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(R) Recommended Green Racing Protocols

RATIONALE

Earlier in its history, motorsport produced numerous innovations in performance, durability, and safety that were very often transferred to mass produced vehicles for road use. The Green Racing Protocols establish guidelines based on sound engineering and environmental principles to enable motorsport competition to again develop technologies and fuels that respond to current and future needs for road vehicles. By adopting Green Racing Elements from these Protocols, racing sanctioning bodies can at once enhance and provide a sustainable future for motorsport. Racing continues to serve as an excellent forum to demonstrate to the public that the advanced technologies and fuels embodied in Green Racing Elements are viable today, and foreshadow what will soon appear in their driveways. Furthermore, adopting Green Racing Elements can lead to more competitive and exciting racing, further strengthening the sport.

Green Racing's definition, mission, best implementation practices, and suggested awards are recommended to motorsports sanctioning bodies in these Protocols. It will become a Recommended Practice for all motorsports worldwide.

INTRODUCTION

Fundamental shifts in energy availability and prices, and the need to reduce exhaust emissions and the carbon footprint of transportation-related activities have altered the world in which racing operates. These shifts have created an opportunity for motorsports to engage and excite the public by contributing the solutions to some of today's most vexing problems. Now is the time for motorsports to respond to society's demands for sustainability of the mobility and energy industries to regain its relevance, restore its stature, and ensure its viability.

Technology development occurs in racing several times faster than in standard manufacturer vehicle development. Motorsport is in a unique position to promote rapid technical innovation and testing under demanding conditions – a requirement for market acceptance of sustainable transportation technologies. These Protocols align motorsports with demands for the transportation system to improve energy efficiency, promote energy diversity, and demonstrate environmental responsibility, while simultaneously supporting motorsport that is entertaining, exciting, cost effective, and safer. By capitalizing on the spirit of human achievement embodied in racing and using it to develop and promote efficiency-enhancing and environmentally-responsible technologies, motorsport can enhance its long-term survival.

1. SCOPE

These Protocols can be used for all forms of motorsports; however, only certain combinations of Green Racing Elements will result in motorsport competitions that are recognized as Green Racing events. As new information, fuels and technologies emerge, addendums or new protocols will be developed.

The SAE International (SAE) Motorsports Engineering Activity is also an invaluable source of reference materials and ongoing technical advice providing access to the constantly evolving set of best safety and operational practices for current and emerging technologies. This is especially true with regard to high voltage safety and the adoption of other advanced propulsion and fuel system technologies.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

NOTE: Users should ensure that the latest revision and updates of these documents are being referenced. Additional related publications may become available at any time, and thus this list should not be considered complete. Each racing sanctioning body is responsible for determining the most appropriate set of standards to its form of motorsports, whether local, national, or international. Complying with SAE standards is voluntary. The standards do not endorse any specific products or company's services.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1715 Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology

SAE J1766 Recommended Practice for Electric, Fuel Cell and Hybrid Electric Crash Integrity Testing

SAE J2344 Guidelines for Electric Vehicle Safety

SAE J2464 Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing

SAE J2578 Recommended Practice for General Fuel Cell Vehicle Safety

SAE J2929 Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells

SAE J2950 Recommended Practices (RP) for Shipping Transport and Handling of Automotive - Type Battery System - Lithium Ion

SAE J2990 Hybrid and EV First and Second Responder Recommended Practice

2.1.2 Federal Motor Vehicles Safety Standards (FMVSS) and Department of Transportation (DOT) Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/

FMVSS 305 Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection

Available from the Superintendent of Documents, U.S. Government Printing Office, Mail Stop: SSOP, Washington, DC 20402-9320.

DOT HS 811 574, 'Interim Guidance for Electric and Hybrid Electric Vehicles Equipped with High Voltage Batteries'

2.1.3 International Organization for Standardization (ISO) Publications

Available from International Organization for Standardization, 1, rue de Varembe, Case postale 56, CH-1211 Geneva 20, Switzerland, Tel: +41-22-749-01-11, www.iso.org.

