

Final Report

An Environmental Assessment of the Australian Turf Industry with a Lifecycle Assessment

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TU16000

Project:

An Environmental Assessment of the Australian Turf Industry with a Lifecycle Assessment TU16000

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Summary

Infotech Research was engaged by Hort Innovation to undertake an environmental assessment of the Australian turf industry and produce a lifecycle assessment of turf. The first aspect of the project was achieved by assessing 30 turf growing sites around Australia and producing environmental benchmarks to assist the industry. The participating turf growers received a report providing useful efficiency benchmarks that relate to environmental outcomes and an assessment of their own site, which enabled comparison of their site's key environmental performance indicators with the others studied. This information was collated in a benchmarking report, which can be utilised by growers outside the study who can undertake their own measurements and make the same comparisons.

The highlights from the benchmarking report and turf growing site assessments were used to produce the following four case studies:

- ***Energy Efficiency Saves***
- ***Lilydale Instant Lawn***
- ***Environmental Controls***
- ***The Carbon Footprint of Turf***

The case studies are based on examples of good industry practice and cover key environmental issues, such as energy and water efficiency, mitigating impacts with safe waste disposal, appropriate environmental controls and Greenhouse impacts of turf growing.

The lifecycle assessment phase of the project involved a review of five turf installation sites over one year. The lifecycle assessment results indicate that a well maintained patch of turf is environmentally healthy, conserves natural ecosystems and will continue to sequester carbon dioxide from the atmosphere through the growth of soil organic matter. From the lifecycle assessment, the project produced an industry generic Environmental Product Declaration (EPD), in line with ISO 14025. Once independently verified, the EPD can be used by the industry to declare its environmental performance to its customers, who increasingly want to know that they are buying environmentally conservative products.

The project has made the following key recommendations for the industry:

1. The turfgrass industry can promote its action against climate change
2. Turf growers can be good environmental custodians
3. The turf product has no end-of-life waste disposal problems
4. Recovering run-off and avoiding losses of chemicals used are necessary environmental controls for turf growers
5. Growers can continuously improve their performance by measurement and goal setting
6. Efficiency of turf growing equals care for the environment (Less is More)
7. Data sharing through continuing benchmarking helps the whole industry.

The natural turf industry has a good story to tell.

Keywords

Environmental assessment; Benchmarking; Lifecycle assessment (LCA); Environmental Product Declaration; Turf growing; Lawn maintenance; Australia; Carbon footprint.

Introduction

The environmental impacts and benefits of turfgrass are important as turf represents the largest area of horticultural land in Australia. Lawn is said to exceed the area of land put to crops. Turf's environmental credentials have suffered from the impacts of fertiliser use and watering, together with energy used in mowing perceived as key negatives.

In October 2016, Hort Innovation engaged Infotech Research to conduct an environmental assessment of turf. This was aligned with the objectives of the turf industry's then Strategic Investment Plan 2012-2017, of increased grower business capability and environmental sustainability. The clear link is through the use of environmental performance measures enabling the industry to improve its sustainability. The industry will have a greater ability to understand and control environmental impacts, at the same time it will have measures to improve resource efficiencies that will save wastes and improve profitability.

The project also has relevance to Hort Innovation's objectives to build strength in the horticultural industries and to develop industry capacity, as well as its *20/2020 Vision* aim to promote the environmental benefits of more green spaces.

In a wider context, the project aims are consistent with national natural resource management principles and practices of environmental protection from a global as well as a local perspective. It is with better knowledge of environmental impacts that the turf industry will be able to plan and adapt management of operations to reduce environmental impacts and provide an improved outcome for natural resource maintenance.

The overall objective of this project was to provide the turf industry with a solid understanding of its environmental performance and ways with which it could improve this without compromising individual business positioning. In February 2017, the study scope was extended to include a full lifecycle study of turf installations to provide a lifecycle assessment (LCA) for the turf industry.

The project sought the following outcomes:

- a) An understanding by the industry of its environmental performance numerically benchmarked against best practice
- b) A set of performance improvement opportunities expressed in a report and within a set of case studies
- c) Recommendations for improved coverage of environmental issues by the turf industry
- d) A full lifecycle assessment of turf that includes the major applications of turf and
- e) A draft Environmental Product Declaration (EPD) for the environmental impacts of turf as an industry generic EPD.

The lifecycle data and EPD assist growers to explain the environmental benefits of turf to the marketplace. This information is sought by environmentally sensitive segments of the market, in particular local government and building owners, looking to gain Australian Green Building Council star ratings for buildings and projects. The lifecycle assessment was produced to provide the industry with data on its *cradle to grave* environmental impacts, which can be used to inform clients about the sustainability of turf installations and to derive EPDs in accordance with the ISO 14025 method.

Methodology

Conditions for turf growing in Australia vary from temperate to tropical climates and pure sand soils to heavy, peaty clays. There are approximately 250 commercial turf growers with farms that range from 300 Ha to 10 Ha or less. This study aimed to cover the differing conditions experienced at growing sites and engage with turf growers from all states. The project was conducted in two phases. The first involved engaging turf growers to participate in the project and receive an individualised report on the environmental efficiency of their growing practices. This information was then used to create a series of environmental benchmarks for the growers and the industry at large, as well as four case studies referencing good industry practice.

The second phase involved studying five turf installation sites over a year to complete a lifecycle assessment of turf and an industry generic Environmental Product Declaration, in line with the requirements of ISO 14025.

Phase 1- Environmental Assessment of turf growing sites

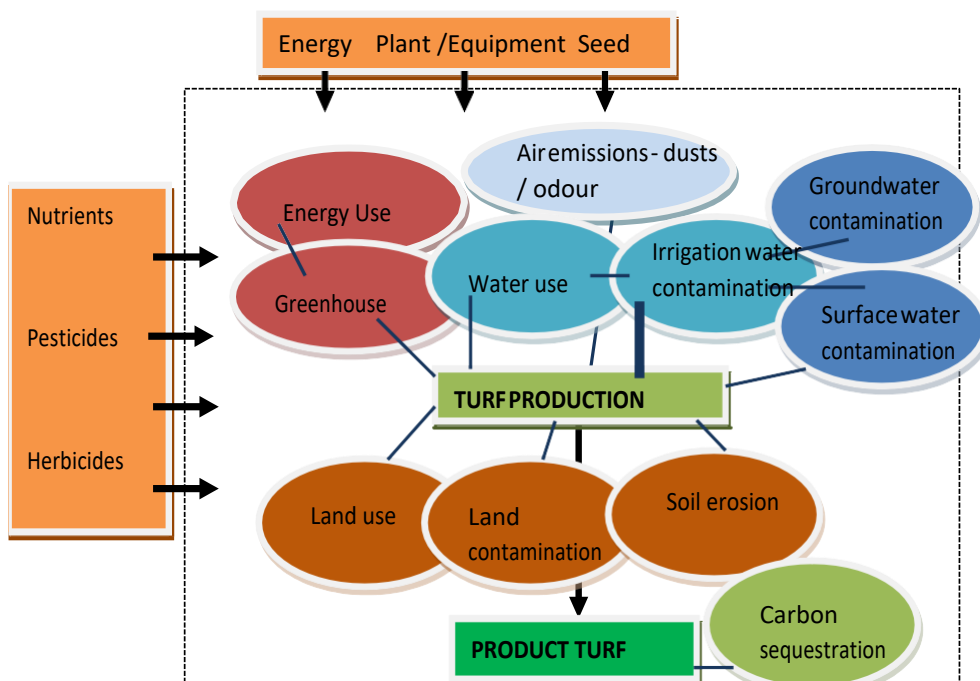
The project involved participation by a representative sample of 30 growing sites around Australia. Of the 30 sites, 28 were physically visited to gather environmental performance data, with two sites providing information remotely. Six of the growing sites were examined intensively, to gain a more detailed understanding of the incorporation of input materials in the product turf and to gauge losses of inputs to the soil, atmosphere, run-off and to groundwater. The remaining 24 sites had a lower level of assessment.

Growing sites were subject to an input-output analysis, in which the materials and energy inputs were measured or data was collected from purchasing records over two financial years, 2015-16 and 2016-17, to allow for year to year variations. The only output that was measured directly was the product turf and the rest of the outputs were deduced from the equation:

For each key material: $\text{MATERIAL LOSS (mass)} = \text{INPUT (mass)} - \text{PRODUCT (mass)}$

and efficiency was calculated as: $\% \text{ MATERIAL EFFICIENCY} = (\text{MATERIAL IN PRODUCT}) / \text{INPUT} \times 100\%$

In addition, the material loss was estimated as a split between air, land, run-off and groundwater from the intensive grower studies.



Inputs and outputs examined in the grower environmental assessment

Water for irrigation was read from water meters, when available, and estimated from electrical energy used and pump efficiencies determined on site by power and flow rate measurements.

Soil samples were taken at 0-10cm, 11-30cm, 31-50cm and 51-100cm collected at four sites from growers to gather an understanding of soil conditions and nutrient buildup.

At six growing sites a more intensive investigation was undertaken, in which 16 soil sampling sites were used in four different turf growing areas and a set of turf product samples were also taken for analysis.

These samples were analysed by Phosyn Laboratories for a standard array of parameters including nutrients, pH, organic carbon, cations and anions. The product turf was analysed for the same nutrients, leaf matter and soil on a dry basis.

From this data material efficiencies for turf growers were calculated and provided to each site with a report on the environmental efficiencies of their growing practices. This data was also used to produce a report for the industry containing benchmarking that indicated the most efficient practices and the distribution of efficiencies in a range of measures we have called Key Environmental Performance Indicators (KEPIs). The key efficiency indicators considered are given in the following table.

Production (m ² /Ha)	Production efficiency m ² per Ha under cultivation (100% efficiency = 10,000 m ² /Ha)
Pumping energy efficiency (kL/kWh)	Irrigation flow in kilolitres per kilowatt hour of energy consumed (electric pumps only)
Water use (Litre/m ²)	The number of litres of water irrigated per year for one square meter of turf produced
ML/Ha	The number of megalitres of irrigation water per Ha of farm
Fertilizer use (kg N/m ²)	Nitrogen application to the farm in kilograms divided by the production in m ²
(kg P/m ²)	Phosphorus application to the farm in kilograms divided by the production in m ²
(kg K/m ²)	Potassium application to the farm in kilograms divided by the production in m ²
Pesticide use (Formulated L/m ²)	Litres of pesticide and herbicide formulations per m ²
Energy use (Diesel L/m ²)	Litres of diesel used on the farm per m ²
(Electricity kWh/m ²)	Kilowatt hours of electricity consumed per m ²
(Total Energy MJ/m ²)	Total energy used (diesel plus electricity) in megajoules per m ²
Greenhouse emissions (kgCO _{2eq} /m ²)	Greenhouse emissions from energy and chemical products used on the farm per m ²
Net sequestered carbon in turf (kgCO _{2eq} /m ²)	Net Greenhouse emissions in the turf product per m ²

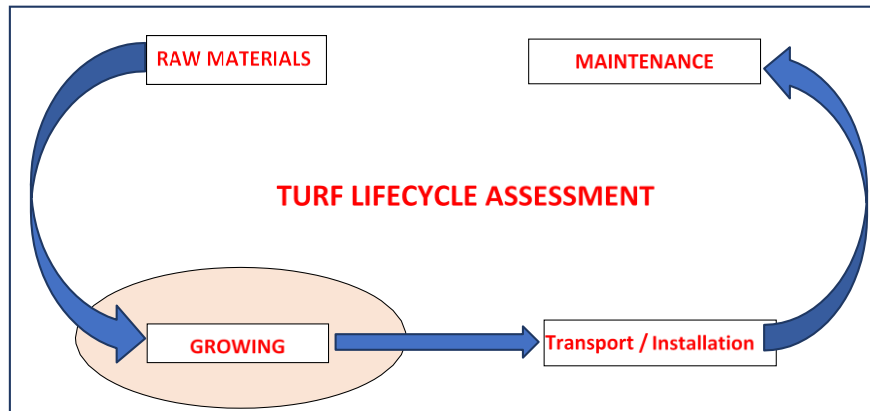
Table 1. Key Environmental Performance Indicators (KEPIs)

From the learnings of the Benchmarking report, the project produced a series of four case studies based on good environmental practices.

Phase 2- Lifecycle Assessment

The second stage of the project was to extend the study along the lifespan of turf through to transport of the product turf to the installation site, the installation and maintenance of the turf for one growing season.

Data on transport was collected from the growers as trucking fuel consumption with estimates of average trips to installation sites. We followed five installation sites of different types: a sports field, a lawn, a residential development and two golf course fairways. With the cooperation of the site owners, soil samples and turf product samples were taken at the time of installation and again after one growing season (Spring and Summer) until the major maintenance activities had stopped for the Winter.



The full lifecycle investigation

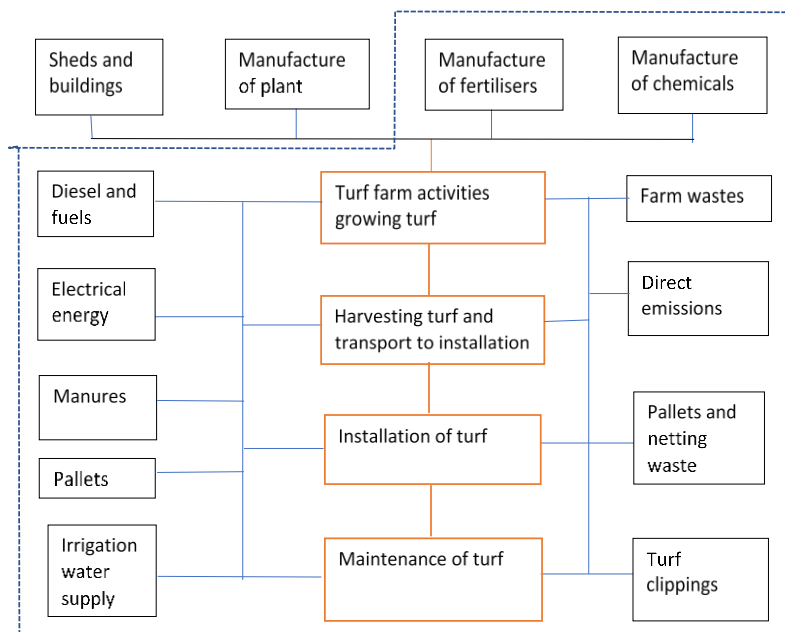
This installation study provided input materials and energy (as fuels) to complete the lifecycle of turf, on the assumption that the maintenance regime is maintained over the life of the turf.

Lifecycle assessments were undertaken with the use of the input and output data over the full lifecycle and expressed using a common functional unit.

FUNCTIONAL UNIT = 1 m² turf installed/year (1, 5 and 10 year default lifespans were used)

The impacts over the lifecycle were modelled using **Open LCA** modelling software and the lifecycle inventory database **ecoinvent** to convert material consumption and energy use data into environmental impacts. The LCA modelling was undertaken by Envisage Works.

A draft industry generic Environmental Product Declaration (EPD) was developed for two applications: sports turf and recreational turf. This EPD is in line with the requirements of ISO 14025 and conforms to a set of product category rules (PCR) that were produced by Infotech Research, to meet industry standards as gained in the grower study.



The boundaries of the Lifecycle assessment as defined in the Product Category Rules

In order for the EPD and PCR to comply with the standard ISO14025 for Type III Environmental Labels, the industry will have to be further consulted and the data and calculations independently verified. This work is outside the scope of the current study.

