

Figure S1: The midpoint category results for climate change for 1 h of football on a pitch with either natural grass or performance infill.

Considering the individual results for Climate Change (CC), long-term, one finds that the contributions are equally distributed in the case of natural grass. While maintenance accounts for approximately 51% of the total impact, no singular flow in the entire system contributes over 10%, with the most relevant flows being silica sand, diesel, treatment of biowaste, and fertilizers for the grass. The cases including performance infill are quite similar as infrastructure steps, such as the construction of piping, infrastructure, or artificial are the same for all infill-types. As the wood-based infill features, bio-based input-material carbon dioxide equivalent emissions are the lowest among the fill-types. ELT shows 29.17 kg CO₂-equivalent which is already higher than the 24.71 kg CO₂-equivalent for natural grass. The biggest driver of this impact category is the disposal of the plastic infill at the end of its lifetime which is responsible for 50% of the impact in this category. The tyres used for the production were modelled with a “zero-burden”-approach and only the conversion to granulate was included in the LCA and only account for 3.34% of the total impact. This is different for EPDM, which was modelled to be made from virgin materials and accounted for much higher emissions for the infill subgroup. 66% (38% for disposal and 28% for production) of the total CC impact of 38.25 kg CO₂-equivalent stem from EPDM, exhibiting thus the highest value for all scenarios. Bauer et al. conducted a similar analysis for the Norwegian environmental agency and found that biobased infill has the lowest end-of-life impacts, followed by ELT and virgin rubber such as EPDM or TPE (Bauer et al., 2017). The overall findings are in line with those reported by Russo et al., who reported higher emissions for natural turf compared to ELT-infilled artificial turf by a factor of approximately 2.5 (Russo et al., 2022). Itten et al., whose data this study is largely based on, also reported lower emissions per playing hour for artificial grass. (Itten et al., 2020) The high difference in CC impact between recycled and virgin materials was also confirmed by Magnusson and Mácsik, who found that ELT only incurs 7.8% of virgin EPDM’s CC impact, which fits our 9.4% (production only, no EoL) (Magnusson & Mácsik, 2017). Climate change, short-term shows slightly higher impacts, albeit on a very similar trend and is thus presented in the Supporting Information.

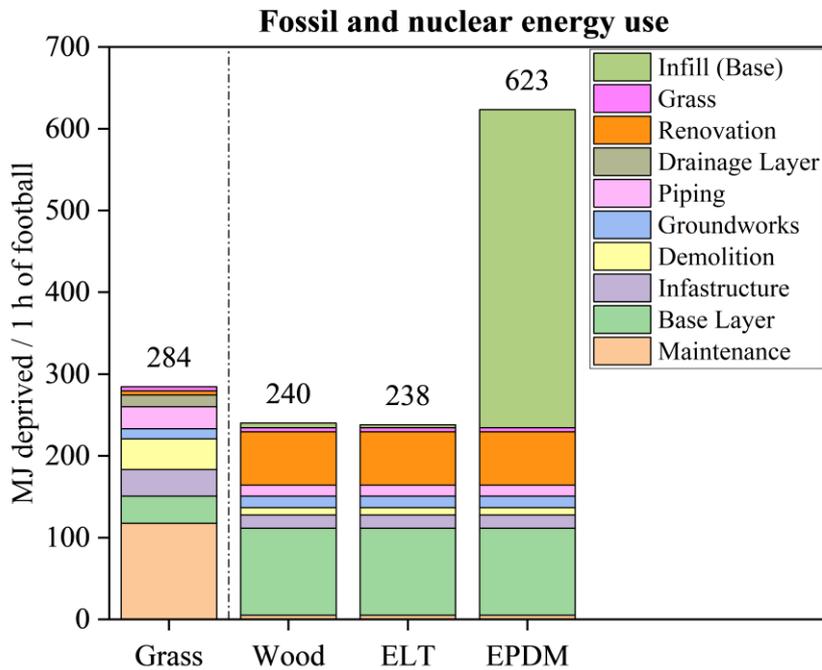


Figure S2: The midpoint category results for fossil and nuclear energy use for 1 h of football on a pitch with either natural grass or performance infill.

