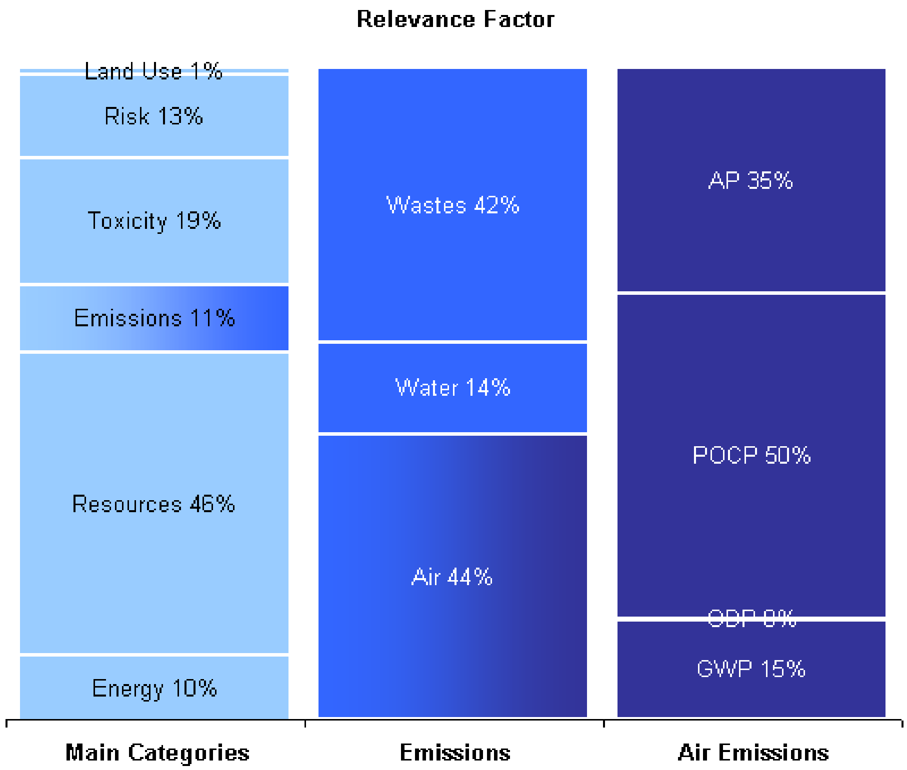

Figure 33: Environmental Relevance Factors – base case analysis

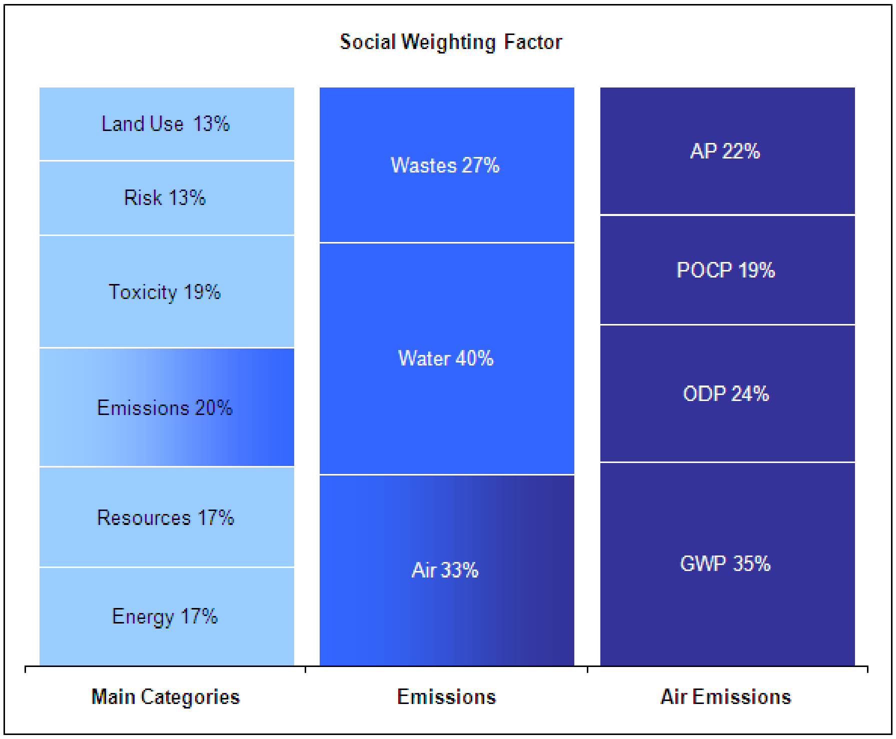

Figure 34: Social Weighting Factors – base case analysis

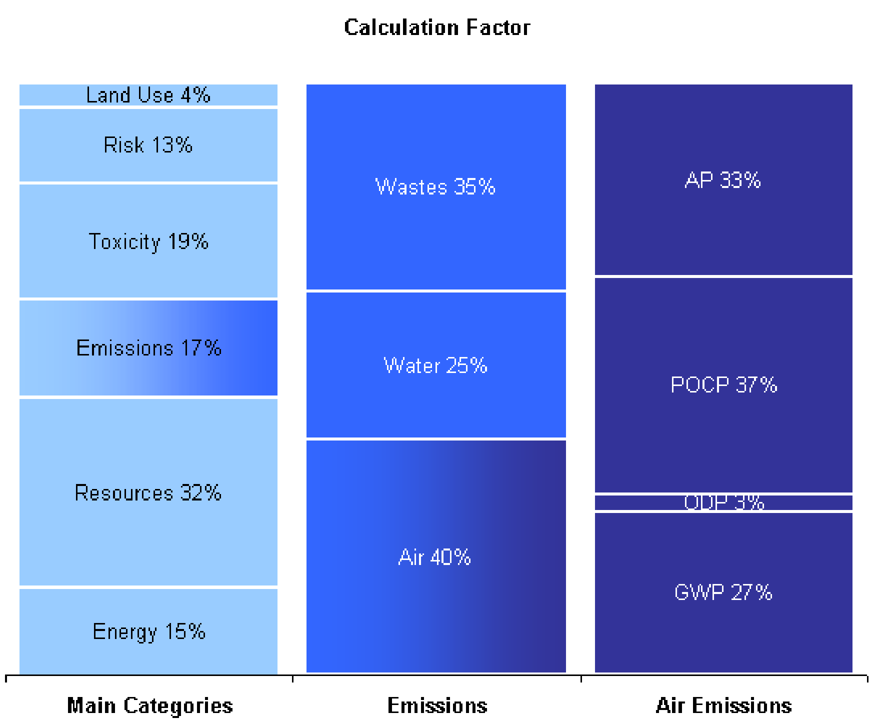

Figure 35. Calculation Factors – base case analysis

As mentioned in the study goals, this analysis was objective in the way it presented the results related to the key project assumption of the availability of natural turf grass field. By incorporating a broad range of availabilities into the base case alternatives considered, stakeholders and reviewers of the report will be able to interpret the results of the study in the context of their specific requirements and experiences. By presenting a broad spectrum of possible availabilities for the natural grass alternatives (high and low) as opposed to just selecting one or two values, the quality and robustness of the study's final results and conclusions are strengthened.

10.2. *Critical Uncertainties:* There were no significant critical uncertainties from this study that would limit the findings or interpretations of this study. The data quality, relevance and sensitivity of the study support the use of the input parameters and assumptions as appropriate and justified. The choice of alternatives for natural turf grass helped eliminate the uncertainty around having to choose one value that would adequately represent a natural grass field over a multitude of applications.

11. Limitations of EEA Study Results

11.1. *Limitations*: These Eco-efficiency analysis results and its conclusions are based on the specific comparison of the production, use, and disposal, for the described customer benefit, alternatives and system boundaries. Transfer of these results and conclusions to other production methods or products is expressly prohibited. In particular, partial results may not be communicated so as to alter the meaning, nor may arbitrary generalizations be made regarding the results and conclusions.

12. References

1. N.Y. State Department of Health. FACT SHEET: Crumb-Rubber Infilled Synthetic Turf Athletic Fields, August 2008. http://www.health.state.ny.us/environmental/outdoors/synthetic_turf/crumb-rubber_infilled/fact_sheet.htm