ISO 6469:2009 Electrically propelled road vehicles - Safety specifications

ISO/TR 11955:2008 Hybrid-electric road vehicles - Guidelines for charge balance measurement

ISO 23274:2013 Hybrid-electric road vehicles - Exhaust emissions and fuel consumption measurements

ISO 26262:2011 Road vehicles - Functional safety

2.1.4 American National Standards Institute (ANSI) Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

Standardization Road Map for Electric Vehicles Version 2.0, May 2013

2.1.5 National Fire Protection Agency (NFPA) Publications:

Available from National Fire Protection Agency, 1 Batterymarch Park, Quincy, MA 02169-7471, Tel: 617-770-3000, www.nfpa.org.

Electric Vehicle Emergency Field Guide (2013)

NFPA 52, Vehicular Gaseous Fuel Systems Code (2010)

2.1.6 Federation Internationale de l’Automobile (FIA) Publications:

Available from FIA Foundation for the Automobile and Society, 60 Trafalgar Square, London, WC2N 5DS, Tel: 44 (0) 207 930 3882, http://www.fia.com/sites/default/files/regulation/file/2013.

Technical Regulations for Alternative Energy Vehicles (2013)

FIA Alternative Energies Cup (2013)

Specific General Prescriptions - Alternative Energies Cup 2013

3. BACKGROUND OF THE GREEN RACING PROTOCOLS

SAE International established a Green Racing Working Group (GRWG) in April 2006 with the intent of becoming a forum for original equipment manufacturers (OEMs), motorsport sanctioning bodies, and those with an interest in addressing racing’s energy and environmental issues in the 21st century. This effort developed the criteria for Green Racing and resulted in the Green Racing Protocols, published in October 2008 as SAE J2880. Since then, the protocols have been an important factor in guiding motorsport to greater energy efficiency, reduced reliance on petroleum, and a smaller environmental footprint. Several major racing series around the world have taken steps outlined in the protocols, and many industry and motorsport leaders support the actions recommended in the protocols.

In October 2012, a committee composed of industry, government, and motorsport representatives was formed to update and revise the protocols as part of SAE’s ongoing effort to keep its technical standards current. The recommendations in this revised document will further contribute to this historical movement.

4. GREEN RACING'S DEFINITION AND MISSION

Green Racing embraces all activities that capitalize on the pivotal role motorsport can play in the development and adoption of technologies that form the basis of sustainable personal mobility. These Green Racing protocols have been established to provide guidance to motorsport's governing bodies to develop better technology-neutral rules and embrace a sustainable transportation future. They serve to provide a foundation for motorsport competitions based on sound engineering and environmental principles.

4.1 Definition of Green Racing

Green Racing is a philosophy that uses motorsports' competition to develop and demonstrate more fuel efficient and environmentally-friendly vehicle designs, technologies, and fuels that can be used in consumer vehicles while helping to create a sustainable future for society and itself. Green Racing's philosophy extends from rewarding innovative engineering on-track to embracing best environmental practices at the track and shop.

4.2 Green Racing Mission

Green Racing uses vehicle competitions to promote and accelerate the use of advanced technologies and renewable fuels. This results in increased availability and acceptance of cleaner and more efficient vehicles in the marketplace worldwide. Green Racing provides exciting and engaging entertainment and a versatile communications platform that attracts growing numbers of fans and sponsors, while presenting industry and the fan base with a path to sustainable personal mobility worldwide. These recommendations also extend to the environmentally-sensitive operation of motorsport facilities and off-track team operations.

5. GOAL AND OBJECTIVES OF THE GREEN RACING PROTOCOLS

5.1 Green Racing Protocols Goal

Develop recommendations that harness racing's accelerated pace of development to increase the availability of energy-efficient and environmentally-friendly technology for production vehicles, accelerate its acceptance and use by consumers worldwide, and return motorsport to technological leadership.

5.2 Green Racing Protocol Objectives

- Provide recommendations for Green Racing that yield competitive, entertaining, cost-effective motorsports while meeting the objectives of sustainable mobility;
- Support environmentally responsible and sustainable technology development in motorsport that can be transferred to future production vehicles by OEMs;
- Promote environmentally friendly operations of motorsport venues, competition events, and racing team facilities;
- Assist sanctioning bodies in establishing a roadmap to increasing green practices, including the measurement of progress; and,
- Provide motorsport sanctioning bodies with information, and work with them to develop flexible options and scenarios, so that they can make informed decisions that incorporate Green Racing Elements in their competitive events.