Outputs

The direct outputs of this project include:

1. Literature review
2. Benchmarking report
3. Individual and confidential environmental assessment reports provided to the owners of the participating turf growing sites
4. Four case studies:
 - a. Energy Efficiency Saves
 - b. Lilydale Instant Lawn
 - c. Environmental Controls
 - d. The Carbon Footprint of Turf
5. Goal and Scope report
6. Lifecycle Assessment Report (Attachment 1)
7. Industry generic Environmental Product Declaration (Attachment 2)
8. Product Category Rules (Attachment 3)

During the course of the project, we received the following references in Turf Australia publications:

Magazine articles:

1. 'Carbon sequestration: turf's big win' Spring 2018 Turf Industry Magazine, Turf Australia, p 18-20
2. Meham. L., 'Measuring the impact of turf on the environment', Summer 17/18 Turf Industry Magazine, Turf Australia, p 14-15

Mentions/project updates in the Turf Australia eNews on:

1. 9 February 2017
2. 22 February 2017
3. 5 April 2017
4. 16 May 2019

Applications have also been made to electronic media for turf environmental stories.

Outcomes

The initial phase of the project provided the owners of the 30 turf growing sites with an independent environmental assessment of their turf growing operations. In this environmental assessment the site's chemical, water and energy efficiencies were gauged, risks to the environment were assessed and opportunities for improvement were provided. Conditions of the soil and mass balances of the inputs with product and losses were provided over two years in a confidential report.

Key environmental efficiencies gained from these assessments were then compiled into benchmarking data for the whole industry to use and see where they fit within the industry. The benchmarking data was assembled into a report that demonstrated, in each category of benchmarking, wide variations in performance.

The median data for two years indicated consistent performance with variations of generally less than 10% between the two years. Comparison of the turf industry efficiency of resource usage with other industries is of limited value, as the production systems are quite different. In general, the turf industry comparisons with vegetable growing indicated approximate equivalence in water usage per Ha and pumping efficiencies, as similar technologies are used. When efficiencies such as water and total energy use per kg of plant matter were compared, turf was significantly less efficient.

Aggregated results	2015-16	2016-17	Source
Production (m ² /Ha)	5,990	6,655	Data provided ¹
Pumping energy efficiency (kL/kWh)		3.23	Measured
Water use (Litre/m ²)	1,098	1,013	Calculated
ML/Ha	6.7	6.1	Calculated
Fertilizer use (kg N/m ²)	0.043	0.051	Data provided
(kg P/m ²)	0.016	0.016	Data provided
(kg K/m ²)	0.018	0.024	Data provided
Pesticide use (Formulated L/m ²)	0.0018	0.0020	Data provided
Energy use (Diesel L/m ²)	0.11	0.14	Data provided
(Electricity kWh/m ²)	0.26	0.23	Data provided
(Total Energy MJ/m ²)	5.2	6.5	Calculated
Greenhouse emissions (kgCO ₂ eq/m ²)	0.50	0.52	Calculated
Net sequestered carbon in turf (kgCO ₂ eq/m ²)	-1.63	-1.63	Modelled

When the data was examined in detail, the variation between growing sites was much larger than 10%. In categories, such as land use efficiency, almost an order of magnitude variation was observed in production per Ha farmed per year. There is a climatic cause of this variation, with the difference in available sunlight and plant temperature from northern to southern Australia. There are additional factors at play, such as fallow fields and differing harvesting cycles.

Fertiliser usage was also quite variable when expressed as kg of N, P and K per m² of product turf. Again there is a variable loss to ground between heavy and light soil types, but the extent of the variation includes practices that either conserve or waste the fertilisers. This points to a considerable opportunity for the industry to tighten up the systems of fertilizer use to be more efficient on the whole. This consideration applies to the use of pesticides and other chemical products by the turf industry.

¹ Data was gathered from the turf growers accompanied by site inspections and soil and water sampling.

All of the farms surveyed managed to be carbon positive, meaning that they all sequestered carbon dioxide from the atmosphere, even after allowing for emissions due to chemical and energy usage. Again there was substantial variation in carbon sequestration performance with the best performers sequestering a net 2.8 kg CO₂/m² and the worst at 0.3 kg CO₂/m².

Risk to the environment from turf farming was examined for growing sites and, in average terms, the following risks were identified and qualitatively evaluated.

Environmental segment	Risks averaged across the surveyed turf farms					
Land	Erosion	Asbestos	Diesel spill	Chemical spill	Product losses	Salinity
Surface waters	Nutrients	Turbidity	Toxicity	Bacterial action	Persistent pollutants	
Ground water	Pesticides	Heavy metals	Salinity	Nutrients		
Air	Odour	Dust	Noise	Spray drift		
Wastes	Litter	Chemical drums	Turf wastes	Infrastructure	Machinery	Old batteries
Low-medium	Medium	Higher				

Spray drift of toxic chemicals into neighbouring properties was potentially a high risk at all of the turf farms visited. This risk was controlled by monitoring wind conditions for spraying operations by all growers, only one grower also used spray screens to stop lateral movement of spray off site.

Nutrient losses to surface and groundwaters were evident in some locations and point to losses of water soluble chemicals in the same mechanism.

Diesel and chemical spills were also considered a medium risk at most sites. Bunding of liquid chemical and fuel stores was practised by more advanced growers.

Good environmental practice by growers was illustrated in the case studies produced by this project.

In the second phase of the project, installations of turf were studied from January 2018 to May 2019, with the inputs and outputs assessed as averages of the two types of installations: recreational and sports turf. This data was used to fill the lifecycle assessment requirements for data and enable modelling of the impacts of turf across its lifecycle. Three scenarios of 1, 5 and 10 year turf installation life were modelled and the environmental product declaration featured the two extremes of one and ten years of turf life.

The key finding of the LCA was that a natural turf installation over ten years will provide a yearly benefit in terms of carbon sequestration of 0.31 kg of CO_{2eq}/year/m² of turf. This does come at a cost of the other main environmental impacts associated with turf production and maintenance of 100 Litres of water per year per m² of turf, energy use of 2 MJ/m² per year (in mowing), loss of 0.007 kg of PO_{4eq} per year per m² and generation of acidification in SO_{2eq} of 0.00059 kg per year per m².

To put this into a context the following table has been calculated from the global population normalisation factors for a household lawn of 150m² where the impact is distributed over three people in that household.

This table shows the top five environmental impacts normalized for a global person's total impacts.

Impact category	Units	Impact per person for all activities per year ² (x 3 people)	10 year scenario for a 150m ² lawn (3 people) Impact of turf % of total personal impact
Water usage	m ³	33 (international) 329 Australia ³	43% 4.3%
Eutrophication potential	kg P _{eq}	40.5 (international)	4.5%
Acidification potential	mole _{eq} H ⁺	8.25 (international)	1.7%
Ozone depletion potential	kg (CFC11)	0.0984 (international)	0.0027%
Global warming potential	kg (CO _{2eq})	25,200 (international) 61,500 (Australia) ⁴	- 0.18% - 0.076%

By way of explanation, the water usage of a household watering a 150 m² lawn at a rate of 100 Litre per m² per year is the equivalent of 43% of the averaged water use for the same household globally. In the Australian context as the average household uses about ten times as much water as the global average, the percentage impact of turf reduces for lawn watering to about 4.3% of the average Australian's water budget.

Eutrophication potential from fertilizing the same 150 m² of lawn per year uses 4.5% of the total eutrophication potential for the global household and acidification potential is about 1.7% of the total in lawn maintenance.

On the other hand, the benefit of carbon sequestration of the same lawn is about 0.18% of the total emissions of a global household (or 0.076% of an Australian household that generates 2.4 times as much emissions of greenhouse gases as the global average).

² Global normalisation factors for the Environmental Footprint and Life Cycle Assessment (2017)

JRC Technical Reports by S Sala, E Crenna, M Secchi and R Pant

³ NSW Government and Riverina Water – Average Water Use - <https://www.rwcc.nsw.gov.au/save-water/average-water-use>

⁴ Quarterly Update of Australia's National Greenhouse Gas Inventory: December 2018

Monitoring and evaluation

The project ran for approximately three years from October 2016 to July 2019. During this time the project was conducted within the framework of the Monitoring, Evaluation, Reporting and Improvement Program (MERI). The efficiency of the project can be evaluated from the perspectives of timeliness, communication with participants, effectiveness of reporting and communication, and fulfillment of scope and objectives. Effective management of the project was achieved through regular management meetings at which the progress of the project was reviewed against the aims and timelines. At the completion of each milestone Hort Innovation project management was informed of progress and adjustments considered necessary to improve the outcomes of the project. Communication of project deliverables has been achieved by providing participating growers with the project's reports and a quarterly newsletter on progress. Project news was also disseminated to the industry via updates on Hort Innovation's website and through industry bulletins and publications.

During the course of the project, alterations have been made to the scope and the number of participating growing sites, with Hort Innovation's approval. The project team also increased the number of growing sites physically visited from 20 to 28 to increase participation rates. Sufficient country wide representation was gained to have a 'picture' for the whole Industry, and for the categories of turf use. All the objectives set at the outset of the project have been completed within the assigned timeframe.

Feedback has also been sought from the participating growers, who were asked to review the project outcomes and rank them from 1 to 10. The highest score was given to the Environmental Product Declaration (8/10) followed by the site assessment report and cost saving or efficiency measures (7/10). Interestingly, the benchmarking report enabling growers to rate themselves against the industry norms rated only 5/10. The turf industry will be able to use the Global Warming potential savings as a strong positive aspect of turf as a living product that continues to provide environmental benefits throughout its life.

An important aspect of project evaluation is consideration of its legacy. The future use of project outcomes is significant in terms of maximising the opportunity for growers to use the findings for their benefit in driving their own sustainability and also in promoting the industry as a conscious environmental manager.

The lifecycle reporting for the two major turf applications of sporting fields and recreation (parks/gardens and domestic lawn) can be utilised by growers to produce their own, or industry wide Environmental Product Declarations, which can be used to verify the environmental benefits of turf.

As well as providing impetus for industry improvement, the information provided through this study may demonstrate a horticultural industry leading the way in environmental performance disclosure and placing the industry in a transparent position in the nation's pursuit of Greenhouse Emission reductions.

The transparency for growers, installers, and other Industry participants to apply to longer term programs can be summarised as follows:

- through individual site assessments and recommendations for action
- by practical guidance from Industry Case Studies
- showing the grower's environmental performance in relation to the status of all Australian sites and the relevant environmental assets
- assuring a future for the Industry based on positive global warming mitigation, very low and controllable environmental impacts and ways in which further improvements can be made and maintained.

The industry will now have more ability to understand and control environmental impacts and as well as improve resource efficiencies that will lead to a reduction in wastes and improved profitability.

This is aligned with Hort Innovation's objectives to build strength in the horticultural industries and to develop industry capacity. The examination of local environmental issues will further boost the ability of the turf growers to fit into ever tightening country and international environmental goals.

Recommendations

The project has made the following key recommendations for the industry:

- The turfgrass industry can promote its action against climate change with good continuing carbon dioxide sequestration throughout its life.
- Turf growers can be good environmental custodians and can promote environmental stewardship to householders and larger residential developers.
- The turf product has no end-of-life waste disposal problems. This is a key aspect of turf that sets it apart from all other possible ground covers synthesized by industry.
- Recovering run-off and avoiding losses of fertilisers and chemicals used makes a good environmental control for turf growers. This control measure can negate the environmental impacts associated with surface run off and protect the environment in cases of chemical spills.
- Growers can continuously improve their performance by measurement and goal setting. While it may be difficult to maintain a continuous improvement program, setting targets and measuring performance towards these targets is relatively easy to manage.
- Efficiency of turf growing equals care for the environment (Less is More). This project measured an average loss of fertilizer nitrogen to the environment of 59% of the nitrogen applied with worse efficiencies for phosphorus and potassium. If the fertilizer waste can be reduced it will result in less problems with unwanted algae in waterways and savings in fertilizer costs to the grower.
- Data sharing through continuing benchmarking helps the whole industry. The turf industry can establish a set of core environmental performance benchmarks and continue to monitor these for the benefit of all growers and the community at large.

While the turf industry is inherently competitive there are advantages to all growers in cooperating to help the industry become more resource efficient which can only happen with resource consumption and output measurement that is best done by the growers themselves.

Turf has a good story that it can tell.

Refereed scientific publications

Nil

References

Global normalisation factors for the Environmental Footprint and Life Cycle Assessment (2017)

JRC Technical Reports by S Sala, E Crenna, M Secchi and R Pant

NSW Government and Riverina Water – Average Water Use -<https://www.rwcc.nsw.gov.au/save-water/average-water-use>

Quarterly Update of Australia's National Greenhouse Gas Inventory: December 2018

Intellectual property, commercialisation and confidentiality

This project has provided measures of environmental performance that are not connected to individual products or companies. These data can be shared without detriment to anyone. No confidentiality is necessary. The project has developed systems of measurement and benchmarking that have value in terms of intellectual property but this can be shared by all.

Acknowledgements

Infotech Research would like to acknowledge the participation of the owners of the 30 turf growing sites and five installations sites, who were integral to the project.

We would also like to thank Hort Innovation, Turf Australia and Lawn Solutions Australia for providing support, advice and promotion of the project.

Appendices

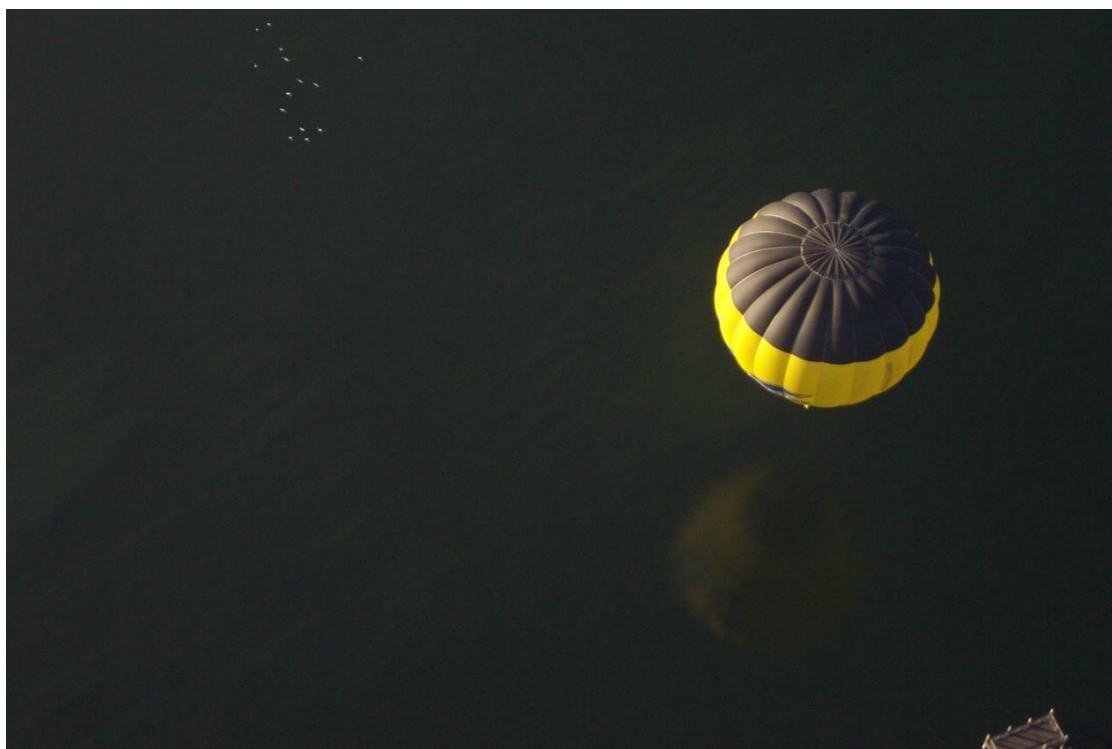
Appendix 1- Lifecycle Assessment Report

Appendix 2- Environmental Product Declaration

Appendix 3- Product Category Rules

Turf Lifecycle Assessment

LCA Report



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July 2019



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Acknowledgements:

Participation by the owners of 30 turf growing sites was appreciated with six of these growers undertaking more detailed investigations.