Commonly, fossil energy use qualitatively follows climate change trends in most case studies. This case is no exception, the bio-based infill exhibited the lowest results. ELT is very similar to wood-based infill, as comparatively little fossil energy is used because of the very clean Norwegian electricity mix, which is needed for the shredding. EPDM, however, does not have any of these advantages and shows by far the biggest impacts of 623.32 MJ / hour of football played. The contributions are distributed evenly for NT, with only two processes contributing over 10%, whereas for the AT cases, asphalt and gravel production have the highest contributions, in addition to infill production for EDPM.

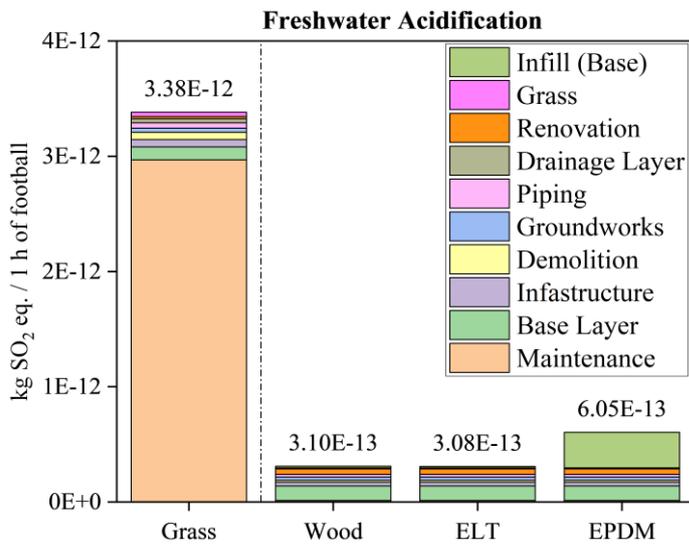
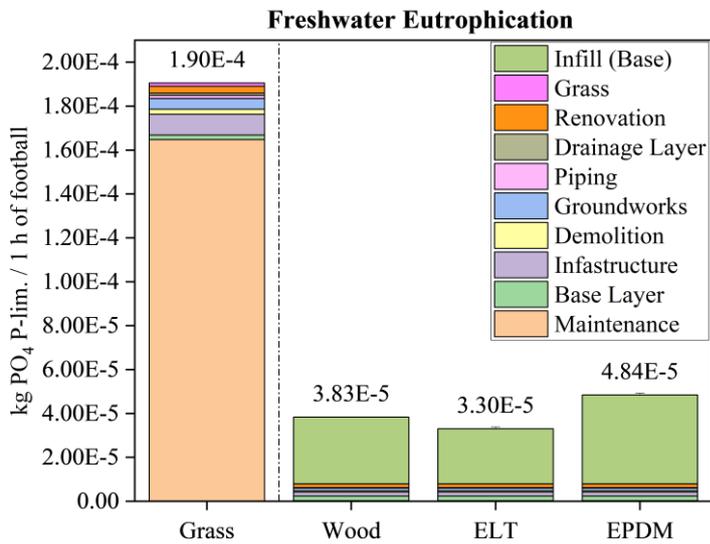
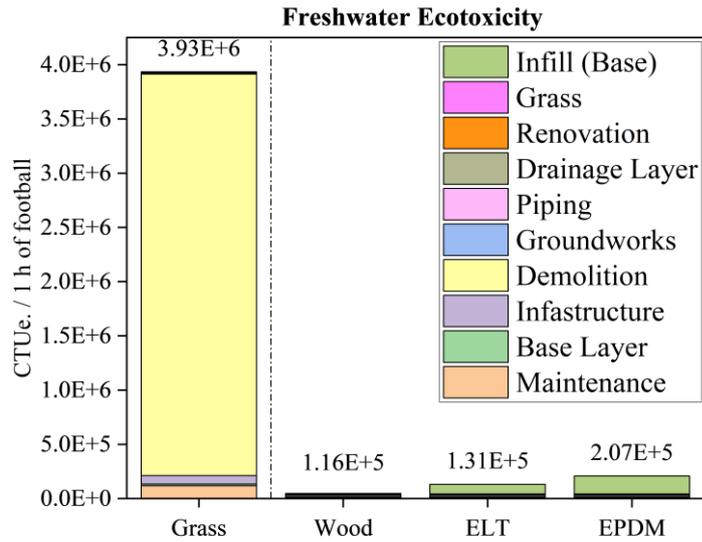


Figure S3: The midpoint category results for freshwater ecotoxicity, eutrophication, and acidification for 1 h of football on a pitch with either natural grass or performance infill.

