Per- and Polyfluoroalkyl Substances and the Non-Road Equipment Industry

Executive Summary

Original Equipment Manufacturers (OEMs) recognize the importance of identifying and addressing the risks associated with their products, whether from operator safety concerns, engine emissions, or chemical management issues. Equipment manufacturers are committed to addressing these issues by serving as a catalyst for innovation and working to educate the public and policymakers on our viewpoints and solutions to these important questions.

The non-road equipment manufacturing industry design products to satisfy various safety, regulatory, durability, quality, and customer requirements to effectively operate in various extreme and demanding environments with lifespans measured in decades. OEMs utilize a mixture of old and new technologies to meet their company goals, with Per- and Polyfluoroalkyl Substances (PFAS) performing a variety of essential use functions to help achieve success. It is crucial to understand, that without the functionality of certain PFAS, the introduction of future non-road products able to meet air quality, climate, safety, durability, waste, sustainability, and alternative power goals will be impossible.

Select PFAS Essential Use Functions:

- **Seals:** Sealing technology prevents fluid leaks and contamination from water, dirt, dust, and debris. PFAS is the only chemical family known to provide the combination of thermal stability, chemical resistance, low frictional characteristics, and sealing capabilities required to operate in harsh machine environments.
- **Hoses:** Hoses transfer fluids and prevent leaks while maintaining the cleanliness of various components and systems. Many hoses contain fluoropolymer coatings to ensure the long-term durability of the component.
- **Hydraulic systems:** PFAS is an additive in hydraulic fluid and lubricant to reduce surface tension, prevent fires, reduce evaporation, and provide corrosion resistance.
- **Refrigerant:** The non-road industry utilizes PFAS to satisfy various health and safety requirements to cool down equipment operators.
- **Alternative Power technologies:** PFAS provides the functional characteristics required to develop new alternative power technologies, including batteries and hydrogen fuel cells.

The non-road industry understands the unique hazard characteristics and environmental concerns associated with certain PFAS chemicals. AEM also recognizes the continued interest in public health and environmental issues by legislators and regulatory officials. With these considerations in mind, AEM recommends the following policy proposals for governmental decisionmakers to consider when developing future PFAS requirements:

- Adoption of a single harmonized list of PFAS chemicals
- Prioritize future regulatory efforts on high risk PFAS chemicals and end-use applications
- Focus regulatory efforts on PFAS chemical release prevention, waste disposal, material handling, recycling and environmental remediation.
- Provide enough time for equipment manufacturers to manage any regulatory requirements placed on the use of select PFAS in the manufacturing environment.
- Provide specific exemptions to aftermarket parts and components to protect against the premature obsolescence of in-service equipment.
- Collaborate with Industry stakeholders to realize meaningful and achievable outcomes.

Introduction to AEM and the Non-Road Equipment Industry

The Association of Equipment Manufacturers (AEM) is the North American-based international trade group representing off-road equipment manufacturers and suppliers with more than 1,000 member companies and over 200 product lines across five diverse industry sectors. Our members develop and produce a wide range of products, technologies, components, and systems that ensure non-road equipment remains safe and efficient, while operating in some of the most demanding and severe environments on earth with a product life cycle measured in decades.

AEM strives to provide industry expertise to decision-makers to help ensure their policy objectives are based on sound science and accurate data. AEM endeavors to consider viewpoints from all stake-holders to better understand the practical realities and challenges associated with regulating and restricting the use of Per- and Polyfluoroalkyl Substances (PFAS) chemicals

Non-Road Equipment

Under the broadest definition, non-road equipment are machines designed to execute specific functions relative to their intended applications in non-road environments. These end uses include operating in the construction, agriculture, mining, forestry, and utility sectors. More specifically, non-road equipment can be broken down even further into more specific categories based on their operations and functionality:

- Equipment that is self-propelled or serves a dual purpose by both propelling itself and performing another function.
  Examples: excavators, tractors, dozers, front end loaders, rough terrain forklifts
- Equipment intended to be propelled while performing its function.
  Example: chippers, plows, cultivators, wagons
- Large-scale fixed installations include a combination of several types of apparatus and, where applicable, other devices intended to be used permanently in a pre-defined and dedicated location.
  Example: tower cranes, light towers, generators, crushers and screeners

This variability of end-uses leads to a large swath of diverse machine forms and product types across the non-road sector. On their own, each machine may possess a unique supply chain that runs ten (10) to fourteen (14) layers deep, with ten thousand unique suppliers scattered throughout the world, and around one-hundred thousand (100,000) individual parts per machine. Due to their size and complexity, non-road machine should be viewed less as a single product and more as a complex collection of parts, components, systems and technologies, designed to perform specific functions in a variety of environments over a product life cycle measured in decades. As much as the non-road industry may resemble and intertwine with other industries, it is important to recognize these unique features and idiosyncrasies.

Introduction to PFAS

Per- and polyfluoroalkyl substances (PFAS) are a large group of synthetic organofluorine chemical compounds characterized by linear or branched carbon-fluorine chains connected to a functional group. The PFAS class contains thousands of chemical entities, however the exact number of PFAS chemicals can vary greatly depending on the specific definition and reference source. For instance, the Environmental Protection Agency's (EPA) toxicity database lists over 10,000 unique PFAS chemical substances[1], whereas the Organization for Economic Co-Operation and Development (OECD) identifies roughly 5,000 under their own classification system[2].

With such a large and diverse family, individual PFAS can vary widely in their chemical and physical properties, environmental fate, mobility, degradation, and toxicity profiles. These characteristics will differ based on the carbon chain length, degree of fluorination, overall chemical structure, and extant functional groups. For many industries, including the non-road sector, PFAS chemistries are selected to provide high thermal and chemical stability, a resistance to heat, pressure, chemical, and friction stressors, as well as very low surface tensions, making them repellent to both water and oil.