Participation by the owners of five installation sites was also invaluable.

Funding and management support for the study from Hort Innovation was central to the success of the project.

Encouragement and publicity was provided by Turf Australia.

Lifecycle Assessment modelling was conducted by Kyle O'Farrell of Envisage Consulting.

Report application

The study and modelling of processes is intended for use by the turf growing industry to support claims of environmental performance. The limitations of the study are evident in the variation in individual grower performance (see the benchmarking report). As such, it is not a claim that can be used by an individual grower without an individual study of their processes, but rather an indicative report on the industry's performance. It does not purport to show best practice in any aspect of the turf industry.



Executive Summary

The environmental impacts and benefits of turf grass are important as turf represents the largest area of horticultural land in Australia. Lawn is said to exceed the area of land put to crops in the United States of America and most likely in Australia as well.

Turf's environmental reputation has suffered from the impacts of fertiliser use and watering, together with energy used in mowing. These impacts have been studied here to gain sufficient information to provide an industry median environmental impact of turf over its lifecycle from the turf farm to the field or lawn.

The process of the turf lifecycle is described as a four stage lifecycle without a clear end of life point.

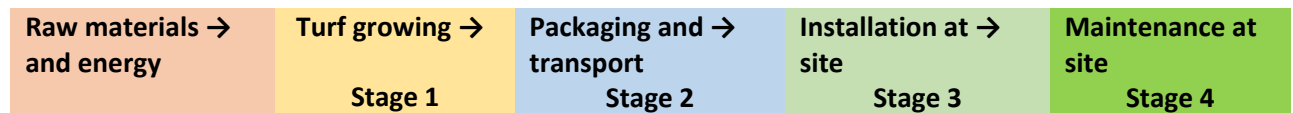


Figure 1. Turf lifecycle stages

These four stages have been analysed in the lifecycle assessment (LCA) to determine the full lifecycle environmental impacts of turf for two applications: recreational and sports turf. Recreational turf has lower maintenance requirements than sports turf, however the stages to installation are basically the same.

The LCA is based on industry median figures from a study of 30 turf growing sites and five installations. Three lifetime scenarios were examined: one year life, five years life and ten years life. The LCA found the key environmental impacts of turf are water use, eutrophication potential, acidification potential and global warming potential. Other environmental impacts were relatively minor in terms of population norms.

The key positive impact of utilising turf to cover an outdoor area is the continuing sequestration of carbon dioxide over its life. The one, five and ten year scenarios yielded a sequestration rate per year per square meter of turf of 0.905, 0.375 and 0.308 kg CO₂ respectively for recreational turf. Due to the higher maintenance requirements of sports turf the only scenario with net CO₂ sequestration was the one year scenario at 0.01 kg CO₂/m².y.

Details of the environmental impacts and their interpretation are given in the results section of this report.

The industry can use this data to strongly indicate the benefits of using natural turf to environmentally sensitive markets. In order to utilise this, the LCA data and any declarations need to be independently verified to meet the requirements of the ISO 14040 standard.



Introduction

The turf industry is well established in all states of Australia with an estimated production area of 4,400 Ha spread over 250 growers (Turf Australia, 2018). Natural turf grass is produced from a variety of cultivars for home lawns, landscaping, recreational areas and sports fields. Turf growers cultivate the soil and grow turf, which is harvested as rolls or slabs for the various types of installations.

As an accountable industry the turf growers have commissioned the study: *An Environmental Assessment of the Australian Turf Industry*. Hort Innovation has funded this study using grower funds and support from the Australian government. This study includes a lifecycle assessment of turf.

Turf production requires sun water, soil and nutrients that are managed by the turf grower. There is a balance between inputs and outputs, both of which generate environmental impacts to be assessed in this study. The first two inputs from nature are variable from season to season and produce an inherent variability in the output of turf from a particular turf farm. As with all agricultural products there are good and poor seasons for growth. These have been taken into consideration by examining the turf farms over a two year period.

A two stage approach has been used where the growers have been assessed followed by an examination of installations to cover the full lifecycle of turf.

Goal and intended application of the study

The intent of this study is to quantify material movements and energy use over the lifecycle of turf and from this to determine the related environmental impacts of the lifecycle as defined herein. This data was then used to calculate the environmental impacts in a form suitable for publication as an Environmental Product Declaration.

Lifecycle assessment

LCA is a technique for assessing the environmental aspects and potential impacts associated with a product or service by:

- compiling an inventory of relevant inputs and outputs of the product or service system
- evaluating the potential environmental impacts associated with those inputs and outputs
- interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.

LCA models the environmental impacts from each stage of a lifecycle across raw materials acquisition, manufacture, use and end-of-life. It incorporates the steps outlined in Figure 2.

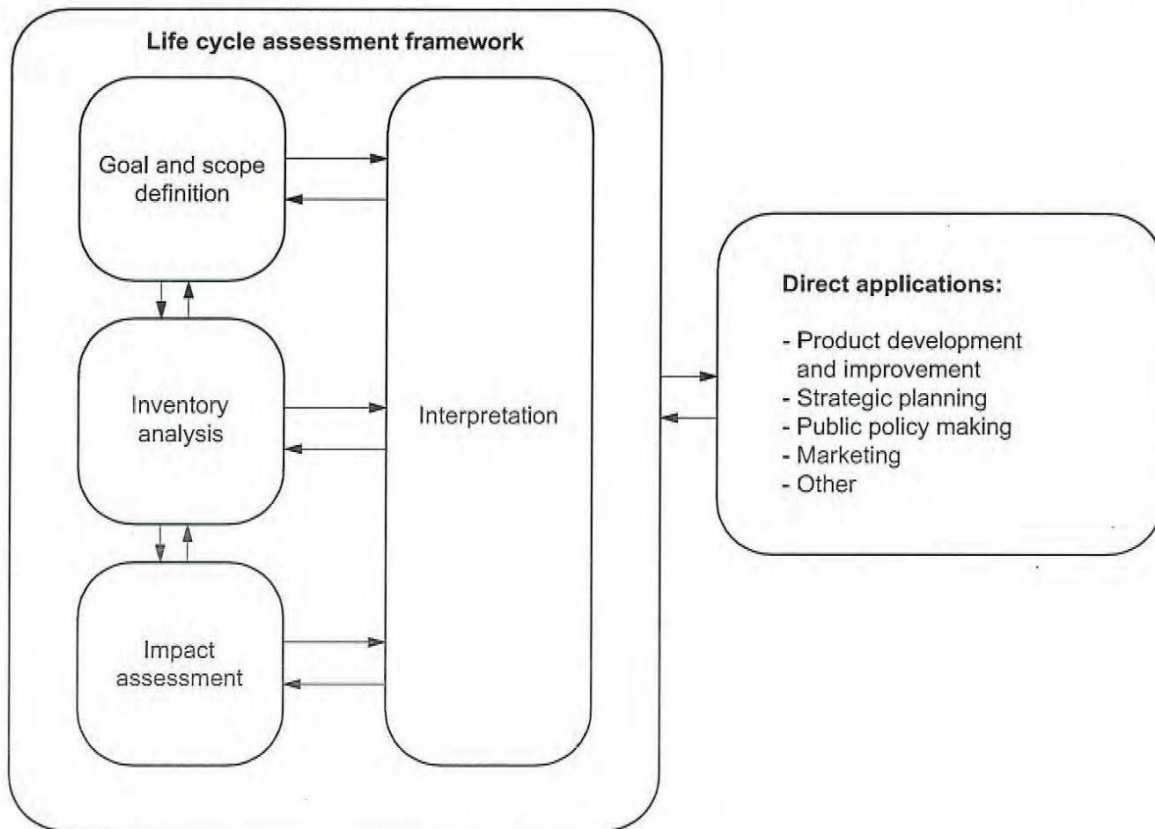


Figure 2. Stages in a lifecycle assessment

The key reference standards that are utilised in undertaking the LCA and Environmental Product Declaration (EPD) development are:

- International Standard ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework, Geneva: International Organization for Standardization.
- International Standard ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines, Geneva: International Organization for Standardization.
- ALCAS Best Practice Guide for Mid Point Lifecycle Assessment in Australia (M.A., 2018)
- International Standard ISO 14025:2006 – Environmental labels and declarations – Type III Environmental Declarations – Principles and Practice

Scope of the study

The data collected has been exclusively from the Australian turf industry for the application of the turf in Australia, under the various conditions encountered. Turf has a lifespan that is limited only by changes in the use of the land. This may occur after a few or many years, so the impacts of growing, transport, installation and maintenance are reported separately to allow users of the LCA to calculate the annual impact based on an assumed lifespan for a specific installation.

This assessment gains its primary data from a study of 30 growing sites and five installations across the major turf growing and installation areas across Australia. The data are expressed as median, or most likely values for the industry as at 2018. It should be understood that there is variability in the environmental conditions, growing and maintenance systems, as well as the function of the turf itself. The function of turf falls into two broad categories: **recreational turf**, which is the majority of



turf applied to function as a lawn in residential and parkland areas and **sports turf**, which is applied to sporting fields and is more carefully installed and maintained.

Functional unit

The functional unit is the basis on which environmental impacts are calculated. Turf is sold by area of cover rather than weight of product, so the inputs are generally expressed and understood as the amount used per area of turf farm. In line with this practice the functional unit used is one square meter of finished product. The lifecycle inputs are expressed as those pertaining to the production of 1 m² of turf and its installation and maintenance over one year so the impacts are calculated as being per m² of turf per year.

FUNCTIONAL UNIT = 1 m² turf installed/year (1, 5 and 10 year default lifespans are used)

Process description

Turf lifecycle has been split into four stages:

1. Growing and harvesting
2. Packaging and transport
3. Installation on site and
4. Maintenance carried out each year

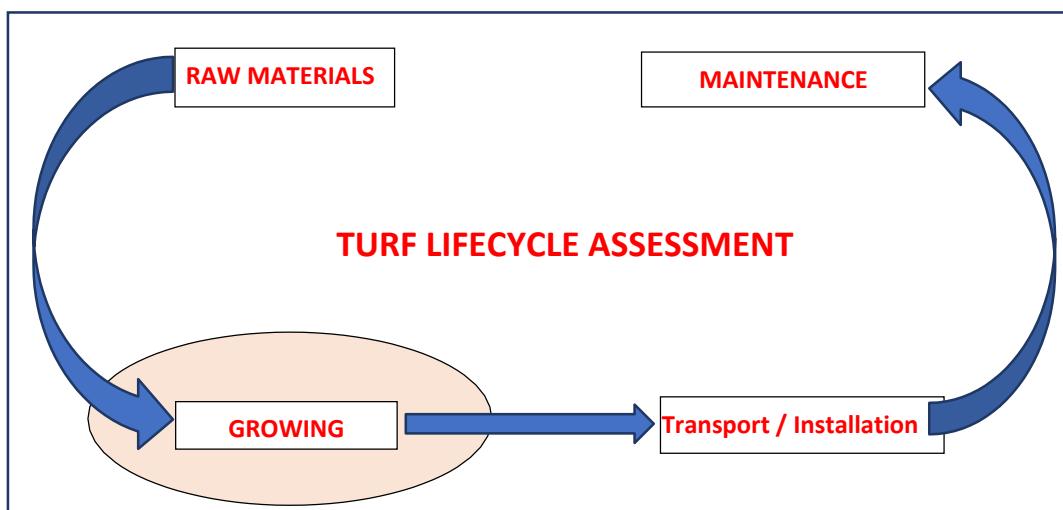


Figure 3. Lifecycle of turf



Stage 1. Growing

Turf grass may be grown from seed but is more commonly propagated from existing turf left remaining in the soil. The predominant varieties of Buffalo, Couch and Kikuyu are propagated in this way from strips of turf left after harvest or from turf grass roots left in the soil.

The diverse set of turf varieties have differing nutrition and water requirements. There was no attempt to split up the turf varieties as each farm produced a set of different products and differentiation of these was not practicable in this study.



Figure 4. Turf strips left for propagation after harvest

The process of propagation involves fertilisation and irrigation with due consideration of the season and growing patterns.

Growth rates are dependent on temperature, sunlight, nutrients and moisture in the soil. At temperate latitudes there is a growth season from Spring to Autumn and a dormant period over Winter. Subtropical regions can grow turf all year round.

During the growing period, water and nutrients have to be supplied for optimal growth and weeds and pests have to be controlled. Each grower has an irrigation program along with fertilisation and chemical addition schedules.

Growers use energy predominantly in the form of diesel fuel. Tractors are used across the farm for most activities, diesel may also be used for irrigation pumps. If not, electrical pumps are used for irrigation, which is the major use of electrical energy by turf growers.

Stage 2. Harvest and transport

Specialist equipment is used to harvest turf with most growers using automated harvesters that produce rolls or slabs. The rolls are placed on a pallet and wrapped to stabilise them. They are then loaded onto a truck (usually a flat bed truck) for transport to the installation site.

As a living product turf is harvested on market demand and transported within a day to the installation site.

Stage 3. Installation

The site is prepared for the turf by levelling the site, adding topsoil or sand if necessary. Fertiliser is added to aid the establishment of the turf. The turf is laid manually and watered in for the first week. A reticulated irrigation system may be used for larger installations. Smaller sites can use moveable sprinkler systems or can be hand watered.



Figure 5. Watering in a turf installation with a moveable sprinkler system



Stage 4. Maintenance

Once the turf is established a maintenance regime is employed. This involves mowing regularly over the growing season, fertilisation to maintain the required growth and watering as required by the turf grass.

It may be necessary to spot spray weeds and apply pesticides if they are having an adverse effect on the turf.

The end of life for a turf installation is dictated by land use rather than the lifespan of the turf, which can go on growing indefinitely if appropriately maintained. As such, there is no definite end of life scenario for turf grass and a one year period has been chosen for the installed lifespan.

The end of life scenario of turf is redevelopment of the site without the need to treat or dispose of any wastes. In most cases the topsoil with the turf will be stockpiled and reused. There are no environmental impacts considered in this analysis.

System boundaries

The examination of environmental impacts considers the operations on the turf farm and the various inputs on farm being: energy, water, fuels, chemicals and other consumables, such as netting. Farm infrastructure is not considered as it is not certain as to whether this was established with the purpose of turf growing in mind and may be utilised by other farming activities at the site. It is acceptable under the reference Product Category Rules¹ (PCR) to exclude infrastructure related inputs and outputs.

¹ Product Category Rules are an agreed set of rules governing the production of a lifecycle inventory and resultant environmental impacts that allows products and systems to be compared with the same “ruler” for measurement.