Figure S3 shows impacts for freshwater ecotoxicity, eutrophication and acidification. Freshwater ecotoxicity is interesting, as NT has a value roughly 100 times higher than the wood-based infill and much higher in comparison to the other cases. 93.59% of the impact stem from the process “treatment of inert waste, sanitary landfill”, which is again almost solely coming from the emission flow of Aluminium III to the ground water. While patents suggest evidence that aluminium can be found in shock pads for sports fields, it is questionable if this is the case for all and if the material would really enter groundwater (Emborg, 2020; Vries, 2020). Freshwater eutrophication showed a similar trend to ecotoxicity, with NT having the highest impact, mostly due to maintenance with 86%. The most important contributions came from grass seed (25%), nitrogen (8%), and potassium (6%) fertilizers. In the case of artificial turfs, the infill contributes 70% for wood, 54% for ELT and 66% for EPDM to the total impact. ELT features the lowest total impact in comparison. In the case of the wood-based infill, the production is the main contributor, emissions of phosphorus to water, to be precise, for EPDM production and treatment contribute almost equally. Freshwater acidification is like eutrophication, as NT features the highest result by far, followed by EPDM, and much lower results for ELT and wood-based infill. In the case of NT, the impact is mostly generated by the emissions of ammonia to the air due to the fertilization process. Nitrous and sulfuric oxide(s) are also contributing elements to the impact of EPDM production, which is responsible for almost half of the total impact in the respective case study. For the other two case studies, the contributions mentioned are not relevant; therefore, the lowest results are reached. In these figures, construction-related flows are dominant, such as asphalt and gravel markets.

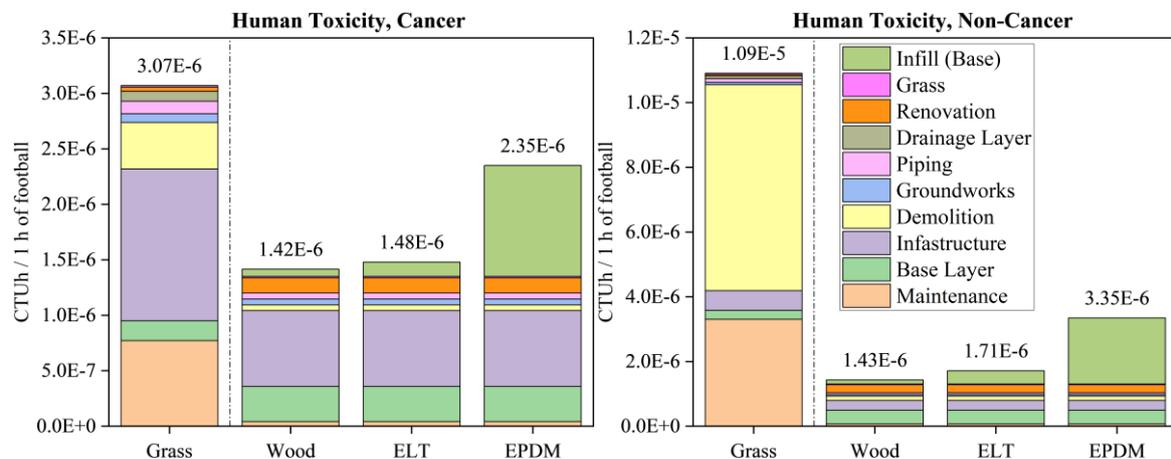


Figure S4: The midpoint category results human toxicity, cancer, and non-cancer for 1 h of football on a pitch with either natural grass or performance infill.

Human toxicity cancer and non-cancer results were similar and had the highest impact for natural turf again, followed by EPDM, ELT, and wood-based infill. For HTP-cancer, contributions are more heterogeneous, yet construction-focused processes dominate, such as markets for steel and reinforcing steel. In the case of natural grass, some flows contribute, such as the fertilizers, which simply do not exist in the artificial turf cases. In the case of EPDM, the production of virgin infill accounted for approximately 41% of the total. For HTP-non-cancer, fewer process steps dominate the overall results in the case of natural grass. The treatment of sanitary waste, discussed in freshwater ecotoxicity, contributed 57%, and the market for grass seeds was 20%. For wood-based and ELT infill, construction-related activities were the main

influences, such as gravel or concrete production, whereas in the EPDM case, virgin production led to 56% of the total emissions.