Despite the numerous useful applications of PFAS, the global regulatory community are expressing concerns over its historic uses and proliferation around the world. Various legislative and regulatory bodies are moving quickly to address these concerns. For example, as of this writing, there have been over 203 legislative and regulatory actions across 31 U.S. states.[3] In seeking to address these concerns, this recent governmental activity risks industry's access to many, if not all, of these valuable chemistries. To ensure a science-based approach that appropriately differentiates between the types of substances in this class, it is imperative that both regulators and regulated stakeholders have a consistent and meaningful understanding of these substances, their uses, and potential risks.

PFAS Use Cases in Non-Road Equipment

The non-road equipment industry, defined by its diverse end-use applications, harsh working environments, and extremely long product lifecycles, demands unique material solutions to meet the safety, environmental and performance requirements of the marketplace. Future regulatory, customer, and societal pressures will continue to push this sector to develop and adopt new technologies to tackle global policy concerns, especially issues around climate change, engine emissions, circular economy concepts, enhanced recycling, energy usage, and sustainable supply chain issues. This complex mixture of impending market conditions requires industry access to distinctive material chemistries to accomplish these goals. Due to their highly specialized and unique properties, PFAS chemicals help provide a critical building block for

1 https://echo.epa.gov/tools/data-downloads/national-pfas-datasets#:~:text=PFAS%20are%20identified%20using%20EPA's,last%20updated%20in%20August%202021.
2 chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV-JM-MONO(2018)7&doclanguage=en
3 https://www.washingtonpost.com/health/2022/11/05/plastic-pfas-chemical-health-dangers

OEMs to meet these objectives. While some industries may find alternatives to specific PFAS applications with sufficient research and development, there are many critical uses which cannot be replaced. Broad restrictions on PFAS will damage product innovation and could render future technology development goals impossible to achieve.

PFAS Essential Use Cases

Manufacturers design their products to operate for decades under extremely harsh, demanding and arduous work environments. Equipment materials, parts, and components need to meet rigorous design and testing requirements to ensure critical product functions continue to operate safely and effectively on the jobsite. With their many useful chemical and physical traits, PFAS provide crucial characteristics necessary to meet various equipment design challenges.

- **Seals:** All non-road machines use fluids to ensure the equipment continues to perform their intended functions. Fluid applications include hydraulic fluid, oil, fuel, refrigerants, coolant, among others. Sealing technology, such as O-rings and gaskets, prevents fluid leaks and ensures water, dirt, dust, and debris stays out of the equipment.

  Properly designed seals must meet various design characteristics to ensure they operate in a reliable, continuous, and efficient manner. The mechanical functions inside a non-road vehicle exposes parts and components to various stressors:

  - Pressure - various systems, such as the hydraulic and engine systems, experience extreme pressure environments up to 500 bar.
  - Temperature - the engine compartment and exhaust system operate at temperatures as high as 800 °C.
  - Chemical - seals interact with various fluids, requiring a high degree of chemical and corrosion resistance to ensure the continued operation of exposed parts.
  - Mechanical – machines possess a high degree of mechanical wear and tear, sealing parts must survive the shear forces due to the mechanical movement of the equipment.

  PFAS are the only chemical family known to provide the combination of thermal stability, chemical resistance, low frictional characteristics, and sealing capabilities required to operate in this harsh machine environment. Several PFAS chemicals, known broadly as fluoropolymers, which include Polytetrafluoroethylene (PTFE), Fluoroelastomer (Viton), and Polyvinylidene fluoride (PVDF) possess many of these crucial chemical traits and have no known substitutes, making them irreplaceable for the heavy equipment non-road industry.

  Replacing PFAS with inappropriate material substitutes would compromise the functionality of corresponding parts and components, ensuring increasing failure rates, fluid leaks, safety issues, and shorter vehicle lifetimes.

- **Hoses:** Similar to seals, hoses are required to transport fluids from one location to another, prevent fluid leaks, and maintain the cleanliness of the equipment's components and systems. Many hoses in the off-road industry use fluoropolymers to safeguard the durability of the machine by protecting its components from various internal pressure, temperature, and chemical stressors.

Under these conditions fluoropolymer lined hoses, especially those with PTFE, provide a necessary level of protection to ensure the durability and long-term reliability of the component. There are no known viable alternatives for PTFE used in hoses. Alternatives, such as rubber hoses, provide less durability, as well as decreased flexibility and strength over time. Inappropriate alternatives will result in increasing fluid leaks, damage to the machine, loss of fluid power, and increasing safety risks for the operator.

- **PTFE Tape:** Over the operational lifetime of a machine, leaks will inevitably occur. Operators looking to fix fluid leaks from seals and hoses require the appropriate materials to withstand the normal operating conditions found inside non-road equipment. PTFE tape provides this level of assurance.
- **Hydraulic Fluid:** Hydraulic fluid enables the transfer of power from the engine to end-use hydraulic systems. The vast majority of non-road equipment rely on hydraulic systems to carry, push, dig or lift heavy loads. Without this important technology, much of the work performed today would require radically different, and less efficient, technology solutions. Prominent examples of machines and systems that use hydraulic power include excavators, cranes, forklifts, lifts, dozers, graders, loaders, shovels, trenchers, and concrete pumping systems, among others.

Hydraulic fluids must possess a variety of crucial properties to protect the longevity of the hydraulic system and its components. In turn, the durability of these systems helps ensure that the machine continues to operate in a safe and efficient manner. Pin hole leaks, sudden drops in pressure, or contamination of the fluid can all cause serious safety issues for the operator or maintenance team. To avoid these types of safety concerns, hydraulic fluid producers utilize certain PFAS based chemicals to provide the corrosion, chemical, temperature and wear resistance needed for the system to operate smoothly.

- **Refrigerants:** Temperature management is a crucial product design requirement in the non-road sector. Many machines have enclosed operator cabins near large diesel engine exhaust systems, with few options for ventilation due to environmental concerns. Ensuring equipment operators remain comfortable while working is an important safety and comfort feature needed in modern machines.