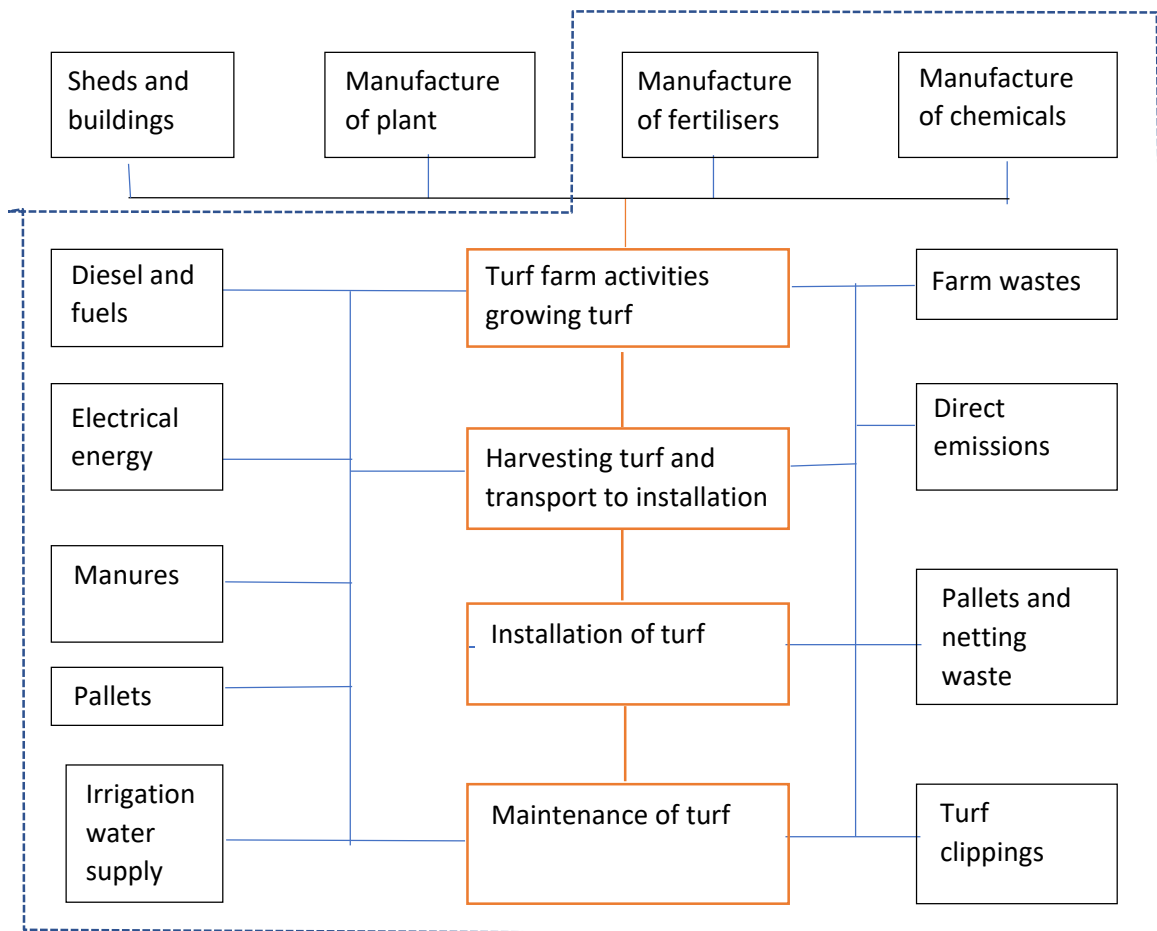


Figure 6. Boundaries of the life cycle assessment of turf (blue dotted line)

Geographical boundaries used were the limits of the Australian continent and Tasmania. The time boundaries used for the study are the financial years 2016-17 and 2017-18 for growing data. However, the installation data collection has been undertaken from January 2018 to March 2019.

The study was intended to cover all turf varieties together and growers in all sizes and Australian locations. Installation studies have been restricted to the Melbourne and Sydney regions.

System inventory data

The system inventory is the materials and energy used within the boundary of the lifecycle. All inputs are considered for inclusion in the lifecycle inventory (LCI), but in order to produce a manageable system decisions may be made to use particular inputs to represent a range of similar materials. For instance agricultural lime is used as the default input for all of the mineral inputs into turf growing and maintenance. Similarly representative chemicals are used for the wide range of chemicals used as pesticides and herbicides.

Growing

Studies of 30 growing sites across Australia, over two annual periods, and a series of five installations have produced data on material flows and energy consumption through the lifecycle of turf. This is presented as the industry mean with high and low limits to cover the performance of 80% of growers. As the application of turf varies from recreational to specialist sporting facilities these are split into categories.



Regional variation in growing conditions has been accounted for by the high and low limits of the data. For instance irrigation water use is considerably higher in the sand belt of Western Australia than it is in clay loam conditions encountered elsewhere.

As data has been collected for the turf growers over two years the data presented represents the average of the 2016-17 and 2017-18 financial years.

Turf grower data (n=30-40)		Median	Average	Top 90%	Bottom 10%
Land use	m ² of land / m ² turf produced per year	1.67	1.5	2.86	0.93
Electricity	kWh/m ² turf produced	0.25	0.38	0.95	0.05
Diesel	L/m ² turf produced	0.12	0.15	0.29	0.06
Energy used	MJ/m ² turf produced	5.5	6.91	14.5	2.39
Greenhouse	Direct emissions kg CO ₂ /m ²	0.51	0.74	1.2	0.26
	Net emissions kg CO ₂ /m ²	-1.63 ²	-1.68	-2.31	-0.9
Water used	L/m ² turf produced	1078	1497	3563	621
Nitrogen	kg(N)/m ² turf produced	0.047	0.071	0.16	0.02
Phosphorus	kg(P)/m ² turf produced	0.016	0.022	0.053	0.0023
Potassium	kg (K)/m ² turf produced	0.021	0.027	0.061	0.00096
Ag chemicals	kg / m ² turf produced	0.0019	0.0023	0.0061	0.00082
Lime +	kg / m ² turf produced		0.092		

Table 1. Turf grower consumption data

Land use is an environmental impact category that may be considered in terms of its use over a set period of time. It also known as change of land use or biodiversity impact. The turf grower can use the same piece of land to produce turf for many years and it is commonly the case that the land has been used to produce turf for generations. The soil is incorporated into the turf product and hence soil is lost to the product. This may be replaced by manures and other additives used by the grower and the soil develops, through the plants, an increase in organic matter. The situation is complex and the soil is not lost to the environment, it is effectively transferred to another site, where it may also act to stabilise soil loss. For these reasons we believe that the impact of land use is simply to be taken as the area of the turf farm for the total production of turf from that farm, expressed in m² of land / m² turf produced per year.

Energy is used as electricity and diesel with a minor amount of LPG used in forklifts to load trucks. The LPG usage is less than 1% of the total and has not been included in the lifecycle assessment. The total diesel used on farm as well as electricity have been used to calculate the usage per m² of turf produced. Where diesel is also used on farm for transport purposes a factor has been applied based

² A negative emission of CO₂ represents capture of atmospheric CO₂ by the system commonly called carbon sequestration or a negative carbon footprint.



on the trucks and product distribution mileage to gain an estimate of the total diesel used on the farm only. In most cases the growers used different accounts for on-farm diesel to the trucks.

For each grower the diesel and electricity usage was used to calculate the greenhouse gas emissions for the farm, together with the greenhouse gas attribution of fertilisers and chemicals used. The net greenhouse gas emissions were calculated from a study of the carbon content of the product turf to gain a net Greenhouse emission per m^2 of turf. In all growers this was a net sequestration of carbon and negative Greenhouse emissions for turf products.

Turf growers use river water or bore water to irrigate turf. In some cases they collect run off from irrigation in dams and reuse this water. It was not possible to determine what the irrigation volume was recycled so the assumption is that all water is fresh. Some growers use waste water recycled from sewage treatment plants. While these growers can discount the water use impact for this wastewater reuse this has not been taken into account in this LCA.

Fertilisers and manures used by the growers were determined according to the NPK content (nitrogen, phosphorus and potassium) and these figures were used to estimate the environmental impact. The N, P and K were determined in the product turf of 6 growing sites and an average used to establish the amount of N, P and K held by the product turf and the remainder that is either held up in the soil or lost to groundwater or surface run off. The turf plant production was used to determine the quantity of carbon in the plant (at 50% of dry plant matter) and from photosynthesis the quantity of carbon dioxide absorbed by the plant from the atmosphere. This has a major implication in the net carbon dioxide emissions (the measure of climate change as $\text{CO}_{2(\text{eq})}$) from the growing stage.

A single grower may have used up to 40 different chemical products in addition to the fertilisers in a year. Most of these chemicals are not registered in the lifecycle inventory used so it was assumed that they were a single common chemical and the total "Ag chemical" usage for the production of one m^2 of turf was calculated and used to determine the total environmental impacts.

The use of lime and other mineral soil additives is haphazard and in response to particular issues on the farm. Lime and dolomite are the most common additives used, but these are not added to the soil regularly by most growers. An average over the two years of the study was 0.092 kg per m^2 of turf produced.

Additional inputs come in the form of pallets and the netting used to stabilise the slabs or rolls of turf placed on them. The pallets are collected after installation and reused by the grower while netting wastes are assumed to be disposed to landfill through general waste bins at the point of installation. Each pallet holds about 80 to 100 m^2 of turf and is held by less than 10 m^2 of netting (approx. 300g). Netting was a minor contribution of less than 1% of the material inputs (0.003 kg/m^2 of turf).

Transport and Installation

Typically a grower is involved in the marketing and delivery of product turf. Some growers are involved in installation and maintenance and others leave the whole marketing process to a third party.



Figure 7. A truck loaded with slabs of turf on pallets

Turf is palletised on the harvesting machine and dropped off at a storage location for truck loading and delivery.

Pallets are loaded and off-loaded from the truck using a forklift. Some were electric but most were either LPG or diesel forklifts.

Turf farms are scattered across the country positioned where irrigation water is available. The distance to market dictates the transport impacts in diesel fuel consumption. This was determined for 16 out of the 30 turf growing sites studied.

Transport to installation fuel use

Fuel	Mean consumption	Average consumption	
	Litre/m ² produced	Litre/m ² produced	
Diesel	0.088	0.096	
LPG	<0.001	<0.001	

Table 2. Fuel consumption in transport

The installation site is levelled either by mechanical or manual means, fertiliser pellets may be added to the site before the turf is installed or fertiliser can be added to the irrigation water.

In the case of sports fields drainage systems are in place and sand is laid over the substrate soil and levelled off. Manure or fertiliser is added prior to the turf installation.

Installation of the turf slabs or rolls is undertaken manually. The rolls are offloaded from the truck and set down by the installation from where they are rolled out or laid in position. When this has been accomplished the turf is watered in.

After installation the turf is watered in with an average daily application of 5mm of water for three weeks.

Input to installation	Quantity	Explanation
Top soil (sand) 150 mm	0.24 kg/m ²	Density assumed 1.6 kg/dm ³ -only applied for sports fields
Fertiliser	0.07 kg/m ² total 0.05 kg N/m ² 0.06 kg P/m ² 0.006 kg K/m ²	Average usage rates from 5 installations studied of which two used no fertiliser
Water	0.047 m ³ /m ²	Average of 5 installations studied watering in for three weeks in each case

Table 3. Inputs for turf installations



Maintenance of turf

The level of turf maintenance is dependent on the application. While recreational area turf or lawn provides a green and pleasant surface for human activities, sports field turf needs to function for the particular use(s) of the sports ground. Recreational turf surface smoothness and consistency is not critical for its use, so the maintenance activities are much reduced when compared to sports turf. For this reason we have split the lifecycle assessment into the two areas:

- Recreational turf and
- Sport turf.

Recreational turf maintenance

There is variation in recreational turf maintenance from just the occasional mowing to serious attempts to maintain the turf in a good condition. In most cases recreational turf is maintained with adequate fertilisation, weed management and watering followed by mowing at regular intervals during the growing period.

In our study of recreational turf maintenance examples of lawn at a tennis centre and lawn in a landscape for a new housing estate were examined. These sites were maintained appropriately and according to the industry regimes.

The activities and inputs expected are given in Table 4. These activities and inputs are expected for a well maintained turf lawn that may be the responsibility of a maintenance contractor. In many cases of domestic lawn maintenance the inputs will be less than is given and it is unlikely that the inputs will be greater.

Maintenance			Recreational turf lawn
Inputs	per year	Expected	Comments
Hand mowing	MJ/m ² /y	0.61	11.9 L of petrol per Ha (15 mows over the year – biweekly in Spring and monthly after 15 Dec)
Watering	L/m ² /y	50	Fortnightly watering to 5mm for 20 weeks per year
Fertilising	kg/m ² /y	0.024	4 kg All Purpose Fert per 500m ² = 0.008 kg/m ² three times per year
Nitrogen	kg/m ² /y	0.0036	Nitrogen 15%
Phosphorus	kg/m ² /y	0.0012	Phosphorus 5%
Potassium	kg/m ² /y	0.0012	Potassium 5%
Mineral additives	kg/m ² /y	0.015	Assume ag lime or similar product addition at 150 kg/Ha (0.015 kg/m ²)
Ag chemicals	kg/m ² /y	0.00015	Weedicides at 150 g/Ha

Table 4. Inputs for recreational turf maintenance

Sports field maintenance

Sports fields require a clean cover of turf laid on top of a sand base to provide an even playing surface with sufficient resilience and consistency. The higher standard of surface requires an increased attention to the health of the turf and hence more inputs than for recreational turf



Maintenance activity	Sports fields			Data from maintenance schedule of a sports field
	per year			
Mowing fuel consumption	L/m ² /y	0.0128		Mowing 2x per week over growing season (32) at 0.4ml/m ² /mow (diesel fuel)
Rolling, aerating	L/m ² /y	0.0064		Once per week equivalent energy use of mowing (diesel fuel)
Watering	L/m ² /y	140		23,300 L/Ha/day for 20 weeks over the growing period
Fertiliser	kg/m ² /y	0.50		Regular fortnightly fertilisation at 48 kg/Ha of 15:3:15 plus one off additions.
Nitrogen	kg/m ² /y	0.052		NPK 5-5-5 added
Phosphorus	kg/m ² /y	0.014		Super phosphate added
Potassium	kg/m ² /y	0.056		Granular slow release granular fertiliser
Mineral additives	kg/m ² /y	0.082		Gypsum, kieserite, trace elements
Ag chemicals	kg/m ² /y	0.00019		Weedicide, pesticides, fungicides, preventative herbicides

Table 5. Inputs for sports field turf maintenance

Assumptions

The LCA inputs rely on the use of industry mean data being representative of a particular case of growing conditions cultivar use and installation geography and climate conditions. The variations in growing conditions can be allowed for with particular data for growing conditions. The installation location of the turf is not known and may vary significantly.

It has been the intent of this study to be conservative in estimation of material and energy use across the lifecycle of turf, so that the environmental impacts provided are also conservative and reflect the potential for all significant material inputs.

The boundary conditions have excluded the impacts associated with infrastructure on the turf farm including the plant and equipment used. This avoids allocation issues as the farm and plant may well be used for functions other than turf growing. Farm infrastructure is likely to have a lifespan of 20–50 years or more and, other than land use, the impact associated with it is assumed to be minor.

Agricultural chemical use has been aggregated into the one of two categories: ag chemicals and mineral additives. The latter is likely to be a soil additive to correct for soil inadequacies such as pH or cation exchange capacity. Ag chemicals are many and varied and most of these have not been characterised in inventories so the impacts associated with their manufacture, transport and marketing have been consolidated into the few that have been characterised in the inventories used as a single chemical product.

Herbicides are the most common ag chemical applied to turf. These are synthetic chemicals generated from petrochemicals, one of the most common of these is MCPA (2-methyl-4-chlorophenoxyacetic acid), another is Simazine a triazine derivative. Nicotinoids are commonly used as pesticides on turf but the application rate is significantly lower than with herbicides.

Mineral additives are used in certain circumstances at a much greater application rate to improve the characteristics of the soils. Common minerals used are lime, dolomite and clay. As the use of minerals is sporadic the total minerals consumption was determined across the 30 growers studied and an average figure used.