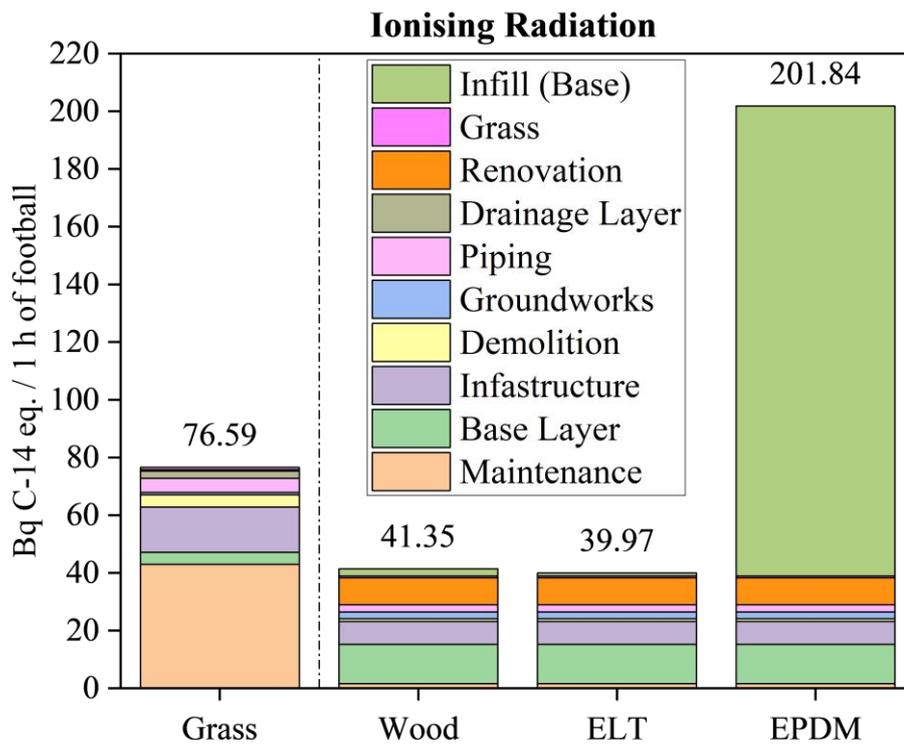


Figure S5: The midpoint category results for ionizing radiation for 1 h of football on a pitch with either natural grass or performance infill.

Ionizing radiation, presented in Figure S6 yields the lowest results for ELT and wood-based infill again, with 39.97 and 41.35 Bq C-14 eq. per hour of playing time, respectively. Natural turf shows 76.59 and EPDM infill 201.84 Bq C-14 eq. This result is because this impact correlates well with energy-intensive operations. For example, the natural turf case has contributions of 16% for nitrogen fertilizer, 10% for potassium fertilizer, and 7% aluminium production. Most of these processes are not found in artificial turf modelling, thereby creating a low impact, except for the EPDM infill, which is responsible for 80% of the overall impact.

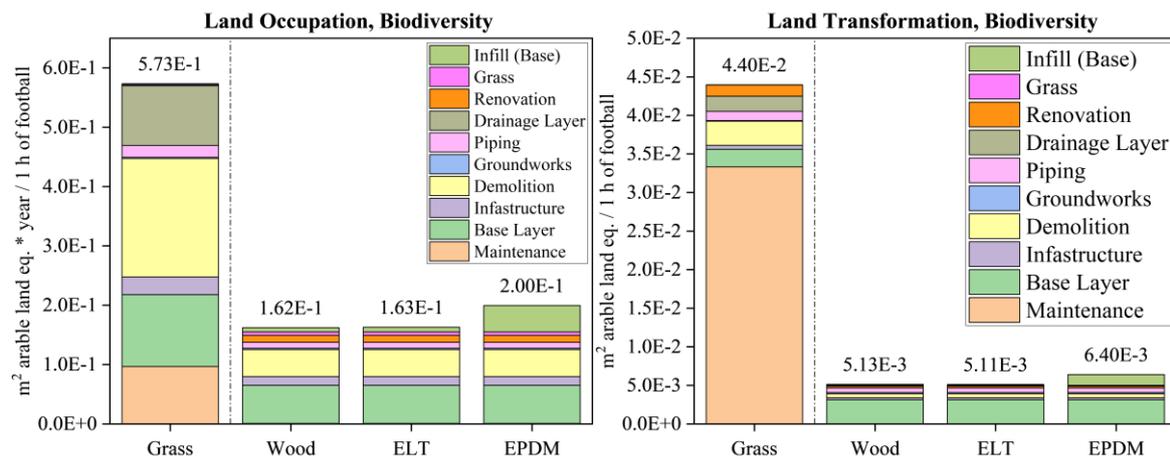


Figure S6: The midpoint category results for land occupation and transformation for 1 h of football on a pitch with either natural grass or performance infill.