Ideal refrigerants need to possess non-corrosive and non-toxic characteristics with a low global warming potential (GWP), zero ozone depleting potential (ODP) and a low boiling point. Most widely adopted refrigerants, such as hydrofluorocarbons (HFCs), hydrofluoro-olefins (HFOs), and hydrochlorofluoroolefins (HCFO's) are used extensively in the automotive, aerospace and non-road sectors. These substances break down quickly in the atmosphere into substances that naturally occur in the environment. Unlike most PFAS chemicals of concern, which may last thousands of years without breaking down, most modern refrigerants have an atmospheric lifetime measured in days, months and in some cases years.

Due to the inconsistencies in defining what is, and what is not, a PFAS chemical, refrigerants sometimes find themselves included with this larger group. Refrigerants, such as HFC-134a and HFO-1234yf, may find themselves in scope of certain PFAS regulatory requirements despite possessing none of the chemical attributes or risk profiles which make PFAS a concern to policymakers. An accurate assessment of these substances using scientifically accurate definitions would help exclude them from the broader definition of a PFAS seen in recent legislative and regulatory actions.

- **Paints:** Coatings protect non-road equipment from chemical, weather, or water erosion. Well-designed coatings can help extend the useful life, and maintenance requirements, for non-road products, and are highly valued by OEM's and their customers. Many coating providers use PFAS in their paints to improve the flow, spread, and glossiness of the coating, as well as to decrease bubbling and peeling. They are also used in specialty paints to give stain-resistant, graffiti-proof, and water-repellent properties.
- **Alternative Power:** Policymakers have long sought to reduce the emissions of criteria pollutants and decarbonize the non-road sector. OEMs and engine manufacturers are looking at many new alternative power sources and technology solutions to meet their ESG goals. While the industry will continue to innovate and experiment in this space, it is clear that PFAS chemistries will play a crucial role in many of these future developments. Two of the most widely discussed technology solutions, batteries and hydrogen fuel cells, use PFAS to fulfill crucial functionality.
  - Batteries utilize chemical binders to hold the internal active materials together to maintain a strong contact between the electrodes and the current collectors. Battery manufacturers use Polyvinylidene Fluoride (PVDF) as a binder in lithium-ion batteries due to its electrochemical and thermal stability, as well as its acceptable binding properties for the cathode. Additionally, certain fluorinated compounds are also used to coat the anodes to prevent unwanted reactions with the electrolyte. Due to their long lasting and chemical stable properties, the fluorinated compounds help extend the useful life of the battery.

    Under standard industry practices, batteries are manufactured in clean-room conditions, preventing the release of any PVDF into the surrounding environment. These closed conditions make it impossible for any PFAS materials to escape. Furthermore, battery recycling operations recover the PVDF through hydrometallurgical treatment processes. The collected PVDF is further broken down and captured by gas scrubbers, preventing any further release.
  - Hydrogen fuel cells use a proton exchange membrane (PEM) to separate the anode and the cathode. The PEM uses fluoropolymers to separate the protons from the electrons at the membrane surface, allowing only the protons to permeate to the cathode. In this technology, the fluoropolymers provide crucial properties that enable the fuel cell to produce electricity. The fluoropolymers used in the fuel cell PEM have no known alternative replacement.
- **Other examples:** fire retardants, electrical insulation (Equipment), personal protection equipment including gloves/shielding/aprons (e.g. Nitrile, Viton)

Risk to Public Policy Goals

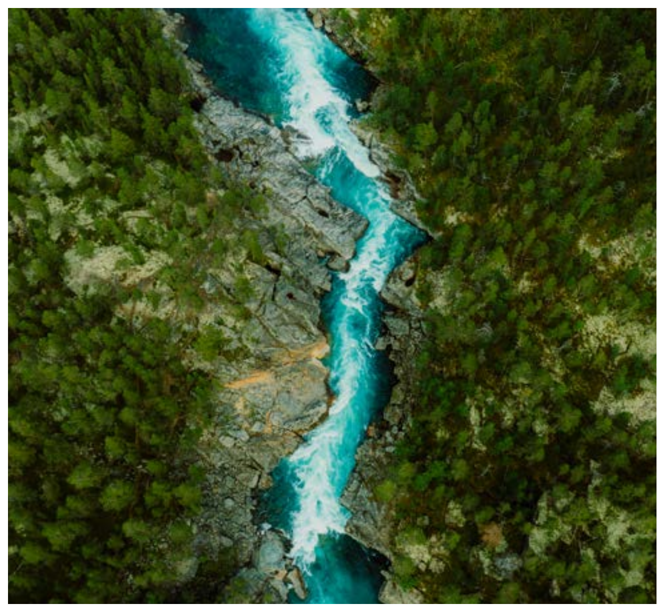
The off-road equipment industry stands at the intersection between societal environmental goals and the practical commercial requirements of today's end-users. This position requires manufacturers to strike a perfect balance between the work requirements of their customers and the aspirations of the public and global policymakers. Despite this tension, the off-road manufacturing industry remains committed to providing solutions that can satisfy both stakeholders. As our industry looks to the future, PFAS provides crucial attributes manufacturers need to develop new technologies, prevent unintended environmental hazards, and ensure our equipment continues to operate safely.

Environmental concerns:

Fluid Leaks:

Almost all off-road equipment requires the use of various fluids to enable the operation of specific machine functions. These fluids run in different systems for numerous purposes. Among these functions:

- hydraulic fluid enables power transfers to the hydraulic systems,
- coolant ensures the engine operates within the ideal temperature range,
- fluid coatings work to prevent corrosion, and
- oils reduce friction between moving parts



While these fluids provide useful functionality to our equipment, they also prevent environmental hazards such as leaks and spills. Equipment manufacturers strive to eliminate these leaks to prevent environmental damage, protect worker safety, and ensure the long-term viability of their products.

Fluoropolymers, such as PTFE and fluoroelastomers, provide crucial characteristics that prevent hose and seal failures throughout the machine. These chemicals possess high temperature, chemical and mechanical resistance, making them ideal for sealing applications. This combination of traits helps ensure the long-term viability of various hoses, seals, gaskets, O-rings, and valves placed throughout the machine. Without fluoropolymers, end-users would likely experience much higher rates of fluid leaks, environmental spills, safety issues, component failures, damage to the machine, and premature obsolescence of the machine itself. Currently there are no known technically, or economically, feasible alternatives to these substances.