	Total additions kg	Total additions / Total m ² kg / m ²
Ag chemicals (n=17)	10,940	0.0012
Mineral additions (n=20)	329,324	0.071

Table 6. Other chemical additions

The fate of fertiliser additions is of concern as these present as nutrients for eutrophication of particular water bodies. Studies of installations for sports fields and grower sites in this project has given a figure of an average loss of nitrogen of 60% of the total amount of N applied. 40% of the N applied is taken up and incorporated into the turf plant while the remaining 60% is lost to the system predominantly by water movement to drains or groundwater bodies. Individual circumstances vary such as sandy sites, where the loss of water is rapid through the soil structure and clay based sites, where an effective barrier holds the water in the soil and the predominant mechanism is run-off to surface water bodies.

Phosphorus losses were also measured in this study as the difference between the applied amount and that taken up by the turf plants.

In either case the potential for eutrophication of the water body is similar and dependent on the nitrogen or phosphorus losses. These were measured at 59% loss of applied N and an 86% loss of applied P. In each stage of the turf lifecycle the applied N and P are assumed to be taken up and lost in these proportions (It could be argued that there are other loss mechanisms for nitrogen and that nitrogen can also be taken up by soil organisms.) Similarly phosphorus can be held up in the soil by biological and chemical adsorption mechanisms. As such this analysis presents a worst case scenario for eutrophication potential.

Outputs

Outputs come in the form of products and wastes. The product is turf: a mixture of the turf plant and topsoil from the growing stage and continuing production of turf, which also promotes the growth of organic matter in the soil. This organic matter consists of 50% carbon per unit of dry weight that accounts for further continuing absorption of CO₂ from the atmosphere. This absorption or carbon sequestration has been studied by a number of researchers from which an average rate of absorption of 0.096 kg C/m²/y is used in this analysis to calculate the lifecycle Climate Change impact of -0.35 kg CO₂/m²/y.

Literature source	Year	Ave Carbon Sequestration as soil organic matter kg Carbon/m ² /y	Sequestered kg CO ₂ /m ² /y
Bruce et.al. (J.Soil Water Conserv. 1999,54,PP382-390)	1999	0.06	0.22
Qian & Follett (Agronomy J. 2002, 94, PP930-935)	2002	0.09-0.1	0.35
Townsend-Small & Czimczik (Geophys Res. Lett. 2010, 37, L02707 PP1-5)	2010	0.14	0.51
Qian, Follet & Kimble (SSSAJ 2010, 74, PP366-371)	2010	0.032-0.078	0.20
Zirkle, Lal & Augustin (Hort. Sci. 2011, 46,5,PP808-814)	2011	0.05 -0.20	0.46
Average for turf urban			0.35

Table 7. Carbon sequestration measurements in turf soils



This organic matter build-up in recreational turf installations does not necessarily apply to sports turf applications, where the fields are turned over regularly and reconstituted. Some authors saw no organic carbon build-up in these soils.

Allocation rules

In cases where an input or an output can be used in other products there is an allocation required for the associated impacts between the different product lifecycles. With turf there is little allocation dilemma, as the inputs are directed solely for the production of turf as no significant by-products exist.

Any allocation issue was addressed through system expansion to include the alternative material uses within the system boundaries.

This approach is consistent with the ISO LCA standards.

Lifecycle inventory analysis outline

The lifecycle inventory analysis (LCI) involves the collation of all inputs and outputs associated with each of the modelled treatment pathways. Inputs and outputs that are included are the consumption of raw materials, energy and water and the environmental discharges to air, water and land.

The result of the analysis is an inventory of inputs and outputs for each lifecycle stage and aggregated across the full life cycle. The completion of the development of the inventory then leads into the life cycle impact assessment phase.

Lifecycle impact assessment

The lifecycle impact assessment (LCIA) phase of an LCA evaluates the environmental impacts associated with the inventory data, providing comparison of the different environmental impacts, which then provides information for the interpretation phase.

The LCIA phase is particularly important, and it is a requirement under ISO 14040:2006 to provide details on it in the scoping phase.

Methodology

The objective of the LCIA phase of this study is to provide comparative analysis around the environmental impacts resulting from the inventory results for each of the modelled material movement pathways. The aim is to provide comparison of the different environmental impacts for each stage and the overall lifecycle of turf.

The LCIA assigns the results of the inventory analysis to different impact categories. Impact categories represent the primary environmental issues of concern to which the life cycle inventory results can be assigned.

Impact categories selection

Selection of appropriate impact categories is an important step in an LCA, and should be selected to cover key environmental issues for the system under investigation.

Localised impacts such as dusts, noise and odour have been discounted in this study as they cannot be adequately accounted for in an industry wide study. In some cases these impacts may well be important.

The major impacts associated with energy inputs directly into the activities studied and indirectly through material inputs are given in table 8.



Environmental impact	Applicability to turf	Environmental significance	Risk to grower	Risk to environment	Included in LCA
Local air pollution	Unlikely	No		Unlikely	No
Energy resource use	Yes	Yes			Yes
Ozone depletion	Yes	Yes		Yes	Yes
Greenhouse emissions	Yes	No		Yes	Yes
Dust emissions	Unlikely	No	Yes	Unlikely	No
Odour emissions	Possible	Possible	Yes	Possible	No
Water resource use	Yes	Yes	Yes	Yes	Yes
Surface water pollution - ecotoxicity	Yes	Yes	Yes	Yes	Yes
Surface water eutrophication	Yes	Possible	Yes	Yes	Yes
Acidification	Yes	Yes		Yes	Yes
Ground water loss	Possible	Possible	Yes	Yes	No
Ground water pollution	Possible	Possible	Yes	Yes	No
Soil loss / erosion	Possible	Possible	Yes	Yes	No
Soil contamination	Possible	Yes	Yes	Yes	No
Land use / Biodiversity loss	Possible (Greenfield sites)	No		Yes	Yes
Land contamination	Possible	Yes		Yes	No
Noise pollution	Unlikely	No	Yes		No
Biodiversity	No	No		Yes	No
Human health impact	Possible	No			Yes

Table 8. Environmental impacts selection

While the environmental impacts of some risks to the environment may be present, it may not be possible to quantify these impacts for the turf industry in general. The impacts in some cases are particular to a micro-location and it is not possible to generalise particular impacts across the Australian turf industry.

The impacts that have been excluded based on this criterion are:

- Dusts
- Odour
- Groundwater pollution
- Soil/land contamination
- Noise

The other impacts have been examined in the LCA through mid-point analysis as described in Table 9.

Modelling software

The LCA modelling software used for this project was Open LCA, supplemented by the use of MS Excel as required. The LCA software was run in a series of modules covering: Greenhouse Gases, Ozone Layer depletion, human and ecotoxicity, water and air pollution impacts and resource depletion.



Inventory data was derived from the Australian AustLCI database and the EcolInvent database. Primary data was provided through this study and literature on the environmental impacts of turf.

Classification

The individual outputs of the processes studied are quantified and classified according to their environmental impacts. This is a function of the lifecycle inventory assessment system and is refined in the model development.

Characterisation models

Characterisation involves the calculation of impact category indicator results. This includes the conversion of LCI results to common units (often using characterisation / conversion factors) and the summation of the converted results to provide the numerical impact category indicator result.

LCI substances that contribute to an impact category are multiplied with a characterisation factor that expresses the relative contribution of the substance. For example, the characterisation factor for CO₂ in the impact category 'climate change' is equal to 1, while the characterisation factor of methane is 31 (across a timeframe of 100 years) and 85 (across a timeframe of 20 years). This means the release of 1 kg methane causes the same amount of climate change as 31 kg CO₂ when measured across a 100 year period.

As with classification, the characterisation factors incorporated into the listed characterisation models have not been modified from their published forms.



The chosen environmental impact categories have the following units and measurement systems.

Environmental Impact category	Units	Explanation (M.A., 2018)
Land use	m ²	Land area used for production of one square meter of turf. There is no change of land use as turf is produced on the same area of land continuously
Climate Change (Global Warming Potential)	kg (CO ₂ -eq)	This is a measure of the equivalent amount of carbon dioxide released into the atmosphere over a 100 year time period. A negative value indicates that there is a net loss of carbon dioxide in the atmosphere.
Ozone depletion	kg (CFC-11 _{eq})	Ozone depletion potential is measured as the equivalent amount of refrigerant CFC-11 emitted
Water consumption	m ³ (H ₂ O _{eq})	This is the amount of water consumed multiplied by the Water Stress Index averaged over Australia (WSI = 0.5)
Eutrophication	kg (PO _{4eq})	Eutrophication is taken as the sum of the nitrogen and phosphorus lost through run-off from the turf farm and installation that impinges on surface water systems. This is measured in phosphate equivalents
Acidification	kg (SO _{2eq})	Simply the acidification potential associated with turf from emissions to land water and air of acidic chemicals express as sulphur dioxide equivalents
Photochemical Ozone formation	kg C ₂ H ₄ eq	Predominantly air emissions with photochemical oxidation potential that can convert oxygen to ozone in the troposphere measured as ethylene equivalents
Aquatic Ecotoxicity	P.A.F.m ³ .day	Potential Affected Fraction (of the ecosystem) for one cubic meter of water for one day
Toxicity Chronic (cancer) Acute (non-cancer)	cases	Toxicity to human health and the environment measured using USEtox methods for acute and chronic toxicity. This is measured simply as the number of cases potentially caused by the outputs
Resource depletion Abiotic depletion (minerals)	kg Sb _{eq}	Total mineral stock abiotic depletion allowing for current reserves and the rate of de-accumulation expressed as kg of antimony.
Resource depletion / Energy use	MJ	Fossil fuel abiotic use expressed as megajoules.

Table 9. Mid-Point Environmental Impacts and measures



Lifecycle Assessment Results

The lifecycle impact assessment split into the impact categories chosen was calculated under three scenarios for two product pathways:

1. A turf lifecycle of one year
2. A turf lifecycle of five years
3. A turf lifecycle of ten years

for recreational turf (lawn/parkland lawn) and sports turf.

In these scenarios the impacts associated with growing, transporting, installing and maintaining the turf are totalled and then calculated on an annual or per year basis. Consequently the impacts of growing, transporting and installing the turf are amortised over the full lifecycle chosen.

The outputs of the analysis are split between the four stages of the lifecycle for the three scenarios.



Recreational Turf LCA outputs

Impacts per m2 of finished turf product per year amortised over the lifecycle.

The impact numbers can be small and require scientific notation³ to display them.

1 year scenario							5 year scenario					10 year scenario				
Turf lifecycle stage	Units	Growing	Transport	Installation	Maintenance	Total /Y	Growing	Transport	Installation	Maintenance	Total /Y	Growing	Transport	Installation	Maintenance	Total /Y
Global warming potential	kg CO2eq	-1.0432	0.2802	0.09985	-0.24189	-0.90504	-0.20864	0.05604	0.01997	-0.24189	-0.37451	-0.10432	0.02802	0.009985	-0.24189	-0.30821
Ozone depletion potential	kg CFC11eq	6.65E-08	3.3778E-08	2.5297E-09	7.3906E-09	1.1E-07	1.33E-08	6.76E-09	5.06E-10	7.39E-09	2.79E-08	6.65E-09	3.38E-09	2.53E-10	7.39E-09	1.77E-08
Acidification potential	kg SO2eq	0.00275	0.00045922	0.00045082	0.00022	0.00388	0.00055	9.18E-05	9.02E-05	0.00022	0.00095	0.000275	4.59E-05	4.51E-05	0.00022	0.000586
Eutrophication potential	kg PO4 eq	0.04395	4.7931E-05	0.0000734	0.00226	0.046331	0.00879	9.59E-06	1.47E-05	0.00226	0.01108	0.004395	4.79E-06	7.34E-06	0.00226	0.006667
Photochemical ozone	kg C2H4eq	0.000114	2.6258E-05	1.7089E-05	1.0445E-05	0.000168	2.27E-05	5.25E-06	3.42E-06	1.04E-05	4.19E-05	1.14E-05	2.63E-06	1.71E-06	1.04E-05	2.62E-05
Resource Use																
Abiotic depletion of resources	kg Sbeq	2.75E-05	5.45E-07	7.11E-06	1.85E-06	3.70E-05	5.49E-06	1.09E-07	1.42E-06	1.85E-06	8.87E-06	2.75E-06	5.45E-08	7.11E-07	1.85E-06	5.36E-06
Water use	m3	5.39E-01		2.35E-02	5.00E-02	6.13E-01	0.1078		0.0047	0.05	0.1625	0.0539		0.00235	0.05	0.10625
Land use	m2	1.67E+00		1.00E+00		2.67E+00	0.334		0.2		0.534	0.167		0.1		0.267
Energy use	MJ	9.05E+00	4.60E+00	4.70E-01	1.27E+00	1.54E+01	1.81	0.92	0.094	1.27	4.094	0.905	0.46	0.047	1.27	2.047
Toxicity																
Fresh water toxicity	PAF.m3.day	7.50E-03	3.78E-04	1.69E-04	6.10E-04	8.66E-03	0.0015	7.57E-05	3.37E-05	0.00061	0.00222	0.00075	3.78E-05	1.69E-05	0.00061	0.001415
Human toxicity (cancer)	cases	2.48E-11	9.93E-13	4.14E-12	1.94E-12	3.19E-11	4.96E-12	1.99E-13	8.27E-13	1.94E-12	7.93E-12	2.48E-12	9.93E-14	4.14E-13	1.94E-12	4.93E-12
Human toxicity (non-cancer)	cases	1.29E-11	1.12E-12	5.78E-13	1.17E-12	1.58E-11	2.59E-12	2.24E-13	1.16E-13	1.17E-12	4.10E-12	1.29E-12	1.12E-13	5.78E-14	1.17E-12	2.64E-12

The 5 and 10 year lifespan scenarios generally show lower numerical impacts because the growing, transport and installation stage impacts are spread over the life of the turf. The exception is Global warming potential, which spreads the carbon dioxide absorption in growing over the lifespan of the turf, consequently diluting it.

³ Scientific notation provides a number as a decimal digit multiplied by a factor of 10 as such: 1.25E-6. This is the number 1.26/10⁶ (or 1.26 divided by one million) or 0.00000126.



Sports Turf LCA Outputs

Impacts per m2 of finished turf product per year amortised over the lifecycle.

1 year scenario							5 year scenario					10 year scenario				
Turf lifecycle stage	Units	Growing	Transport	Installation	Maintenance	Total /Y	Growing	Transport	Installation	Maintenance	Total /Y	Growing	Transport	Installation	Maintenance	Total /Y
Global warming potential	kg CO2eq	-1.0432	0.2802	0.1017	0.65182	-0.00948	-0.20864	0.05604	0.02034	0.65182	0.51956	-0.10432	0.02802	0.01017	0.65182	0.58569
Ozone depletion potential	kg CFC11eq	6.6474E-08	3.38E-08	7.42E-05	2.56E-08	7.44E-05	1.33E-08	6.76E-09	1.48E-05	2.56E-08	1.49E-05	6.65E-09	3.38E-09	7.42E-06	2.56E-08	7.46E-06
Acidification potential	kg SO2eq	0.00275	4.59E-04	4.55E-04	0.00259	0.006254	0.00055	9.1844E-05	9.0984E-05	0.00259	0.003322	0.000275	4.59E-05	4.55E-05	0.00259	0.002956
Eutrophication potential	kg PO4 eq	0.04395	4.7931E-05	0.0000734	0.00226	0.046331	0.00879	9.59E-06	1.47E-05	0.00226	0.01108	0.004395	4.79E-06	7.34E-06	0.00226	0.006667
Photochemical ozone	kg C2H4eq	0.00011373	2.63E-05	1.72E-05	9.83E-05	0.000255	2.27E-05	5.25E-06	3.44E-06	9.83E-05	1.30E-04	1.14E-05	2.63E-06	1.72E-06	9.83E-05	0.000114
Abiotic depletion of resources	kg Sbeq	2.75E-05	5.45E-07	7.16E-06	2.63E-05	6.15E-05	5.49E-06	1.09E-07	1.43E-06	2.63E-05	3.34E-05	2.75E-06	5.45E-08	7.16E-07	2.63E-05	2.98E-05
Water use	m3	5.39E-01		2.35E-02	7.00E-02	6.33E-01	0.1078		0.0047	0.07	0.1825	0.0539		0.00235	0.07	0.12625
Land use	m2	1.67E+00		1.00E+00		2.67E+00	0.334		0.2		0.534	0.167		0.1		0.267
Energy use	MJ	9.05E+00	4.60E+00	4.70E-01	4.76E+00	1.89E+01	1.81	0.92	0.094	4.76	7.584	0.905	0.46	0.047	4.76	3.792
Fresh water toxicity	PAF.m3.day	7.50E-03	3.78E-04	1.69E-04	1.28E-03	9.33E-03	0.0015	7.57E-05	3.39E-05	0.00128	0.00289	0.00075	3.78E-05	1.69E-05	0.00128	0.002085
Human toxicity (cancer)	cases	2.48E-11	9.93E-13	4.16E-12	2.78E-11	5.77E-11	4.96E-12	1.99E-13	8.32E-13	2.78E-11	3.38E-11	2.48E-12	9.93E-14	4.16E-13	2.78E-11	3.08E-11
Human toxicity (non-cancer)	cases	1.29E-11	1.12E-12	5.94E-13	3.31E-12	1.80E-11	2.59E-12	2.24E-13	1.19E-13	3.31E-12	6.24E-12	1.29E-12	1.12E-13	5.94E-14	3.31E-12	4.78E-12

Sports turf impacts are generally greater as more materials and energy are used for the installation and maintenance stages. The carbon footprint of sports turf actually becomes positive due to a lack of organic carbon build-up in the soil structure.