For Land Occupation in natural grass, turf was the most important (35%) flow of inert waste, which has already been shown to influence freshwater ecotoxicity. Sand and silica sand in the base and drainage layer categories are also quite influential, as sand is known to have a high impact on land occupation and transformation. Wood-based infill is also dominated by asphalt production and disposal (approximately 40%) of gravel, sand, and concrete production. While the picture is virtually unchanged for the ELT infill, the EPDM infill has a higher impact as land occupation for the production facilities is included. This represents an imbalance, as the same is not true for wood-based infill and ELT production facilities, and should thus be treated with care.

Land transformation for natural turfs is heavily influenced by the alkyd paint used to draw the lines. 73% of the total impact could be attributed to this process. To be more precise, only one flow influences the results, "Transformation, to arable land, unspecified use." This is likely due to bio-based inputs for alkyd paint production, such as vegetable oils (Alam et al., 2014; Ifijen et al., 2022; Kumar et al., 2008). As the LCI is mostly based on Itten et al., we did not investigate why the paint is not used on the artificial pitches; however, there are alkyd paints for synthetic turfs available for purchase. While the result would be higher for natural grass even without alkyd paint, it still creates a massive discrepancy and should be investigated in further studies with a different focus. In addition to the paint, the results for the pitches were similar to the previous category, mostly hailing from the production of building materials such as concrete, sand, or gravel.

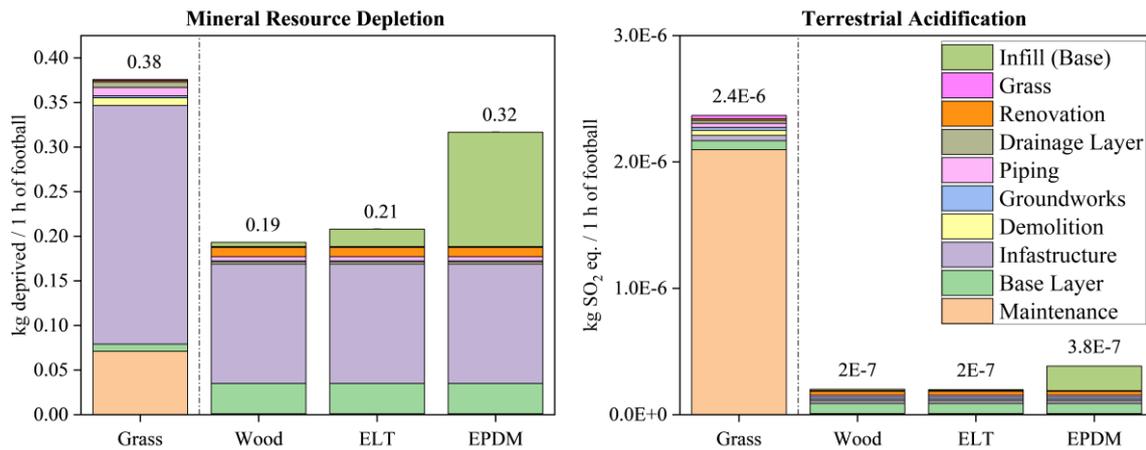


Figure S7: The midpoint category results for mineral resource depletion and terrestrial ecotoxicity potential for 1 h of football on a pitch with either natural grass or performance infill.

The results for photochemical oxidant formation are presented in Figure S8. The natural turf and EPDM-infilled artificial turf show 0.14 kg NMNOV eq. per 1 h of football, while wood-based infill and ELT exhibited a value of 0.073 kg NMNOV eq. In this category, diesel plays a major role for natural grass, due to the nitrous oxide compounds being emitted. For other infills, gravel and asphalt production were dominant. This fits well, as these production routes also involve heavy machinery. Ozone Layer Depletion, also in Figure S8 exhibits a similar trend between results, only with the difference that artificial grass has a lower impact than EPDM infill. For AT, fertilizers and pesticides have the greatest impact, while wood-based and ELT infill mastic asphalt production accounts for more than 50% of the damage. With EPDM, infill production has the largest share, with a 61% increase in the environmental load compared to the recycled ELT infill material.