2. Natural and Synthetic Turf: A Comparative Analysis. A report prepared by Lemar Morrison for the San Francisco Recreation and Parks Department December 20, 2005 http://www.cityfieldsfoundation.org/Comparison_fieldturf.pdf
3. Osseo Minnesota School District (ISD 279). Synthetic Turf Fact Sheet Feb 19, 2009
4. The University of Tennessee Institute for Agriculture – UT Extension Turf Grass Establishment and Maintenance Guidelines. http://tennesseeturf.utk.edu/default.htm
5. A Guide to Synthetic and Natural Turfgrass for Sports Fields. Selection, Construction and Maintenance Considerations. 2nd Edition. Sports Turf Managers Association 11/2008.
6. Cost Analysis comparing Natural Grass and Synthetic Turf. Brad Fresenberg. University of Missouri. http://cafnr.missouri.edu/research/turfgrass-costs.php
7. Estimating the Required Global Warming Offsets to Achieve a Carbon Neutral Synthetic Field Turf System Installation. Jamie Meil, Lindita Bushi Athena Institute
8. IPCC (Intergovernmental Panel on Climate Change) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 11: N_2O Emissions from Managed Soils and CO_2 emissions from Lime and Urea Application, Table 11.3 2006

9. Boustead Consulting Ltd UK, The Boustead Model 5.1.2600.2180 Life Cycle Inventory Database.
10. Managing Sport Facilities 2nd Edition, Author: Gil Fried Publisher: Human Kinetics; December 15, 2009; page 137
11. AstroTurf® and General Sports Venue Press Release. May 7, 2008 http://www.astroturfusa.com/Science-behind-Safety.aspx
12. The University of Tennessee Institute for Agriculture – UT Extension Publication SP651 www.utextension.utk.edu/publications/spfiles/SP651.pdf
13. Synthetic Turf Council website. Frequently Asked Questions (FAQ) http://www.syntheticturfcouncil.org/displaycommon.cfm?an=1&subarticlenbr=64
14. Michigan State University Extension – Department of Crop and Soil Services. "Sand Cap Build-up Systems for Michigan High School Fields" A.R. Kowalewski, J.N. Rogers III and J.R. Crum. www.turf.msu.edu/assets/ArticlePDFs/E0007TURF.pdf
15. Sports Turf Managers Association (STMA) Literature. Natural Grass Athletic Fields brochure. Pg. 11 MSU synthetic field maintenance budget details 2004-2005