Climate Change & Ozone Depletion:

Various international stakeholders are working to mitigate the impact that humans have on the climate. Like many other sectors, the off-road equipment industry continues to develop new strategies and solutions to reduce its environmental footprint. These efforts may include replacing current refrigerant options with lower GWP alternatives, developing zero-emission powertrains, or working to build new system efficiencies within the equipment to reduce fuel burn. Fluorinated gases will remain a critical substance in these efforts, without which the road to more environmentally friendly technologies will be much more difficult to achieve.

- Refrigerants: Refrigerants and refrigerant systems are already highly regulated for their contribution to atmospheric ozone depletion, and, more recently, their global warming potential. Recently, our organization successfully concluded an application for the use of HFO-1234yf as a refrigerant in off-road equipment through the EPA's Significant New Alternatives Policy (SNAP) program. Commonly used in the automotive sector, HFO-1234yf not only delivers zero ozone depleting potential (ODP), but also provides a greatly reduced global warming potential (GWP) when compared to its immediate predecessor, HFC-134a.

  Unfortunately, many governmental jurisdictions incorrectly identify these fluorinated refrigerants as PFAS chemicals based on the adoption of overly broad regulatory definitions. For this reason, any family wide restriction on PFAS would invariably restrict the use of this substance as a refrigerant in off-road equipment and eliminate the associated environmental gains.

- Alternative Power: Regulatory bodies have a decades long history of looking at on-road and non-road engines to address air quality criteria pollutant concerns. With a growing focus on climate change, policymakers are also looking at engines to help address concerns over GHG emissions. Manufacturers will need to develop new low carbon powertrain technology solutions to achieve the criteria pollutant and GHG reduction levels set by regulators. Within the off-road sector, manufacturers are researching new alternative power technologies, such as lithium-ion batteries, hydrogen fuel cells, and alternative fuels to provide low carbon solutions to their customers and markets they serve. Once again, PFAS provides the functional characteristics required to help foster the maturity and adoption of these new technologies across the market. Without access to certain PFAS, none of these technologies will remain viable in the future.

Undesirable Alternatives:

Non-road equipment manufacturers require thorough testing and validation of new materials prior to their integration into a final product design. Substance specifications vary based on their intended purpose within the larger machine. Due to the nature of the work, manufacturers often require highly durable and robust materials that can operate consistently under very extreme conditions. Replacing proven materials with alternative substances can, under the right circumstances, produce desirable environmental outcomes. However, transitioning away from irreplaceable or highly specified materials can often lead to higher environmental and human health risks, as well as suboptimal product performance outcomes.

For example, FKM materials provide high chemical, temperature and pressure resistance in gaskets, seals, and hoses. This material performs so well, that it is widely considered to be irreplaceable for the continued operation of most modern equipment. Its closest alternative, ethylene propylene diene monomer (EPDM), also known as synthetic rubber, does not perform well in the high pressure and temperature environments found in modern equipment. More troubling, synthetic rubber utilizes N-methylpyrrolidone (NMP) during its synthesis, which is a regulated Substance of Concern (SoC) in a variety of regulatory jurisdictions.

It is important to ensure that OEMs receive enough time and support when transitioning away from regulated substances. Annex I highlights many of the considerations and concerns manufacturers must face when reviewing alternative substances. Companies struggle with making informed and responsible decisions when faced with short implementation timeframes, discordant regulatory requirements, and overprescribed rulemakings. Policymakers need to provide the appropriate time, resources, and public-private collaboration necessary to ensure manufacturer stakeholders can identify and adopt desirable alternatives for their SoC.

Waste Streams:

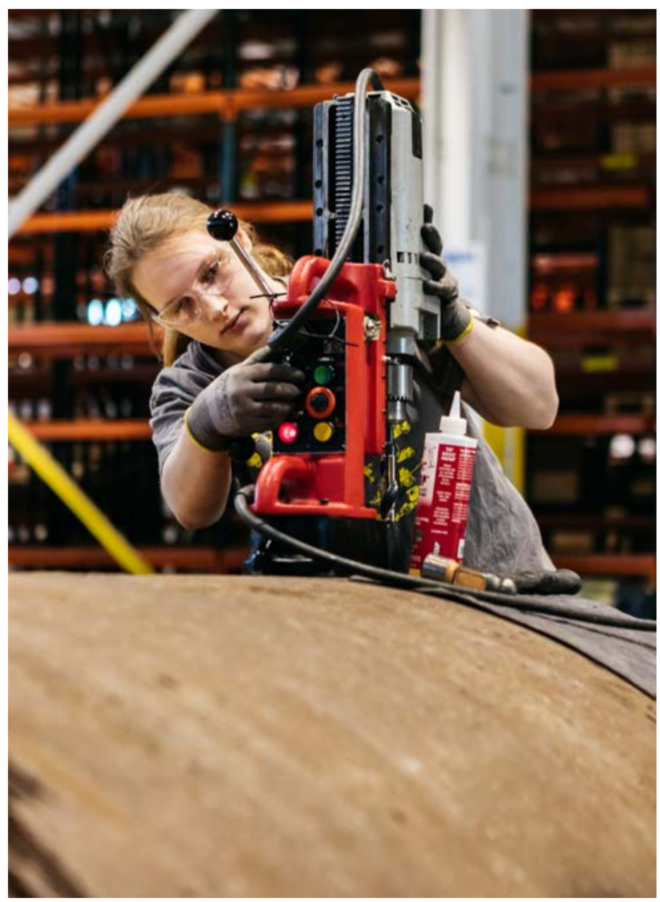
Certain PFAS provide advantageous properties that ensure the long-term functionality of off-road equipment. Preserving the useful life of hoses, seals, gaskets, coatings, and electrical components ensures the machine continues to operate for an extended period under severe conditions. Without the use of certain PFAS, machinery in the field will prematurely fail requiring an accelerated need for new parts and components, thus increasing the generation of waste.