6. ELEMENTS OF GREEN RACING

The committee identified a range of technologies, fuels, and operational procedures that support development of a sustainable future for both motorsports and personal mobility, and organized them into five Green Racing Elements. These Elements represent broad areas of technology and fuels development that underpin efforts by vehicle manufacturers and energy suppliers to respond to demands from the market and regulators shaping future vehicle designs. Although these Elements are written at a high level, their intent is to encompass the entire scope of actions by motorsport sanctioning bodies. They provide means to meet the needs of vehicle manufacturers, sponsors, and fans while creating new interest in the broader public laying the foundation for future growth of the sport.

The Elements of Green Racing are:

- Propulsion Systems: In response to demands for greater energy efficiency and extremely low emissions, powertrain diversity has become a fact of life for the automotive industry. Racing has played a significant role in this development in the past and still can contribute to future efficiency gains from engines, electric motors, transmissions and differentials/axles. Currently, hybrid and electric vehicles have limited opportunities in motorsports. These and other types of energy converters are now viable options and should be allowed and encouraged to join in competition. Allowing these advanced propulsion technologies to compete would increase their robustness and improve their acceptance by the vehicle-buying public by demonstrating they are ready for even the most demanding street use. In addition, an explosion in transmission options has made ten-speed automated and continuously variable transmissions production realities. More development of these and other propulsion system technologies are needed to meet the future demand for efficient, clean vehicle technologies. The Propulsion System Element captures and organizes a wide range of propulsion technologies of and places them into an ascending order of difficulty in applying them to motorsports. Given the substantial amount of engineering, investment, and expense required to develop Propulsion Systems, the Committee has given a weighting factor of two for this Element of Green Racing beyond the Core commitment level. These additional points also recognize the substantial effort required by sanctioning bodies who allow these advanced powertrains to balance performance of various powertrain solutions through sporting regulations to assure exciting, competitive racing.

- Fuels/Energy Carriers: With the wider diversity in propulsion systems comes a wider diversity in fuels and energy carriers. Racing should reflect the choices that are or will soon be available to the public, while reducing the amount of petroleum used in transportation fuels – a cornerstone of U.S. energy policy for more than two decades. Additionally, gaseous fuels have significant potential in motorsports, particularly natural gas, as well as energy carriers such as electricity and hydrogen. This Element gives sanctioning bodies a way to embrace new and consumer-relevant technologies in the future.

- Energy Recovery: One of the great opportunities for motorsports is facilitating the recovery of energy produced for vehicle propulsion and enabling it to be reused for increased performance and efficiency. Significant energy is available for harvesting, such as engine exhaust and the kinetic energy from the vehicle itself. Improved methods of storing recovered energy are urgently needed for production as well as racing vehicles. This Element includes electric, kinetic, and hydraulic/pneumatic methods of storage, and ways to better incentivize the development and validation of advanced energy storage technologies. The complexity, cost, control, and development of waste energy recovery technologies increase dramatically above the Core commitment level. The Committee has given a weighting factor of two for this Element of Green Racing beyond the Core level.

- Improved Efficiency: All racing rewards efficiency, whether kinetic, aerodynamic, energy conversion, or tractive. The Improving Efficiency Element echoes the primary engineering challenge for production vehicles, while providing tangible ways for motorsports to build on this fundamental principle of sustainability. This Element also seeks to reduce consumables other than fuel such as tires and lubricants, as these also have a large impact on the sport's energy consumption as a whole.

- Emissions Reduction: Reducing carbon emissions remains one of the most important and challenging issues facing the automotive industry, and is central to its long-term sustainability; it is the principal focus of this Element mirroring its relevance to production vehicles. This Element also seeks to establish a baseline of current exposure levels where large numbers of fans congregate to ensure they are not exposed to potentially harmful levels of criteria emissions from the wider variety of potential fuel types.