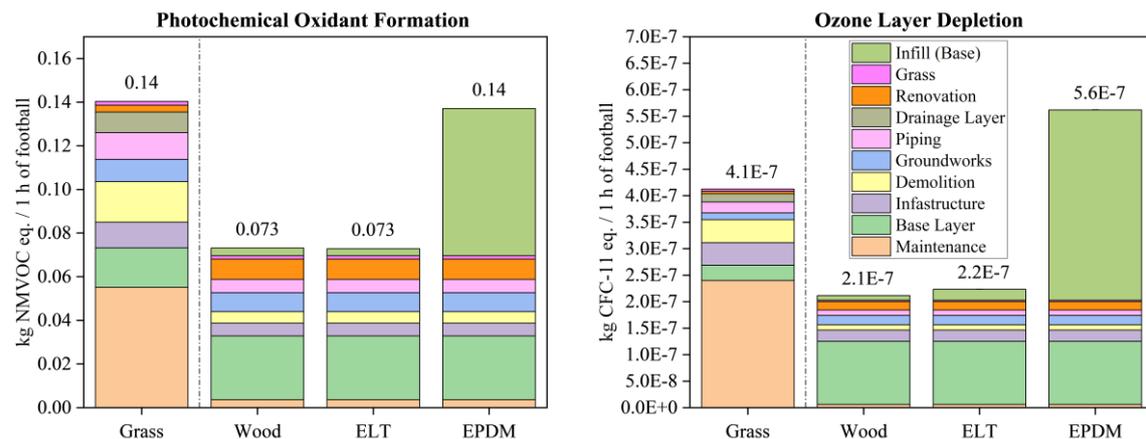


Figure S8: The midpoint category results for photochemical ozone depletion potential and ozone depletion potential for 1 h of football on a pitch with either natural grass or performance infill.

Water related midpoint categories such as marine eutrophication and water scarcity are shown in Figure S9. For marine eutrophication natural turf shows an extremely high impact, when compared to other infill materials, mostly due to nitrate released during the maintenance process. For the infilled-turfs asphalt and gravel production are again the main contributors, however on a much lower level than artificial grass. Water scarcity is very straightforward, as

irrigation is the most important contributor throughout the cases (72%, 64%, 60%, and 34%, respectively). Naturally, natural grass has a high need than artificial turf, thus explaining the higher impact for NT. As EPDM features production of virgin materials, a higher impact with 72.7 m³ world eq. was recorded as water is also consumed for the production.

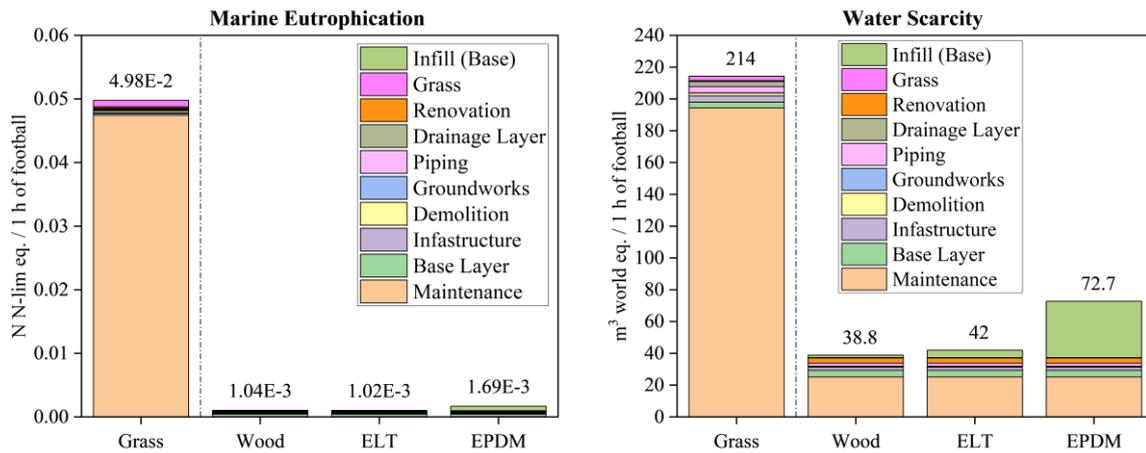


Figure S9: The midpoint category results for marine eutrophication and water scarcity for 1 h of football on a pitch with either natural grass or performance infill.