Recreational turf impacts are dominated by the Global Warming Potential in numerical terms. The majority of the negative carbon footprint in the one year scenario is the sequestration of CO₂ by the plant. In turf maintenance this sequestration is still through photosynthesis but it is stored in the soil carbon.

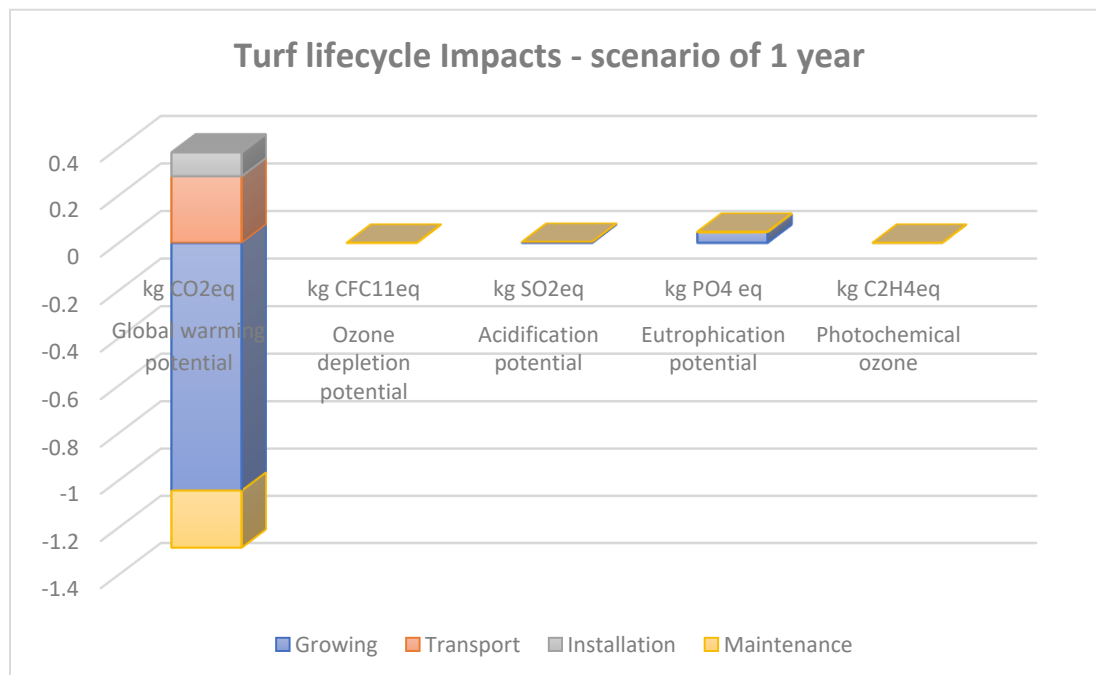


Figure 8. Recreational turf impacts

Eutrophication potential from fertiliser losses to water systems is the other impact that features here and is a cause for concern both from an environmental degradation viewpoint and an economic aspect to the turf farmer or the lawn owner.

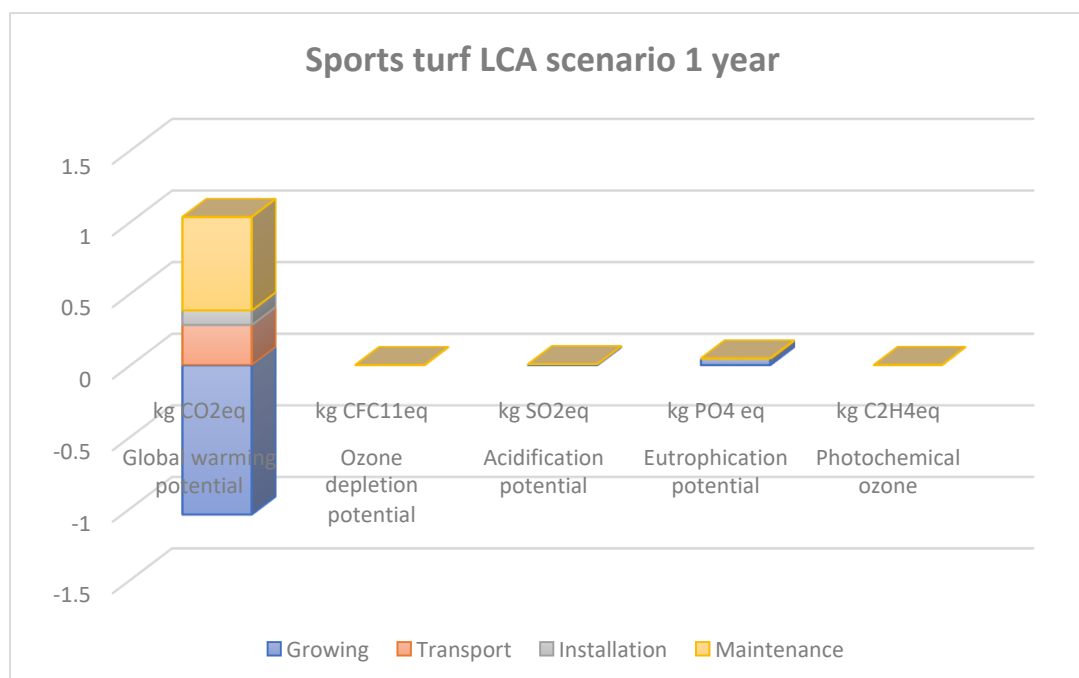


Figure 9. Sports turf impacts



Sports turf indicates a similar picture to recreational turf except that the Global Warming Potential for maintenance is positive rather than negative, due to the loss of the growth in soil carbon plus the higher energy and chemical use.

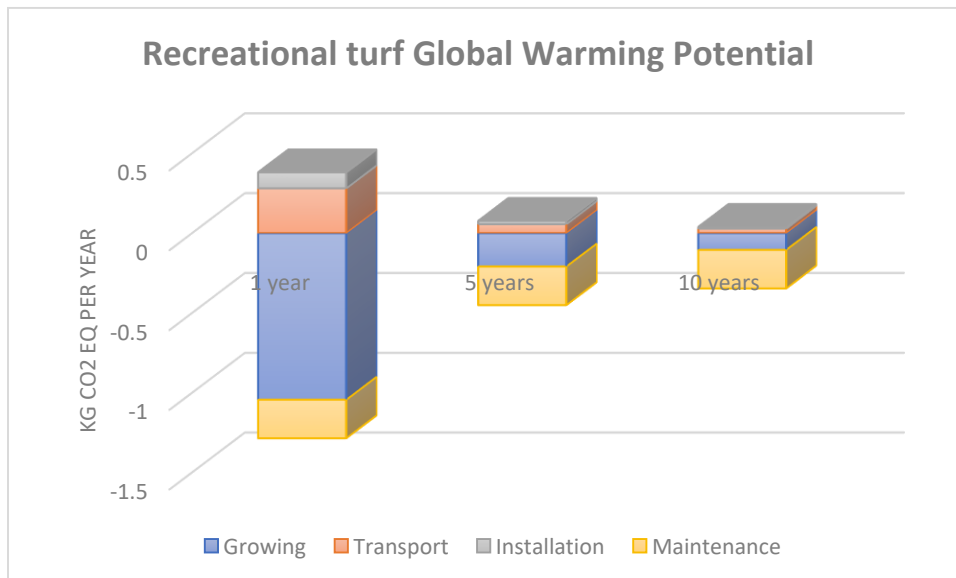


Figure 10. Recreational turf scenarios for global warming potential

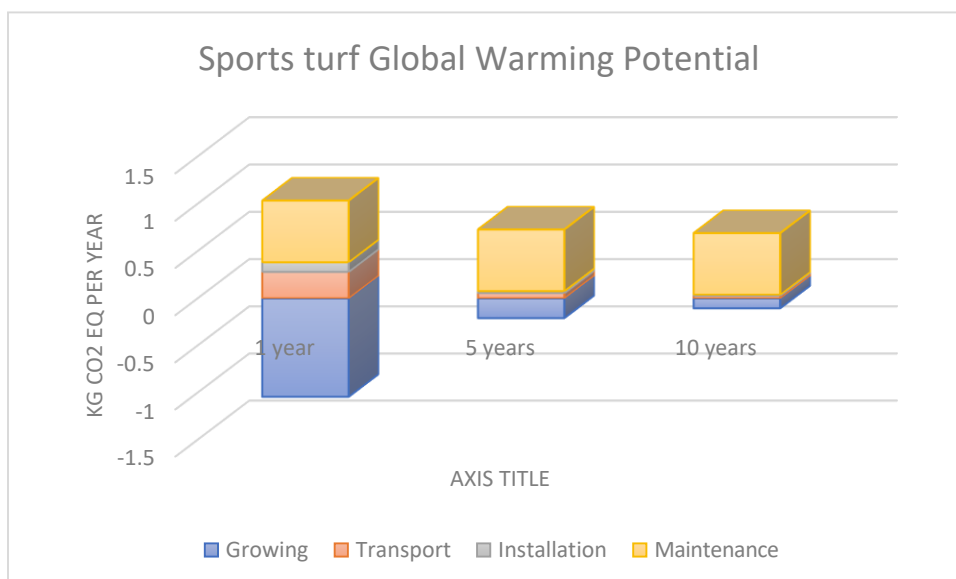


Figure 11. Sports turf scenarios for global warming potential

Sports turf does not provide a net benefit in negative carbon footprint after the first year of turf lifespan. In ten years the maintenance impacts predominate the full array of environmental impacts (not just global warming potential).

On the other hand recreational turf continues to sequester carbon through its lifespan and this impact outweighs the CO₂ emissions, due energy and fertiliser/chemical applications in this analysis. The interpretation here varies from other studies in which the energy use in park maintenance was



calculated to outweigh the build-up of soil carbon. In the study in question (Czimczik, 2010) energy from council uses other than lawn maintenance appeared to be included.

Resource consumption

Resource usage was measured by examination of the materials purchased, water consumption metered, land employed for growing and installation and energy bills. The energy embodied in materials such as fertilisers was included in calculations.

Resource use	Units /m ² /y	1 year	5 years	10 years
Abiotic depletion of resources (minerals)	kg Sb _{eq}	3.70E-05	8.87E-06	5.36E-06
Water use	m ³	6.13E-01	0.1625	0.10625
Land use	m ²	2.67E+00	0.534	0.267
Energy use	MJ	1.54E+01	4.094	2.047

Table 10. Resource use scenarios for recreational turf

Mineral resource depletion is minor compared to the consumption of water at 613 litre per m² of turf in the first year. Energy consumption at 15.4 MJ in the first year is significant and sets a measure for process improvement.

Toxicity

Toxicity is calculated from material usage from the LCI (inventory data). Toxicity is due to the nature of the chemicals used and lost to the environment in air emissions, water pollution and to land. The toxicity in air emissions from burning fossil fuels for energy is included with the direct toxicity of chemicals used on the turf that are lost to the environment.

Toxicity	Units /m ² /y	1 year	5 years	10 years
Fresh water toxicity	PAF.m ³ .day	8.66E-03	2.22E-3	1.42E-3
Human toxicity (cancer)	cases	3.19E-11	7.93E-12	4.93E-12
Human toxicity (non-cancer)	cases	1.58E-11	4.10E-12	2.64E-12

Table 11. Toxicity scenarios for recreational turf

The effect of turf on water ecotoxicity is significant while the human toxicity factors are more minor.

Lifecycle interpretation

The life cycle interpretation phase of the study is intended to analyse results, reach conclusions, explain limitations and provide recommendations based on the findings of the preceding phases of the study, and to report the results of the life cycle interpretation in a transparent manner (AS/NZS ISO 14044:2006).

The results of the LCA are generally conservative and err on the side of general industry performance rather than best practice. Nevertheless there is a wide range of variation in industry practice and environmental conditions that require this conservatism for the industry to be confident in putting forward this data.



Conclusions

Turf is a product that has the potential to provide a negative carbon footprint due to the sequestration of carbon dioxide from the atmosphere and also the build-up of carbon in the soils over many years of turf cover (G Zirkle, 2011). Turf growing exhibits a negative global warming potential calculated at 1.0 kg CO₂eq per m² of turf at the median grower performance. The net global warming potential per year in a 10 year scenario is 0.31 kg CO₂eq per m² of turf, or a total of 3.1kg CO₂eq per m² of turf over 10 years.

Resource depletion caused by material and energy use over the lifespan of turf is significant, particularly water use and energy consumption. This study sets a performance that can be used as a benchmark for industry improvement.

Ecotoxicity generated by the discharge of chemicals into waterways in particular and eutrophication of waterways from excess fertilisers is a concern that can be monitored by individual growers and lawn owners with the aim of impact reduction.

Identification of significant issues

While the study has been conservative in its claims there is a variation that is significant and can impact the confidence of claims made by individual growers.

Losses of fertiliser nitrogen as nitrate did not show build-up or losses of nitrate to the lower levels of the soil profile. This was unexpected and unexplained as the nitrogen loss to the soil and water systems was determined to be 60% at the mean grower performance.



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ENVIRONMENTAL PRODUCT DECLARATION

in alignment with ISO 14025

Owner of the declaration Infotech Research

Program holder Horticulture Innovation Australia Ltd

Publisher Horticulture Innovation Australia Ltd

Declaration no. tba

Issue Date tba

Valid to tba

Australian Turf – from Australian turf farms across Australia



**Hort
Innovation**
Strategic levy investment

**TURF
FUND**



General Information

	Turf grass Grown in Australia
Program holder Horticulture Innovation Australia Ltd Level 7, 179 Elizabeth Street Sydney NSW 2000	Owner of the declaration Infotech Research 17 Clowes Street South Yarra Victoria 3141
Declaration no. tba	Declared product / declared unit Living turf in a soil matrix 1 m ² turf
This declaration is based on Product Category Rules: PCRTurf v1.0	Scope: The declaration applies to all Australian grown turf presented as a slab or roll that incorporates the turf plant in a soil matrix. The declared environmental impacts refer to the median of a survey of 30 Australian grown turf products.
Issue date tba	Verification Independent verification of this declaration according to ISO 14025
Validity to	Signature:
Signature:	Name:
Name:	

Product

Product description

Turf is provided as “ready to lay” product in slabs or rolls, usually 600 mm wide by 1200 mm long. The turf grass can be any one of a range of grass varieties such as Buffalo, Couch, Kikuyu, Zoysia and many others.