The Green Racing philosophy applies not only to activities on the track, but also to adopting more environmental- and energy-conscious race track and team operations off the track and in the shop as well. Many sports venues have taken this holistic approach in reducing waste, improving recycling and conserving energy. As a result, they have experienced an improved image with the fans, media, and government and improved their bottom line. In an effort to increase the focus and reduce the complexity of these Protocols, track and team operations are not included as a separate Green Racing Element; however, it is strongly encouraged that racing series and teams adopt this aspect of the Green Racing philosophy as an integral part of their Green Racing program. A significant amount of helpful material towards these ends is available. For example, track owners can find a wealth of tools and success stories from a wide variety of sports venues on the Green Sports Alliance website, at http://greensportsalliance.org/. In particular, track operators are encouraged to collect information regarding their operations to develop an understanding of their energy and environmental footprint. Information on their electricity and diesel use, volume of recyclables, landfill and other waste, water use and traffic patterns can establish a baseline from which improvements can be measured. For teams, the Fabricators and Manufacturers Association, publishers of Green Manufacturing magazine available at www.greenmanufacturing.net, has similar information. A prime target for tracks and teams is to reduce the amount of diesel fuel consumed by temporary generators used for paddock and hospitality operations at the track, and those used to power trailer transporters and motorhomes. In order to reduce non-renewable fuel use and local air pollution, these operations and temporary work and living facilities should be connected to the electrical grid whenever feasible.

7. GREEN RACING ELEMENTS MATRIX

Since there are hundreds of forms of motorsports around the world, not one set of recommendations for future sustainable racing could fit them all. The committee sought to organize and differentiate various stages of Green Racing activities and provide incentives to gradually increase commitments to relevant and sustainable motorsports. Thus, a matrix of Green Racing Elements was created to combine the four commitment levels with the five Elements as a way to rate the degree of Green Racing activities for a given race series. Use of the matrix allows many approaches to Green Racing to be validated and recognized.

The four commitment levels in the Matrix are:

- Core: The Core commitment level represents the minimum commitment most race series take to begin the process of adopting Green Racing Elements as an important aspect of their form of motorsports. Many race series will find they already employ several Core commitment level actions for one or more of their categories and will find that the effort and commitment required to raise their series up to the Enhanced level is straightforward and relatively easy. Adopting Core level action(s) for each Green Racing Element is awarded one Green Racing point, used to determine eligibility for recognitions and awards, as shown in the Matrix in Table 1.

- Enhanced: The Enhanced commitment level builds on Core actions to extend the reach of Green Racing Elements into individual race series or categories. The content of this level has been designed to complement actions at the same level in other Green Racing Elements. Implementing Enhanced level action(s) for each Green Racing Element is awarded the number Green Racing points shown in the Matrix in Table 1.

- Elevated: The Elevated commitment level is a significant step above the previous level, with many “and/or” options to tailor the Element to the situation, race series, or category. Achieving Elevated level action(s) for each Green Racing Element is awarded the number of Green Racing points shown in the Matrix in Table 1.

- Pinnacle: The Pinnacle commitment level is the highest expression of Green Racing achievement. It also presents race series and their categories with a series of “and/or” options that allow it to be responsive to a wide range of racing formats and content. This highest rung of the Green Racing achievement ladder also includes the flexibility to respond to unforeseen innovation in adapting to fast-moving technology developments. The unforeseen innovation classification is intended to apply only to technologies and fuels that represent the highest level of Green Racing achievement concurrent with the spirit of Green Racing. Reaching Pinnacle level action(s) for each Green Racing Element is awarded the number of Green Racing points shown in the Matrix in Table1.

Combining the Elements of Green Racing and four commitment levels in the Matrix results in a condensed method of both communicating and assessing the degree of Green Racing activities in a race series. Considerable thought went into the content of each cell of the Green Racing Matrix. A description of each Green Racing Element and the content of the commitment levels below explain the rationale of the committee.

Propulsion Systems Element

- Core Level: Either spark ignition (SI) engines with equal to or greater than ten percent renewable fuel or compression ignition (CI) engines using any diesel fuel. No spec powertrain series can qualify for this level unless modifications are allowed to foster innovation and improve the efficiency and performance of the engines operating on the allowable renewable fuel(s).