Additionally, future broad-based prohibitions or restrictions of PFAS could jeopardize the off-road industry sector's general recycling and remanufacturing efforts. The off-road sector invests a lot of time and money to ensure their equipment is responsibly recycled, remanufactured and resold into secondary markets. These efforts reduce the amount of wasted materials the industry produces, prevents equipment from going to landfills, and avoids the premature obsolescence of our products. Any restriction of materials needs to protect against endangering these recycling efforts, and the associated unintended environmental consequences.

Safety Concerns

Safety concerns are perhaps the most important issue the off-road industry attempts to mitigate in their design processes. Heavy equipment, operating in hazardous environments, and under severe stress with various workers on the job site provides ample safety challenges for equipment manufacturers to consider. Under these conditions, machine operators look for reliable and durable equipment with the appropriate safety standards designed into the machine. Several PFAS plays a key role in ensuring the products continue to operate safely:

- Fluoropolymers in seals and hoses ensure hydraulic systems maintain pressure. Sudden pressure losses due to hydraulic hose failures can cause loads to drop suddenly on a jobsite, significantly increasing potential harm to workers.
- Heavy equipment operates at very high temperatures, requiring unique chemical solutions to mitigate any potential fire issues. Due to the pressure and temperature stability some PFAS chemistries are used to decrease the potential for fire, thereby protecting worker safety.



Economic Concerns

PFAS provides important functionality to a multitude of critical global industries. These industries include electronics, chemicals, textiles, coatings, plastics, pharmaceuticals and consumer products to name a few. Global manufacturers, including the non-road equipment industry, use PFAS to satisfy a multitude of design requirements and will likely continue to rely on these substances into the future. The critical role that these chemicals play in many industries, combined with the interconnected nature of the global economy, means any future restriction or prohibition on PFAS will be felt throughout the entire world. All future regulatory and legislative actions should prioritize high risk PFAS substances and their end-use applications and avoid broad prohibitions against the entire PFAS family.

- The semi-conductor industry, for example, requires the use of certain PFAS chemicals in their production processes. Broad prohibitions against PFAS would not only shut down the semi-conductor industry, but all downstream users of their products, including the automotive, aerospace, utility, computer, phone, and non-road equipment industries.

Contributions From the Non-Road Sector

Relative size of non-road waste streams

The non-road equipment industry represents a variety of sectors that provide valuable services to society. Despite the impact our equipment has on society, the amount of PFAS used by the industry is relatively small compared to adjacent sectors. Comparing the non-road industry to other industry sectors can help illustrate the relative differences in size.

- Automotive sector: $2 trillion (USD) annually
- Consumer electronics industry: $1 trillion (USD) annually
- Aerospace sector: $900 billion (USD) annually
- Construction & Agricultural equipment sector: less than $300 billion annually

In addition to the comparative annual revenues of related industries, the non-road sector tends to deal in lower production volumes at relatively higher costs. For instance, the auto industry has nearly 275 million cars on the road with an extra 17 million vehicles produced each year.[4] Consumer vehicles have an average lifespan of 12 years, and rarely undergo any remanufacturing activity. Conversely, the combined construction and agricultural equipment sectors will only reach 500,000 total units in-service by 2027.

The low number of machines when compared to other sectors highlights the relatively limited environmental impact of our industry. In turn, non-road equipment manufacturers design their equipment for maximum durability with an operating lifetime measured in decades. Unlike consumer electronics, cars and textiles, off-road equipment will out last all of them by years before reaching the end of its lifecycle. Overall, this leads to less products, less waste, and less environmental and human exposure routes.

4 https://www.statista.com/statistics/183505/number-of-vehicles-in-the-united-states-since-1990

Re-manufacturing:

The durability, quality, and material composition of non-road equipment make them incredibly valuable machines.

The non-road equipment sector uses PFAS chemicals in a variety of component applications to ensure the continued operability of our machines. PFAS chemicals are not used in tremendous quantities, but they are used to provide crucial functionality for our products.

Owing to the tremendous value, durability and cost of our industry's machines, most of the OEMs utilize robust remanufacturing operations to recycle, rebuild and reintroduce their equipment back into the market following its initial life cycle. For this reason, most of the equipment in the market today will not find its way into a municipal solid waste (MSW) facility. Remanufactured equipment will undergo rebuilds, refurbishments, and reintroduction into secondary and tertiary markets for decades of continued use. For this reason, the total quantity of potential PFAS contamination from non-road component parts is negligible.

Recommendations:

The non-road equipment industry works to provide product-based solutions to specific societal needs in the agricultural, construction, forestry, mining, and utility sectors. These products are designed to deliver critical functionality to our customers, perform these tasks in a safe, reliable, and consistent manner, and provide decades of service while operating under extreme environmental conditions. At the same time, key industry and governmental stakeholders are pressuring equipment manufacturers to introduce more sustainable and environmentally friendly products to the marketplace.

OEMs remain committed to offering the same functional and reliable product offerings to the market, while at the same time working to achieve the environmental and sustainability requirements of their customers and other industry stakeholders. Under these guiding principles, OEMs will utilize a mixture of old and new technologies to realize their Environmental, Social and Governance (ESG) goals, with PFAS performing a critical role in the ultimate success of these plans. It is crucial to understand, that without the functionality of certain PFAS substances, the introduction of future off-road products able to meet societal air quality, climate, safety, durability, waste, sustainability, and alternative power goals will be impossible.