The calculations refer to average conditions of the turf product 12.7 kg/m² for the product consisting of 1.4 kg/m² of plant matter and 11.3 kg/m² of supporting soil. This can vary from one product to the next, but is representative of the industry as a whole.

Application

Turf is laid on prepared ground and watered in for a period to encourage root growth into the substrate soil. The final application is most often for residential lawns. Other applications include parklands, gardens, nature strips and median strips along roadways. These applications are labelled as “recreational turf”.

A different type of application is used for sports fields and golf course tees and greens, which have more critical performance criteria and are labelled as “sports turf”. Installation and maintenance of sports turf is more intense and consumes more materials.



Declared unit

Name	Value	Unit
Declared unit	1	m ²
Conversion factor to kg	0.079	m ² /kg
Mass reference	12.7	Kg/m ²

The declared unit refers to 1m² of turf as the output of the growing stage of the lifecycle of turf.

System boundary

Type of EPD: Cradle to grave

System boundaries of stages growing, transport, installation and maintenance:

Growing

Energy in the forms of electricity and fuels used on the farm, manures, fertilisers, ag chemicals, irrigation water, mineral soil additives. Run-off and loss of materials to the environment is estimated from farm study results.

Transport

Packaging systems (pallets and netting wrapping) and fuels used for transport to installation site from the farm gate are calculated.

Installation

Added materials to prepare the surface and fertiliser used to promote the turf growth are considered. Water used to keep the plant turf alive and to promote root growth over the installation period. Installation is generally manual and no fuels or energy supply is used.

Maintenance

Inputs to maintenance included: fertilisers, herbicides and pesticides are determined on a yearly basis. Watering metered to the installation site is included and fuels used for mowing and rolling the turf in the case of sports fields.

End-of-Life

There is no end of life scenario as turf can remain alive indefinitely. Earth works for future states are not considered.

Input information

Growing inputs

Name	Unit / year	Value
Land use	m ² of land / m ² turf	1.67
Electricity	kWh/m ² turf	0.25
Diesel	L/m ² turf	0.12
Energy used	MJ/m ² turf	5.5
Water used	L/m ² turf	1078
Nitrogen	kg(N)/m ² turf	0.047
Phosphorus	kg(P)/m ² turf	0.016
Potassium	kg (K)/m ² turf d	0.021
Ag chemicals	kg / m ² turf	0.0019
Lime +	kg / m ² turf	0.092

Transport inputs

Diesel	L/m ² turf	0.088
LPG	L/m ² turf	<0.001
Polyethylene	Kg/m ² turf	0.003

Installation inputs

Topsoil (sand) 150 mm	kg/m ²	0.24
Fertiliser	kg/m ² total	0.07
	kg N/m ²	0.005
	kg P/m ²	0.006
	kg K/m ²	0.006
Water	m ³ /m ²	0.047

Maintenance inputs

Name	units	recreational	sports
Mowing	L/m ²	Petrol 0.018	Diesel 0.0128
Rolling and aerating	L/m ²		Diesel 0.0064
Watering	L/m ²	50	140
Fertilising	kg/m ²	0.024	0.50
Nitrogen	kg/m ²	0.0036	0.052
Phosphorus	kg/m ²	0.0012	0.014
Potassium	kg/m ²	0.0012	0.056
Mineral additives	kg/m ²	0.015	0.082
Ag chemicals	kg/m ²	0.00015	0.00019



LCA Results

The LCA results are produced here for two scenarios of turf use – recreational and sports fields. They are also produced for two end of life scenarios – 1 year of use and 10 years of use. The 10 year results are calculated by multiplying the maintenance stage of the lifecycle by 10, adding this to the other stages and dividing the total by 10. This has the effect of extending the impacts of growing, transport and installation over the 10 years of turf life.

Recreational turf scenario

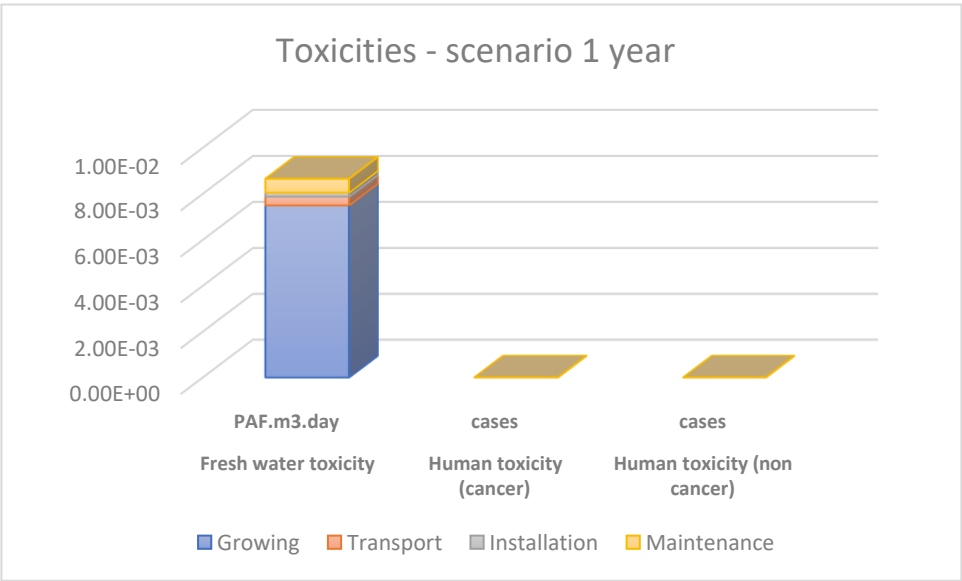
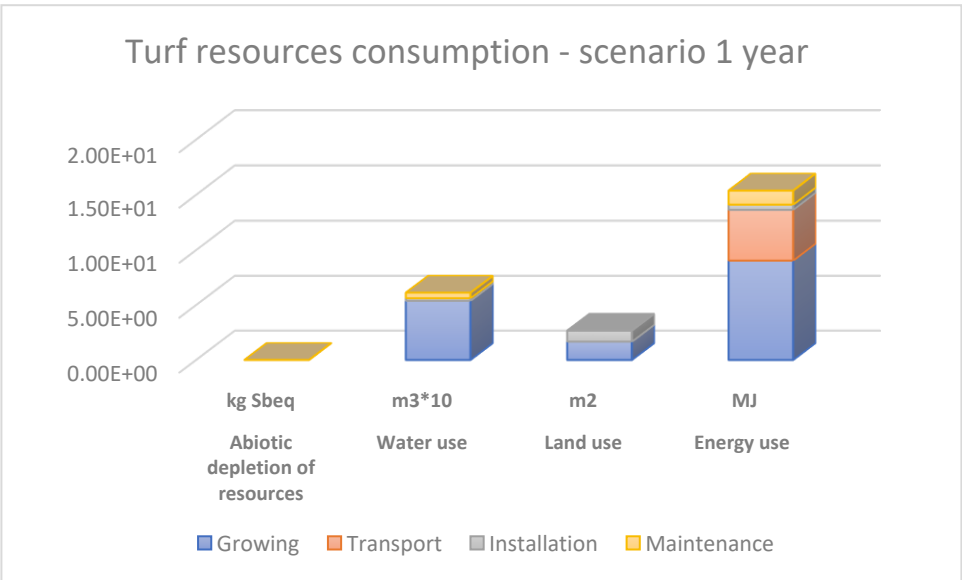
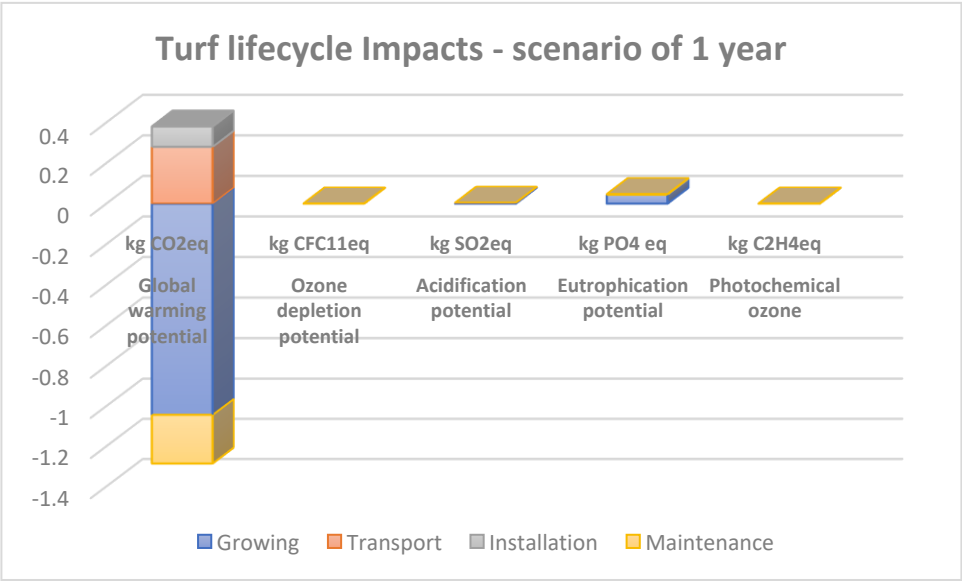
1 year lifespan							10 year lifespan				
Turf lifecycle stage	Units	Growing	Transport	Installation	Maintenance	Total /Y	Growing	Transport	Installation	Maintenance	Total /Y
Global warming potential	kg CO ₂ eq	-1.0432	0.2802	0.09985	-0.24189	-0.90504	-0.10432	0.02802	0.009985	-0.24189	-0.30821
Ozone depletion potential	kg CFC11eq	6.65E-08	3.3778E-08	2.5297E-09	7.3906E-09	1.1E-07	6.65E-09	3.38E-09	2.53E-10	7.39E-09	1.77E-08
Acidification potential	kg SO ₂ eq	0.00275	0.00045922	0.00045082	0.00022	0.00388	0.000275	4.59E-05	4.51E-05	0.00022	0.000586
Eutrophication potential	kg PO ₄ eq	0.04395	4.7931E-05	0.0000734	0.00226	0.046331	0.004395	4.79E-06	7.34E-06	0.00226	0.006667
Photochemical ozone	kg C ₂ H ₄ eq	0.000114	2.6258E-05	1.7089E-05	1.0445E-05	0.000168	1.14E-05	2.63E-06	1.71E-06	1.04E-05	2.62E-05
Resource Use											
Abiotic depletion of resources	kg Sbeq	2.75E-05	5.45E-07	7.11E-06	1.85E-06	3.70E-05	2.75E-06	5.45E-08	7.11E-07	1.85E-06	5.36E-06
Water use	m ³	5.39E-01		2.35E-02	5.00E-02	6.13E-01	0.0539		0.00235	0.05	0.10625
Land use	m ²	1.67E+00		1.00E+00		2.67E+00	0.167		0.1		0.267
Energy use	MJ	9.05E+00	4.60E+00	4.70E-01	1.27E+00	1.54E+01	0.905	0.46	0.047	1.27	2.047
Toxicity											
Fresh water toxicity	PAF.m ³ .day	7.50E-03	3.78E-04	1.69E-04	6.10E-04	8.66E-03	0.00075	3.78E-05	1.69E-05	0.00061	0.001415
Human toxicity (cancer)	cases	2.48E-11	9.93E-13	4.14E-12	1.94E-12	3.19E-11	2.48E-12	9.93E-14	4.14E-13	1.94E-12	4.93E-12
Human toxicity (non-cancer)	cases	1.29E-11	1.12E-12	5.78E-13	1.17E-12	1.58E-11	1.29E-12	1.12E-13	5.78E-14	1.17E-12	2.64E-12

Sports turf scenario

1 year lifespan							10 year lifespan				
Turf lifecycle stage	Units	Growing	Transport	Installation	Maintenance	Total /Y	Growing	Transport	Installation	Maintenance	Total /Y
Global warming potential	kg CO ₂ eq	-1.0432	0.2802	0.1017	0.65182	-0.00948	-0.10432	0.02802	0.01017	0.65182	0.58569
Ozone depletion potential	kg CFC11eq	6.647E-08	3.38E-08	7.42E-05	2.56E-08	7.44E-05	6.65E-09	3.38E-09	7.42E-06	2.56E-08	7.46E-06
Acidification potential	kg SO ₂ eq	0.00275	4.59E-04	4.55E-04	0.00259	0.006254	0.000275	4.59E-05	4.55E-05	0.00259	0.002956
Eutrophication potential	kg PO ₄ eq	0.04395	4.7931E-05	0.0000734	0.00226	0.046331	0.004395	4.79E-06	7.34E-06	0.00226	0.006667
Photochemical ozone	kg C ₂ H ₄ eq	0.000113	2.63E-05	1.72E-05	9.83E-05	0.000255	1.14E-05	2.63E-06	1.72E-06	9.83E-05	0.000114
Abiotic depletion of resources	kg Sbeq	2.75E-05	5.45E-07	7.16E-06	2.63E-05	6.15E-05	2.75E-06	5.45E-08	7.16E-07	2.63E-05	2.98E-05
Water use	m ³	5.39E-01		2.35E-02	7.00E-02	6.33E-01	0.0539		0.00235	0.07	0.12625
Land use	m ²	1.67E+00		1.00E+00		2.67E+00	0.167		0.1		0.267
Energy use	MJ	9.05E+00	4.60E+00	4.70E-01	4.76E+00	1.89E+01	0.905	0.46	0.047	4.76	3.792
Fresh water toxicity	PAF.m ³ .day	7.50E-03	3.78E-04	1.69E-04	1.28E-03	9.33E-03	0.00075	3.78E-05	1.69E-05	0.00128	0.002085
Human toxicity (cancer)	cases	2.48E-11	9.93E-13	4.16E-12	2.78E-11	5.77E-11	2.48E-12	9.93E-14	4.16E-13	2.78E-11	3.08E-11
Human toxicity (non-cancer)	cases	1.29E-11	1.12E-12	5.94E-13	3.31E-12	1.80E-11	1.29E-12	1.12E-13	5.94E-14	3.31E-12	4.78E-12

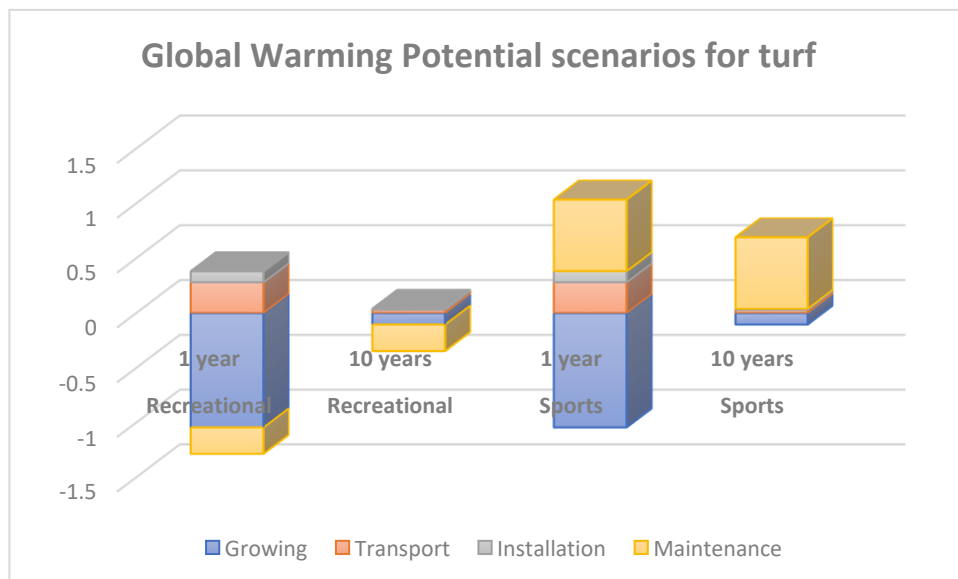


Graphical outputs for turf lifecycle impacts – recreational application





Global warming potential comparisons for recreational and sport applications



Notes in proof

1. Wastes are considered as losses of fertiliser components to the environment at 60% loss rates.
2. Turf clippings are predominantly left on the turf surface and clippings waste management is not considered.
3. The maintenance of turf results in a net growth of organic carbon in the soil that is incorporated in the Global Warming Potential results as a yearly carbon dioxide sequestration of 0.35 kg/m²/y. With sports turf there is no net growth in soil organic carbon, due to the growing medium being sand. Consequently there is a positive Global Warming Potential for each year of maintenance.
4. LCA modelling was undertaken by Kyle O'Farrell of Envisage Works using Open LCA software and the EcoInvent LCI database.