- Enhanced Level: SI engines with 10 percent or more renewable fuels content and CI engines using any diesel fuel must both be allowed to move up from the Core Level. Powertrain development and diversity are an essential part of Green Racing, so once again, no spec engines qualify for this level unless modifications are allowed to simulate innovation, engine efficiency and power optimization.

- Elevated Level: Enhanced content and/or electrified propulsion (e.g., HEVs) and/or natural gas-fueled engine characterize this level. Racing series that allow either SI or CI engines with electrified propulsion components qualify for this level.

- Pinnacle Level: Elevated content plus non-spec plug-in powertrains and/or fuel cell prime mover, or similar unforeseen innovation must be exhibited. The highest Propulsion System level consists of advanced technologies that will accelerate development and validation of candidate technologies for future road vehicles.

Fuels/Energy Carriers Element

- Core Level: Must demonstrate a 10 percent reduction in Well-to-Wheel (WTW) oil use over baseline of no renewable fuel use. The WTW perspective used in this document is based on a Total Life Cycle philosophy that takes into account the entire impact of using a resource from its location, extraction, refining, transportation, and use. It is a holistic approach that seeks to completely and fairly characterize the resources' impact to allow the most informed decisions regarding its best use. See Appendix 1 for a more complete discussion of this application of Total Life Cycle analysis and examples of how these data are obtained. The 10 percent oil use reduction requirement is typically achieved with 10 percent first or second generation renewable fuels, but can come from any combination of traditional fuels and higher percentages of renewable fuels. First generation renewable fuels are those made from seeds or fruit usually reserved for animal or human consumption like corn, sugar cane, millet, or rapeseed. Second generation renewable fuels are made from crop waste or plants that are not food crops (e.g., switch grass). Third generation renewable fuels are typically algae-derived, but can include biomass gasification. At the time of this writing, third generation renewable fuels were still in early stages of development, but could be ready for demonstration in motorsports within the five year time horizon for this revision. Increasing renewable fuel use is a cornerstone of national energy policy that will produce substantial economic and energy security benefits. The imperative to reduce the dependency of the transportation system on non-renewable oil resources while reducing carbon emissions is the driving rationale for this Green Racing Element and the Core Level content. No leaded fuels can be used and be eligible for Core achievement status.

- Enhanced Level: Twenty percent reduction in WTW oil use over baseline of no renewable fuel use must be achieved. This requirement is typically accomplished with 20 percent first generation or second generation renewable fuels, a combination of both, or with third generation biofuels. The 20 percent reduction in petroleum use can come from any combination of traditional fuels and higher percentages of renewable fuels.

- Elevated Level: Thirty percent reduction in WTW oil use over baseline of no renewable fuel use or/and electricity for plug-in hybrid vehicles or/and a gaseous fuel (natural gas, hydrogen, or liquefied petroleum gas) must be achieved. This requirement is typically accomplished with 30 percent first, second generation renewable fuels, or a combination of both. This level seeks to increase utilization of renewable biofuels and increase diversity for non-traditional fuels.

- Pinnacle Level: The highest level for Fuels/Energy Carriers targets either a 50 percent reduction in WTW oil use over baseline of no renewable fuel use, a mix of these fuels with a gaseous fuel, electricity as the only fuel, or an unforeseen innovation in fuels or energy carriers. This requirement is typically achieved with 50 percent first or second generation renewable fuels or a combination of both with third generation biofuels. The 50 percent reduction in WTW oil use can come from any combination of traditional fuels and higher percentages of renewable fuels. Room for an unforeseen innovation of similar significant impact has also been provided at the Pinnacle Level.

Energy Recovery Element

- Core Level: Using the waste exhaust energy from the engine to enhance performance defines the Core level for Energy Recovery technologies. The most common method to use waste exhaust energy is the turbocharger, although bottoming cycle power production also meets this definition.

- Enhanced Level: The largest source of available energy for recovery is the kinetic energy of the vehicle. This level's technologies capture this energy mechanically or electrically and reuse it for propulsion. Limitations to energy storage system size are established by their energy capacity. Restrictions on the frequency that energy storage systems can be changed during the season are also included to incentivize durable energy storage and control costs.