Non-road equipment manufacturers recognize the current regulatory environment's focus on the risks associated with certain PFAS chemicals. AEM and its member companies are committed environmental stewards seeking productive collaborations with industry stakeholders and environmental policymakers. With these considerations in mind, AEM recommends the following policy proposals for governmental decision makers when considering future PFAS requirements:

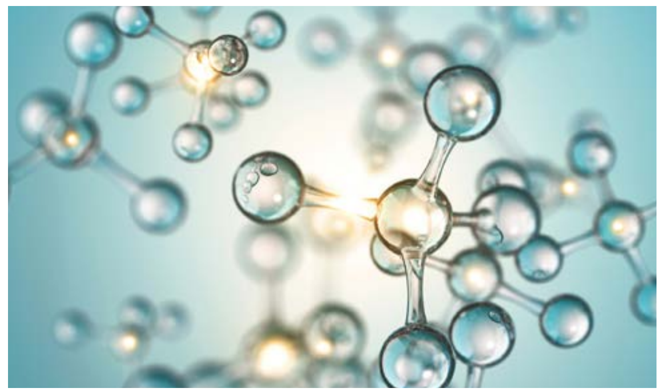
Harmonize PFAS Lists

Agreeing on a single international harmonized list of PFAS chemicals helps provide clarity and certainty in identifying and addressing PFAS substances of concern. As stated previously, there exist multiple lists across different regulatory jurisdictions, using different definitions and methodologies. As shown in

Annex I, multiple lists in different regions adds to the complexity and costs of identifying and replacing targeted substances. Harmonized lists, even very large ones, simplifies tasks and helps reinforce reporting processes.

AEM recommends that public policy makers adopt a single harmonized list of PFAS substances, similar to international efforts like the Kigali amendments and POPs Protocols.

Prioritize Efforts on High Risk PFAS Chemicals



Not all PFAS chemicals possess the same hazard profile. Certain fluorinated compounds, such as PFOA and PFOS, possess established, well understood, environmental and human health risks, whereas refrigerants such as HFO-1234yf have none of the PBT risk characteristics found in PFOA and PFOS. The fluoropolymers used in sealing, hoses and myriad other applications meet internationally accepted criteria to be considered "polymers of low concern".[5] Treating the thousands of identified PFAS chemicals as a single group with a common hazard profile, endangers the future use of advantageous and benign PFAS constituents, while overloading industry with unnecessary work to phase out the use of low risk, low hazard chemicals.

AEM recommends that public policy makers focus future regulatory efforts on high risk PFAS chemicals, as opposed to categorizing all PFAS chemicals together into one large group. Prioritization can help focus industry resources on high-risk substances, and lead to achievable outcomes.

Prioritize Risk Profiles of PFAS Applications

Certain PFAS chemicals can provide a great societal benefit, with low environmental and human health risks based on the manufacturing process and end-use applications. Due to the fact that PFAS are used in a wide range of applications with various risks associated with their intended use. These end use applications require further assessment and consideration by policymakers to determine their true hazard profile.

- Fluoropolymer seals in heavy duty equipment provide critical functionality to the machine with minimal exposure routes to the environment or the operator. Furthermore, these seals mitigate fluid leaks and prevent the premature obsolescence of the machine. Applications, like this, represent low risk end-uses and should be deprioritized when compared with higher risk applications that present clear and recognizable exposure pathways to people or the environment. Furthermore, the difference in end-uses highlights the danger in treating all PFAS substances as one group. Treating the entire PFAS family as one chemical entity risks future restrictions on crucial non-hazardous applications.

AEM recommends that public policymakers focus future regulatory efforts on prioritizing high risk PFAS applications as opposed to looking at the entire PFAS family as one group.

5 https://setac.onlinelibrary.wiley.com/doi/10.1002/ieam.4646

Avoid Broad Prohibitions

Many PFAS applications, when handled appropriately, present a very low risk to public health and the environment. Manufacturers employ several industrial processes to mitigate the release and exposure routes associated with various hazardous chemicals, PFAS among them. PFAS applications in batteries, for instance, are manufactured in clean room environments and, when recycled, are collected, captured and broken down during the remanufacturing process, mitigating and eliminating potential PFAS exposure routes. Eliminating the use of PFAS chemicals based solely on their hazard characteristics ignores the long history of allowing industry to use hazardous substances under controlled safe conditions.

AEM recommends that policy makers focus on proper PFAS chemical release prevention, waste disposal, material handling, recycling and environmental clean-up processes, as opposed to blanket prohibitions to the entire chemical family. Chemical management requirements protect against potential environmental and human health concerns, while providing industry continued access to the benefits provided by PFAS.

Time

Due to the high number of listed PFAS substances, the process of identifying, replacing, validating, and phasing out substances of concern will take a tremendous amount of time and resources to successfully implement. Annex I assumes industry needs a minimum of 87 months to fully transition away from a limited list of PFAS substances, roughly 12 chemicals at a time. With equipment containing over 100,000 parts and a supply chain that can run 14 layers deep, the time and costs to accomplish a full transition away from all PFAS substances would take significantly longer to accomplish than if industry only had to focus on a few high priority substances at one time. Furthermore, concentrating industry efforts on transitioning away from all PFAS chemicals consumes finite company resources intended for other policy and business goals, such as engine emission reductions and decarbonization efforts. The non-road sector can accomplish quite a few ambitious goals, but they cannot tackle all issues at the same time.

AEM recommends that policy makers provide enough time for equipment manufacturers to manage any regulatory requirements placed on the use of select PFAS in the manufacturing environment.

Aftermarket parts and components

Longevity is one of the defining characteristics of off-road equipment. A key aspect of manufacturing products that can survive 50 years is maintaining a distribution network that can provide replacement parts to repair in-service equipment. Many legacy parts for key components and systems contain PFAS. Removing these aftermarket parts from the value stream will cause the early obsolescence of many older machines. This premature end-of-life for many product lines will place an undo burden on equipment operators, waste handling streams, and equipment manufacturers. Much of this burden will fall on the equipment operators themselves, many of whom are small businesses who rely on the off-road industry going great lengths to keep their product models viable.

For any future PFAS regulatory action, AEM recommends that policy makers provide specific exemptions to aftermarket parts and components to protect against the premature obsolescence of in-service equipment.

Stakeholder Collaboration

AEM's member companies recognize the environmental policy goals of the global compliance environment. Our members are committed to the principles of environmental stewardship and strive to reach common solutions with our industry stakeholders.