**Hort
Innovation**
Strategic levy investment

**TURF
FUND**

PRODUCT CATEGORY RULES

Environmental Product Declarations – Turfgrass in Australia

Identifier: **PCRTurf v1.0**

Date: July, 2019

Infotech Research

Introduction:

Natural turf or turfgrass is a living product with the potential to self-propagate for many years, or to be limited in lifespan to the duration of a particular installed environment. Turf is grown in Australia on turf farms situated across the continent. Turf or lawn covers a large area of residential Australia. It is maintained in parklands, golf courses and sports fields and provides a green and healthy living environment for human recreation.

As a natural product and a living plant, turf continues to grow throughout its life requiring sun, water and nutrients from the soil, water and air. Turf growing and maintenance equates to environmental impacts. This document has developed a set of boundaries and conditions to provide declarations on the environmental impacts (Environmental Product Declarations) of turf over its lifecycle.

This document is aimed to conform to the systems and limits specified in the standards ISO 14040, ISO 14001 and ISO14025, which cover environmental lifecycle assessment, environmental management systems and Environmental labels. It is also set to conform to the quality standard ISO 9001.

Definition of the product group – turf:

While turf can be grown on site through seeding, this specification pertains to the turf that is produced at a remote turf farm and transported to the installation site at which it is laid and maintained.

Turf is grown in large areas and then harvested by cutting under the turf, taking topsoil and the plant to a depth of 5 to 10 mm. Turf as a product is grown at the turf farm and sold as either slabs of turf or rolls that are palletised for transport. Varieties of turf grass are numerous and no attempt is made to specify the plant or to limit the range of grasses that conform to this description of turf.

Purpose of the Product Category Rules

These rules specify the conditions to be used in generating an Environmental Product Declaration (EPD) for turf in Australia over its lifecycle. This should enable better comparison of individual turf products on a basis of equal metrics over the same conditions.

These rules clearly state how a turf EPD is to be structured and what elements are required to meet this industry approach.

Environmental Product Declaration (EPD) specification

The EPD is required to contain the following information:

Section	Information required
Definition of the product group	Turf grasses that are living and packaged for transport Turf shall have a root system capable of growing in the soil medium it is bound to
Manufacturer The author needs to be given with signature to confirm authenticity. The EPD issue date is required along with a validity period.	Company name and contact details Site at which the turf was grown Environmental management on growing site Particular aspects of the turf production (An industry wide EPD may be defined as an alternative to a particular company and product)
Product specification	Species of turf Format dimensions of the slab or roll Packaging system Chemical additives applied
Functional unit	One square meter of turf (1m ²) Impacts expressed as unit per m ² of turf per year over the lifecycle of 1, 5 or 10 years
Measurement units	S.I. (metric)
Material content of product turf	Total weight (kg/m ²) Vegetable matter (kg/m ²) Soil content (kg/m ²) Moisture (%) Netting or wrap (kg/100 m ²)

System boundaries

These are defined as the major processes as indicated, including the input materials, listed on the left of the diagram and outputs on the right. Farm infrastructure is not included and neither is the infrastructure used in turf installation and maintenance.

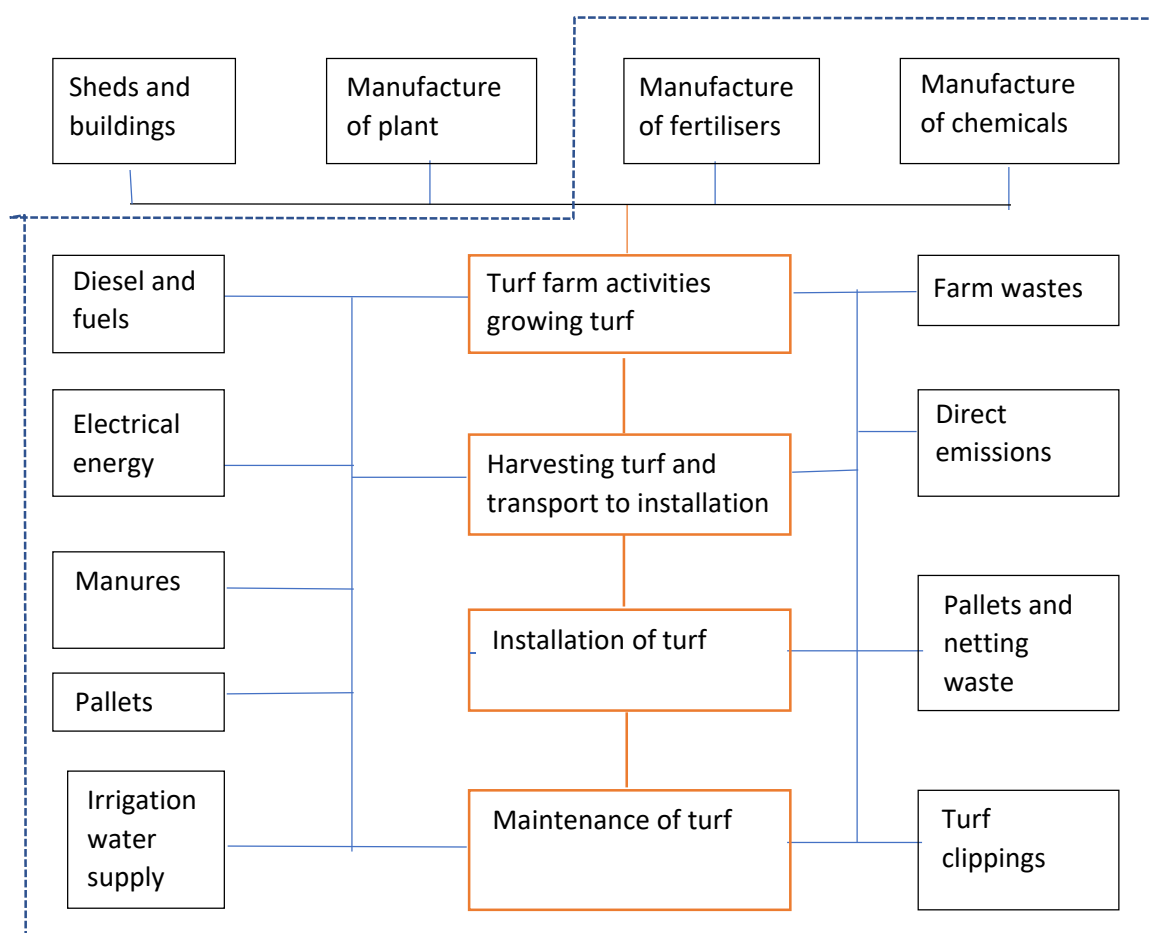


Figure Boundaries of the life cycle assessment of turf (blue dotted line)

System boundaries	Information required
Geographical	Site of growing Seasons and climate description Distance of transport to market (median)
Time	Growing cycle explained Harvest after cultivation Time from harvest to installation
Natural boundaries	Natural barriers Roads Waterways
Other product lifecycle intersections	Other businesses on the site Composting use of turf wastes if occurring

Cut off rules

In general the materials and energy allocations should cover 99% of the total of the flows through the system. If a greater material or energy amount is cut off, a justification in terms of the effect on the impacts must be provided. The effect on impacts should not be greater than +/- 5% in total.

Allocation rules

If a material is used within another product lifecycle, such as turf clipping wastes used as a raw material for composting or as fodder for animals, an economic allocation to the different product lifecycle impacts is to be made.

Alternatively the lifecycle boundaries can be expanded to include the other product.

Stages in the lifecycle of turf and process descriptions

Stage of lifecycle	Requirement
1. Growing turf	Process description
	Materials used at each point in the process (expressed as kg/m ² of turf produced)
	Energy used at each point in the process (fuels, electrical and thermal Expressed as L,kWh,MJ/ m ² of turf produced for each energy type)
	Water used for irrigation (m ³ /m ² of turf) Sources of water (volume split by source eg river water, ground water, recycled water...)
	Fertiliser usage expressed as N kg/m ² P kg/m ² K kg/m ²
	Ag chemicals usage in total expressed as Active herbicide kg/m ² Active pesticide kg/m ²
	Minerals added (lime dolomite, clays, sands accumulated expressed as kg/m ²
	Waste description and treatment
	Waste volumes (expressed as kg/m ²)
	Cut off can apply to shed wastes such as oils, drums, other packaging
2. Harvest and Transport to site	Process description
	Average distance to installations (km) Truck fuel consumption (L/m ² of turf)
	Netting or other wrapping material (kg/m ²)
	Pallet wastes if applicable (kg/m ²)
3. Installation	Process description
	Water used for irrigation (m ³ /m ² of turf) Sources of water (volume split by source eg river water, ground water, recycled water...)
	Fertiliser usage expressed as N kg/m ² P kg/m ² K kg/m ²
	Ag chemicals usage in total expressed as Active herbicide kg/m ² Active pesticide kg/m ²
	Minerals added (lime dolomite, clays, sands accumulated expressed as kg/m ²

Stage of lifecycle	Requirement
4. Maintenance	Process description (annual)
	Water used for irrigation (m^3/m^2 of turf) Sources of water (volume split by source eg river water, ground water, recycled water...)
	Fertiliser usage expressed as N kg/m^2 P kg/m^2 K kg/m^2
	Ag chemicals usage in total expressed as Active herbicide kg/m^2 Active pesticide kg/m^2
	Minerals added (lime dolomite, clays, sands accumulated expressed as kg/m^2
	Wastes and treatment used
	Waste volumes by type (kg/m^2)

Lifecycle assessment methods

Section	Requirement
Lifecycle Impact assessment method	Description of the method used, including the modelling software, the lifecycle impacts covered, and outputs which must be an internationally recognised system conforming to ISO14040
Assumptions used	Assumptions adopted should be described along with a suitable rationale
Lifecycle Inventory	This must be an internationally recognised lifecycle inventory (such as Ecolnvent or AUSTLCI database for Australian inputs and outputs) or data collected directly from study of the systems involved

Environmental midpoint impacts

The following impact categories represent a set of impacts that can be produced. This can be reduced to a smaller set depending on the purpose of the EPD and the modelling system used.

Environmental Impact category	Units	Explanation
Land use	m ²	Land area used for production of one square meter of turf. There is no change of land use as turf is produced on the same area of land continuously
Climate Change (Global Warming Potential)	kg (CO ₂ -eq)	This is a measure of the equivalent amount of carbon dioxide released into the atmosphere over a 100 year period. A negative value indicates that there is a net loss of carbon dioxide in the atmosphere
Ozone depletion	kg (CFC-11 _{eq})	Ozone depletion potential is measured as the equivalent amount of refrigerant CFC-11 emitted
Water consumption	m ³ (H ₂ O _{eq})	This is the amount of water consumed multiplied by the Water Stress Index averaged over Australia (WSI = 0.5)
Eutrophication	kg (PO _{4eq})	Eutrophication is taken as the sum of the nitrogen and phosphorus lost through run-off from the turf farm and installation that impinges on surface water systems. This is measured in phosphate equivalents
Acidification	kg (SO _{2eq})	The acidification potential associated with turf from emissions to land water and air of acidic chemicals express as sulphur dioxide equivalents
Photochemical Ozone formation	kg C ₂ H ₄ eq	Predominantly air emissions with photochemical oxidation potential that can convert oxygen to ozone in the troposphere measured as ethylene equivalents
Aquatic Ecotoxicity	P.A.F.m ³ .day	Potential Affected Fraction (of the ecosystem) for one cubic meter of water for one day
Toxicity Chronic (cancer) Acute (non-cancer)	Cases	Toxicity to human health and the environment measured using USEtox methods for acute and chronic toxicity. This is measured simply as the number of cases potentially caused by the outputs
Resource depletion Abiotic depletion (minerals)	kg Sb _{eq}	Total mineral stock abiotic depletion allowing for current reserves and the rate of de-accumulation expressed as kg of antimony
Resource depletion / Energy use	MJ	Fossil fuel abiotic use expressed as megajoules

Mid-Point Environmental Impacts and measures

LCA Results section

The lifecycle impacts can be calculated under differing scenarios for particular products and maintenance regimes. It is required to provide at least one set of LCA impact results for one year of maintenance, as well as the expected lifespan of approximately ten years.

1. A turf lifecycle of one year
2. A turf lifecycle of ten years

In these scenarios the impacts associated with growing, transporting, installing and maintaining the turf are totalled and then calculated on an annual or per year basis. Consequently the impacts of growing, transporting and installing the turf are amortised over the full lifecycle chosen (i.e. converted to an impact per year basis in all cases).

The outputs of the analysis are split between the four stages of the lifecycle for the three scenarios.

Impacts are given in a matrix showing the chosen impact categories referenced against the lifecycle stages.

Turf lifecycle stage	Units	Growing	Transport	Installation	Maintenance	Total /Y
Global warming potential	kg CO ₂ eq	-1.0432	0.2802	0.09985	-0.24189	-0.90504
Ozone depletion potential	kg CFC11eq	6.65E-08	3.3778E-08	2.5297E-09	7.3906E-09	1.1E-07
Acidification potential	kg SO ₂ eq	0.00275	0.00045922	0.00045082	0.00022	0.00388
Eutrophication potential	kg PO ₄ eq	0.04395	4.7931E-05	0.0000734	0.00226	0.046331
Photochemical ozone	kg C ₂ H ₄ eq	0.000114	2.6258E-05	1.7089E-05	1.0445E-05	0.000168
Resource Use						
Abiotic depletion of resources	kg Sbeq	2.75E-05	5.45E-07	7.11E-06	1.85E-06	3.70E-05
Water use	m ³	5.39E-01		2.35E-02	5.00E-02	6.13E-01
Land use	m ²	1.67E+00		1.00E+00		2.67E+00
Energy use	MJ	9.05E+00	4.60E+00	4.70E-01	1.27E+00	1.54E+01
Toxicity						
Fresh water toxicity	PAF.m ³ .day	7.50E-03	3.78E-04	1.69E-04	6.10E-04	8.66E-03
Human toxicity (cancer)	cases	2.48E-11	9.93E-13	4.14E-12	1.94E-12	3.19E-11
Human toxicity (non-cancer)	cases	1.29E-11	1.12E-12	5.78E-13	1.17E-12	1.58E-11

Example of LCA results table for one year of installation

These outputs can be graphed to visually display the information. This is commonly done for the “major” environmental impacts. Graphs can compare differing products as well as lifecycle processes.

Declaration verification

The EPD needs to be independently verified by a person with suitable knowledge of the LCA process and the product. This is a specific requirement of ISO14025. The verifier must sign off on the EPD and declare that they do not have any conflict of interest.