- Elevated Level: Includes the provisions of the Enhanced Level but changes the basis of limits on energy storage applied to hybrid electric vehicles to its available power. Not all energy storage systems have the same power output for the amount of energy stored, and power is more important for motorsports applications than energy so limits based on power are more appropriate for racing (e.g., the difference between batteries and supercapacitors). Also included in this level on an "and/or" basis are other technologies for recovering waste energy for propulsion or to power auxiliary loads and energy storage systems based on compressing liquids or non-flammable gases. These additional technologies have shown promise for production vehicles and are included to encourage thinking outside the box in this important area of developing technology.

- Pinnacle Level: This top level in Energy Recovery includes the content of the Elevated Level, but changes the philosophy of limiting energy storage size to a mass-only approach. This metric focuses the development and validation of energy storage technology on the key technical barriers of improved power and energy density. There should be no restrictions on harvesting or use of recovered energy at this level. A provision for unseen innovations in these rapidly changing technologies with similar impacts to those described is also provided at this level.

Improving Efficiency Element

- Core Level: Since efficiency is an important consideration in most forms of racing, this base level consists of traditional sporting regulations that restrict intake air for engines and add mass and aerodynamic drag to balance performance levels between cars. These rules form the basis for taking low-cost steps to improve and encourage more efficiency from today's racing cars and changing the approach to designing tomorrow's competitive machines. Essential to this level is the measurement of each car's energy consumption. This fosters an understanding of the energy and environmental impact of each car, series, or category, and establishes a baseline from which progress can be measured. This requirement for is also included in the Core Level for the *Emissions Element*, and is a critical part of Green Racing.

- Enhanced Level: This includes actions in the Core Level and adds energy recovery for propulsion and/or changing the approach to balancing performance. Energy recovery used for propulsion or auxiliary loads is central to improving vehicle efficiency, and is included here as well as in the Enhanced Level in Energy Recovery. Whenever possible, an approach should be taken that balances performance with efficiency by means of vehicle mass and drag reduction for the rest of the field instead of adding mass or increasing drag to a single car. Implementing this bias towards increased efficiency and reduced energy consumption (and associated costs and emissions) promotes the understanding that efficiency is valued and embraced by the race series or category. In so doing, we seek to improve the efficiency of the field instead of increasing the mass or drag of a specific car causing a deliberate deterioration of that car's efficiency to balance performance.

- Elevated Level: This level includes actions contained in the Enhanced Level, adds the use of limits in fuel flow to control engine power, and replaces air restrictors that choke off oxygen needed for combustion. Engines convert fuel to work, and limiting the rate of fuel they consume provides additional incentives to increase engine efficiency. Improving the efficiency of engines is a major focus for advanced production vehicles, and is an opportunity for racing to provide major contributions to the field. Additionally, this level sets a target for reducing the number of tires used per season. Over their lifetime, each set of tires represents more energy than the car consumes on the race track. Reducing tire use is an important part of reducing energy consumption and environmental impact of racing. Based on a 2010 baseline, the metrics of tires/vehicle/km of racing over one season should show a 15 percent reduction.

- Pinnacle Level: The highest level in Energy Efficiency includes actions contained in the Elevated Level, but adds energy allocations – setting a maximum amount of energy available per race for any fuel or energy carrier. This further incentivizes the use of available energy most efficiently. Recovered and reused energy is not to be considered part of the energy allocations. Reduction in tire use by 30 percent from the 2010 baseline using the tires/vehicle/km metric over the course of the season is also a target for this level. All electric race vehicles also meet the Pinnacle Level requirements. A provision for unforeseen innovations of similar magnitude to the other provisions of this level is also provided to allow flexibility to recognize innovations that further efficiency.

Emissions Reduction Element

- Core Level: This base level requires a 10 percent reduction in WTW greenhouse gases (GHG) emissions over a baseline of no renewable fuels, and requires that no smoke be visible from any exhaust under racing conditions. Compliance with this provision may require particulate matter (PM) filters on any direct-injected engine; however, use of PM filters for diesel-powered race cars has also proven highly effective. Accurate measurement of energy use by car and for the Series is also included to enable race series to create an energy consumption baseline and measure reductions in GHGs in subsequent levels. This target for WTW GHG emissions is typically achieved with 40 percent first generation renewable fuels or 10 percent second generation renewable fuels, but can come from any combination of traditional fuels and higher percentages of renewable fuels. There are several publically-available WTW models that allow accurate calculation of GHG impact from many different types of fuels. See Appendix 1 for a more complete discussion of calculating GHG results. For amateur classes based on emissions-certified street cars, functioning positive crankcase ventilation (PCV) systems, OEM catalysts and closed-loop engine control systems must be retained.