In order to achieve viable solutions, AEM recommends that policy makers collaborate with industry subject matter experts to share information, understand future challenges and opportunities, and create agreed upon goals based on sound science.

Annex I: Time and Cost Analysis

Many current PFAS applications have no known chemical alternatives available for use in non-road products. Their unique blend of properties and characteristics make them essential to the continued operation of the non-road industry. Even with PFAS chemicals providing this essential functionality throughout industry, AEM's member companies recognize the environmental and health concerns of this chemical group and remain dedicated to finding safe chemical alternatives where possible. Despite this awareness and commitment to change, any transition away from PFAS will require time and resources to achieve.

The following section details the time and cost assumptions, as well as detailed descriptions of the current logistical challenges associated with the industry wide phase-out of PFAS chemicals:

Table 1: Summary Timeline to Identify, Validate, Test and Recertify a Product Containing PFAS Materials

ACTIVITY	TIME
IDENTIFICATION	
IDENTIFY ALL SUBSTANCES CLASSIFIED as PFAS from reg. list	1 months
IDENTIFY high risk COMPONENT TYPES	6 months
create list of at-risk parts and subcomponents	6 months
update internal data collection and compliance systems	9 months
Supplier Communication and training	3 months
request data from suppliers	12 months
Format data, check accuracy & Store Data	1 months
Total	**38 months**
VALIDATE AND TEST	
Validate PIP PFAS presence with supplier	1 months
Investigate alternative Material	6 Months
Procure Prototype Materials	6 Months
Component Validation of new Material	6 Months
Product Validation with new Material Components	12 Months
Turn inventory to purge supply chain & ensure Compliance	6 Months
Total	**37 months**
RECERTIFICATION	
Recertification	12 Months
Total	**87 Months**

Analysis Assumptions

The following sections attempt to identify the resource costs associated with an industry wide transition away from the use of PFAS chemicals. Certain assumptions are required in order to establish a believable estimate associated with this effort. The importance of the following assumptions undergirding Annex I cannot be overstated.

Assumptions:

1. This timeline assumes a limited list of around a dozen chemicals under assessment at any one time.
    a. There is a designated list to reference
    b. Available time to prepare for the phase-out work.
2. PFAS substances have identifiable, functional, and economic alternatives
3. The alternative is available and scalable to production quantities
4. Supply chain delays are minimal or non-existent
5. The testing and development cycle experiences no delays, or unexpected roadblocks

Identification:

The first step in highlighting the inherent risks of PFAS for the non-road industry is the lack of a common universal baseline for the total number of substances of concern. Various global regulatory and governmental agencies possess unique lists of known PFAS substances.6 These lists range from a few dozen to over ten thousand unique PFAS entities. To complicate this issue further, different references from academic research, regulatory agency activity or incoming legal requirements use different descriptions of PFAS to define their scope. Some of these definitions are narrower requiring multiple adjacent carbon atoms with a varying number of attached fluorine atoms to the larger chemical structure, to the broadest definition which includes any compound whose structure contains at least one carbon atom attached to a fluorine atom. This definitional difference introduces confusion to the marketplace hampering a company's efforts to identify the total number of PFAS compounds in their products. Before any largescale identification effort takes place, universal agreement on one definition and one list would help provide clarity and reduce complexity.

A second challenge in addressing global PFAS exposure risks, is the sheer number of PFAS substances identified through various stakeholder group research. Even with one universal agreed upon definition of PFAS, having a single list that still requires industry to identify and account for over 10,000 unique chemical substances is an extremely challenging task. Requiring companies to account for long lists of chemicals of concern, without corresponding de minimis relief provisions, takes time, effort, and resources to accomplish. Keeping future chemical lists focused on high risk PFAS, instead of the entire substance family would help industry identify and track important substances of concern.

6 Reference various lists

While not solely unique to the non-road equipment industry, the issue of supply chain education and communication presents a substantial challenge to global OEMs. Historically, the non-road industry had very little expertise and history regarding the collection and storage of data for chemical management regulations. This educational issue, endemic throughout the supply chain, is compounded by the wider compliance environment many of these companies operate in. Smaller manufacturers of components often do not store chemicals above the reporting thresholds required under US law (e.g. CDR, SARA 313 reporting rules. As a result, many companies in our supply chains never cultivated the systems or expertise needed to gather and store the relevant chemical data for the components and parts they manufacture and distribute. Their task is made more difficult due to the CBI protections many bulk chemical manufacturers utilize to conceal the composition of their products, making downstream reporting extremely challenging to accomplish. Additionally, International suppliers follow various global regulations which differ from each other, deepening the data collection obstacles faced by the global supply chain. Absent a data reporting system adopted globally across our industry sector that can track and monitor chemical substances throughout the supply chain, it remains an extraordinarily difficult task for a single OEM to know the chemical composition of the articles they currently market.

Table 2: Estimated Timeline for the Non-Road Mobile Machine Industry to Comply with the Data Collection and Reporting Requirements of the EPA's PFAS Final Rule

ACTIVITY	TIME
IDENTIFY ALL SUBSTANCES CLASSIFIED as PFAS from reg. list	1 months
IDENTIFY high risk COMPONENT TYPES	6 months
create list of at-risk parts and subcomponents	6 months
update internal data collection and compliance systems	9 months
Supplier Communication and training	3 months
request data from suppliers	12 months
Format data, check accuracy & Store Data	1 months
Total	**38 months**

From the timeline listed in Table 2, obtaining data from 80% of the supply chain would take a minimum of 38 months to complete. This assumption relies on upstream suppliers providing high quality chemical information to downstream manufacturers. The scale and complexity of the global supply chain will challenge this estimated timeline. Response rates will differ based on supply chain knowledge gaps, unfamiliarity with chemical regulations, the absence of pre-established systems for collecting material data, as well as the issues associated with CBI protected chemical products. The contrasting formats and methods used to distribute chemical data throughout industry further complicate this project. Some industries, like the automotive industry, use an established system (IMDS) to collect material disclosures for their parts and components. This system uses known CAS numbers, established de minimis reporting thresholds, and other criteria to assist in tracking chemical substances in articles. The non-road industry does not possess a system like this, nor do they utilize a common format to collect the required information. Full material disclosures collected on the common formats are received on average 25% faster than "non-standardized" or company specific formats. The uncoordinated and inexperienced nature of the global supply chain creates immense compliance obstacles for OEMs, which will challenge a manufacturer's ability to meet these estimated timelines.