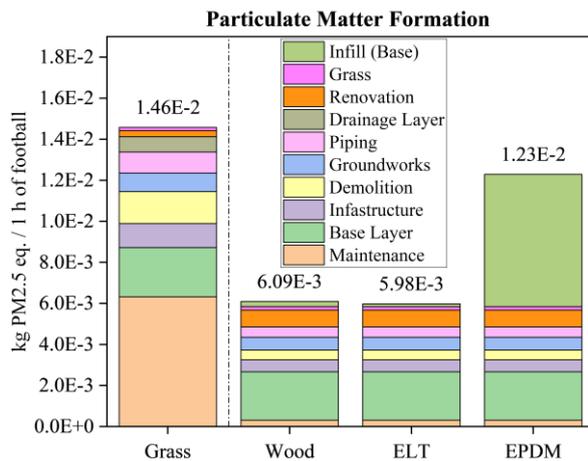


Figure S10: The midpoint category results for particulate matter formation for 1 h of football on a pitch with either natural grass or performance infill.

Ultimately, the results are similar to many other midpoint categories, as wood and ELT infill have the lowest impacts, while EPDM and natural grass take a higher toll on human health. The contributions are spread out again, with the main contributors being diesel consumption, gravel and sand production, and the production of virgin rubber for the EPDM.

References

- Alam, M., Akram, D., Sharmin, E., Zafar, F., & Ahmad, S. (2014). Vegetable oil based eco-friendly coating materials: A review article. *Arabian Journal of Chemistry*, 7(4), 469–479. <https://doi.org/10.1016/j.arabjc.2013.12.023>
- Bauer, B., Egebæk, K., & Aare, A. K. (2017, November). *Environmentally friendly substitute products for rubber granulates as infill for artificial turf fields* – Miljødirektoratet. Miljødirektoratet/Norwegian Environment Agency. <https://www.miljodirektoratet.no/publikasjoner/2018/januar-2018/environmentally-friendly-substitute-products-for-rubber-granulates-as-infill-for-artificial-turf-fields/>
- Emborg, M. (2020). *Drainage structure* (European Union Patent EP3670743A1). <https://patents.google.com/patent/EP3670743A1/en>
- Ifijen, I. H., Maliki, M., Odiachi, I. J., Aghedo, O. N., & Ohiocheoya, E. B. (2022). Review on Solvents Based Alkyd Resins and Water Borne Alkyd Resins: Impacts of Modification on Their Coating Properties. *Chemistry Africa*, 5(2), 211–225. <https://doi.org/10.1007/s42250-022-00318-3>
- Itten, R., Glauser, L., & Stucki, M. (2020). *Ökobilanzierung von Rasensportfeldern: Natur-, Kunststoff- und Hybridrasen der Stadt Zürich im Vergleich* (p. 124). Zürcher Hochschule für angewandte Wissenschaften, ZHAW. https://digitalcollection.zhaw.ch/bitstream/11475/20774/3/2020_Itten-Glauser-Stucki_Oekobilanzierung-Rasensportfelder.pdf
- Kumar, A., Vemula, P. K., Ajayan, P. M., & John, G. (2008). Silver-nanoparticle-embedded antimicrobial paints based on vegetable oil. *Nature Materials*, 7(3), Article 3. <https://doi.org/10.1038/nmat2099>
- Magnusson, S., & Mácsik, J. (2017). Analysis of energy use and emissions of greenhouse gases, metals and organic substances from construction materials used for artificial turf. *Resources, Conservation and Recycling*, 122, 362–372. <https://doi.org/10.1016/j.resconrec.2017.03.007>
- Russo, C., Cappelletti, G. M., & Nicoletti, G. M. (2022). The product environmental footprint approach to compare the environmental performances of artificial and natural turf. *Environmental Impact Assessment Review*, 95, 106800. <https://doi.org/10.1016/j.eiar.2022.106800>
- Vries, L. D. (2020). *Shock pad for artificial sports fields* (World Intellectual Property Organization Patent WO2020104523A1). <https://patents.google.com/patent/WO2020104523A1/en>