- Enhanced Level: The Enhanced Level adds a twenty percent WTW GHG reduction requirement over a baseline of operation on fuels with no renewable content to the Core Level. This level of GHG reduction can typically be attained with use of 75 percent first generation renewable fuels, 20 percent of second generation renewable fuels, or a blend of thirty percent hydrogenated vegetable oil and diesel fuel for CI engines. The 20 percent reduction in GHG use can come from any combination of traditional fuel use and appropriate higher percentages of renewable fuels. This Element also includes periodic measurement of ambient air quality in dense spectator area(s) to ensure spectators and competitors are not exposed to unhealthy air quality. This concern is most acute at venues with dense seating in close proximity to the race track. This is where cars use a high percentage of renewable fuels with limited opportunity for dilution of race car exhaust in normal air. Race venues that operate in locations with marginal background air quality are also candidates for emissions monitoring. Including this provision will lessen instances of spectator sickness, as well as facilitate a better understanding of when criteria emissions from motorsports may have negative impacts on spectator or competitor health. Sanctioning bodies are responsible for determining where and how frequently air quality monitoring is necessary. This depends on the venues, fuels, and form of motorsports they are operating, but monitoring is typically done at least twice a year starting at the venues most likely to produce unhealthful conditions. Assistance from the U.S. Environmental Protection Agency (EPA) and state environmental agencies can be requested by sanctioning bodies to comply with this requirement.

- Elevated Level: This level includes the Enhanced Level content, but extends the GHG reduction to 30 percent over a baseline of fuels with no renewable content calculated on WTW basis. This GHG reduction can be attained from the use of thirty percent second generation renewable fuels for SI engines and a forty percent blend of vegetable oil and diesel fuel for CI engines, but can also come from any combination of traditional fuels and higher percentages of renewable fuels.

- Pinnacle Level: At this highest Emissions level, GHG reduction is elevated to 50 percent over a baseline of fuels with no renewable content calculated on WTW basis while retaining the other provisions of the Enhanced Level. This GHG reduction can be attained from the use of 50 percent or higher blends using second-generation renewable fuels, and a 70 percent or higher blend of vegetable oil and diesel fuel for CI engines. It can also come from any combination of traditional fuel use and higher percentages of renewable fuels. The provision for unforeseen innovations to lower GHG and criteria emissions at this highest level of Emissions achievement is also included.

The combination of all the Green Racing Elements, their Commitment Levels, and Green Racing Points is summarized in Table 1 below.