Alternatives and Substitutes

It remains unclear if there are any current technical or economically feasible alternatives to the PFAS substances used in non-road equipment that do not compromise safety, durability, or reliability of the finished product. AEM members produce equipment designed to voluntary consensus safety standards and subject to third party certifications, customer requirements, and regulatory testing obligations. Changes to materials and formulations which affect fit, function, performance, or safety must undergo extensive testing to ensure new designs meet internal quality benchmarks, design specifications, and regulatory requirements. The sheer variety of applications and functionality provided by PFAS chemicals make it difficult to estimate the time needed to identify, test, and qualify alternative chemical substances for each end use.

Table 3: Timeline to Identify, Validate, and Test Alternative Substances after Likely Viable Alternatives are Identified

ACTIVITY	TIMELINE FOR EQUIPMENT MANUFACTURING INDUSTRY
Validate PIP PFAS presence with supplier	1 months
Investigate alternative Material	6 Months
Procure Prototype Materials	6 Months
Component Validation of new Material	6 Months
Product Validation with new Material Components	12 Months
Turn inventory to purge supply chain & ensure Compliance	6 Months
Total	**37 months**

Estimated timelines assume suitable alternative materials exist, that manufacturers do not encounter dead ends during these assessments, and that current supply chain issues throughout the world do not hamper shipping and transportation timelines. Furthermore, the timeline estimates assume the total number of PFAS substances used in non-road equipment is a manageable size. The higher number of PFAS substances used in the components and systems of the end-product, the longer the timeline will be.

Testing and material validation requirements often take the longest time to complete when assessing new material adoption. Non-road equipment operates in some of the most demanding and severe environments over a product life cycle measured in decades. Such equipment is subject to various fire safety and flammability regulatory requirements set by a variety of domestic and international regulatory agencies. Beyond various mandatory requirements,[7, 8, 9, 10, 11, 12] manufacturers must perform a host of safety, durability, and performance tests to ensure their products meet industry standards, internal quality specifications, as well as customer and regulatory requirements.

Due to the prevalence of PFAS throughout industry, manufacturers will likely see these substances present within different systems of their products. Manufacturers would need to conduct simultaneous redesign work on various alternative substances across multiple product platforms, resulting in different batteries of

7 Flammability Test for Motor Vehicle Interiors, 49 § C.F.R. 571.302(1998)
8 Fire Protection and Prevention, 29 § C.F.R 1926.24(2000), Fire Prevention, 29 § C.F.R 1926.151(2001)
9 Fire Resistant Hydraulic Fluids, 30 § C.F.R 35(2012), Requirements for the Approval of Flame-Resistant Conveyor Belts, 20 § C.F.R 14(2008), Fire Protection 30 § C.F.R 75.1100, Fire Protection, 30 § C.F.R 77.1100, Fire suppression systems for diesel-powered equipment and fuel transportation units, 30 § C.F.R 75.1911
10 Recommended Fire Safety Practices for Rail Transit Materials Selection, U.S. Department of Transportation, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/NASFM_Recommended_Practices.pdf, 2008
11 49 CFR 216, 223, 229, 231, 232, 238 – Passenger Equipment Safety Standards – correct citation
12 Flammable Fabrics Act, Public Law 83-88; 67 Stat. 111, June 30, 1953

tests across a wide swath of machine types. Of course, manufacturers can run changes to multiple systems simultaneously, but they cannot implement changes across all product lines simultaneously as test cells, qualified staff, and other resources are all limited.

Testing and Re-certifying Components and End Products

Due to the efficacy of using PFAS in high stress environments, many equipment manufacturers will likely find this substance present in critical parts used in their engine and emission control systems. Engine emission sensors, as an example, designed for non-road equipment to comply with the Clean Air Act, likely rely on PFAS to survive the high-pressure environment in the engine compartment. Any identified alternative materials will require expensive and time-consuming in-house and third-party certification testing before the product can satisfy the current regulatory standards governing its safety and performance.

The EPA, as part of their General Compliance Provisions for Highway, Stationary, and Nonroad Programs[13], identifies emission-related components in Appendix I to Part 1068. Changes to these critical components and systems require engine manufacturers to conduct a battery of emissions tests to ensure the equipment still meet national emission standards. Generally, a single engine platform requires around four years of development, or roughly the timeline associated with the cadence of engine emission regulatory changes. Depending on the prevalence of PFAS in these crucial emission control systems, manufacturers may need to undergo complete engine emission recertifications across all their product lines. As stated in the previous section though, manufacturers can run changes to multiple systems simultaneously, but they cannot implement changes across all product lines simultaneously as test cells, qualified staff, and other resources are all limited. Furthermore, changes to the engine may force design changes to the end-product, lengthening the entire process for the manufacturer.

As shown in Table 4 below, AEM's member companies estimate the industry would need a total of 12 months to recertify their products under current US emission requirements. This estimate assumes that material changes to critical engine control systems would not require a full engine redesign and recertification. If this assumption proves incorrect, the likely timeline for full recertification under the law would take between 4 to 8 years to fully complete.

Table 4: Timeline to Test and Re-Certify End Products

ACTIVITY	TIMELINE FOR EQUIPMENT MANUFACTURING INDUSTRY
Recertification	12 Months

Total Time and Costs:

The total time and costs associated with identifying, substituting and testing their products is significant. The above estimates are based on various crucial assumptions: presence of alternatives, availability of supply, minimal supply chain disruptions, as well as a flawlessly executed validation and certification process. If these assumptions are correct, the entire effort will take at least seven years to finish for a single batch of PFAS chemicals. See Table 1 for entire timeline summary.

13 40 CFR Chapter I, Subchapter U, Part 1068

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