TABLE 1 - MATRIX OF GREEN RACING ELEMENTS AND COMMITMENT LEVELS

	Commitment Level							
Green Racing Element	**Core**	**Green Racing Points**	**Enhanced**	**Green Racing Points**	**Elevated**	**Green Racing Points**	**Pinnacle**	**Green Racin g Points**
Propulsion Systems	SI engines with 10% or more renewable fuels content *or* diesel engines only	**1**	SI engines with 10% or more renewable fuels content *and* diesel engines allowed	**4**	Enhanced *and/or* electric drive *and/or* natural gas prime mover	**6**	Elevated *and* plug-in powertrains *and/or* fuel cells *or* unforeseen innovation	**8**
Fuels/Energy Carriers	A 10% reduction in WTW oil use over baseline of no renewable fuels	**1**	A 20% reduction in WTW oil use over baseline of no renewable fuels	**2**	A 30% reduction in WTW oil use over baseline of no renewable fuels *or* electricity for PHEVs *and/or* a gaseous fuel	**3**	A 50% reduction in WTW oil use over baseline of no renewable fuels *or* a mix of renewable fuels with a gaseous fuel *or* electricity as the only fuel *or* unforeseen innovation	**4**
Energy Recovery	Use of waste heat for engine performance enhancement (e.g. turbochargers or bottoming cycle systems)	**1**	Kinetic energy recovery for propulsion *and* energy storage limited by energy capacity *and* limits on Energy Storage System replacement during the season	**4**	Enhanced but with energy storage for hybrid electric vehicles limited by useable <u>power</u> *and/or* waste energy recovery for auxiliary loads or propulsion *and/or* pneumatic or hydraulic energy storage	**6**	Elevated *and* open energy storage limited by mass only *or* unforeseen innovation	**8**
Improving Efficiency	Fuel use measurement *and* intake air restriction *and* traditional sporting regulations with mass and aero drag additions to balance performance	**1**	Core *and* energy recovery for auxiliaries or propulsion *and/or* mass and aero drag <u>*reductions*</u> to balance performance where possible	**2**	Enhanced *and* fuel flow limits replace air restrictors *and/or* 15% reduction in tire use over the season from 2010 baseline	**3**	Elevated *and* energy allocations *and/or* 30% reduction in tire use over the season from 2010 baseline *or* electric drive only *or* unforeseen innovation	**4**
Emissions Reduction	Fuel use measurement *and* no visible exhaust smoke *and* 10% reduction in WTW GHG over baseline of no renewable fuels *and* amateurs retain PCV, OEM catalysts, closed-loop control	**1**	Core *and* 20% reduction in WTW GHG over baseline of no renewable fuels *and* periodic air quality monitoring in dense spectator area(s)	**2**	Enhanced *with* 30% WTW GHG reductions over baseline of no renewable fuels	**3**	Enhanced *with* 50% WTW GHG reduction over baseline of no renewable fuels *or* unforeseen innovation	**4**

8. RATING RACE SERIES' GREEN RACING ELEMENTS

Every motorsport sanctioning body is highly encouraged to decide how its race series can adopt elements of Green Racing to reduce the environmental and energy footprint of their races and reward innovation. Each Commitment Level for the five Green Racing Elements in the Matrix is allocated a specific number of Green Racing points as shown in the Matrix in Table 1. To calculate the Green Racing score of any race series, sum up the Green Racing points associated with the four commitment levels described in Section 7. This simple process provides a means to rate a race series on its Green Racing status and determine it qualifies for recognition and awards as described below. In addition, the Matrix enables sanctioning bodies to understand how modifications to their sporting regulations can be made to increase the Green Racing influence of their series.

The Committee recognizes that race series are continuously evolving and they typically revise their technical and sporting regulations on a three-to-five year cycle. In order to keep these Green Racing Protocols up-to-date and relevant, we are establishing a three year rolling window of technical content and Green Racing Points to match the sanctioning bodies' timetable for adjusting their regulations. Under this approach, Green Racing's criteria, as well as points, recognitions, and award structure are guaranteed not to change for the next three years on a continual rotating basis. An annual review of the state of the Green Racing Protocols and motorsports in general will be conducted, and if no adjustments are deemed necessary three years hence, the content, points, recognitions, and awards will remain unchanged over the following three year window. This procedure will provide a minimum three year time frame of certainty for sanctioning bodies, and allow adjustments to the recognition, award levels, and content from experience gained over time and changes in motorsports itself. The Green Racing Committee, operated by SAE International, will determine whether changes are appropriate three years in the future by the end of each calendar year starting in 2014. This committee has the support of the U.S. Department of Energy (DOE) and EPA, and may comprise representatives of those agencies and members of SAE's Motorsports Engineering Activity. By the end of 2014, the committee will determine whether changes to the Green Racing rating system are to be made starting in the 2018 racing season. This three year rolling window process will continue until it is deemed no longer necessary.

9. BEING RECOGNIZED AS A GREEN RACING SERIES

Sanctioning bodies that seek recognition of their Green Racing status can request an official determination of their Commitment Level by applying for review of their sporting regulations to the SAE Green Racing Committee. The summary table in Section 10 displays all the recognition and award levels for Green Racing. The exact procedures for applying for recognition and awards will be determined by the Green Racing Committee and made available by SAE International.

Race series that want to adopt Green Racing Elements may find it more feasible to begin implementing these elements into just one class or category in their race series. After the first Green Racing Element is successfully integrated into their series, it is easier to then extend Elements into additional categories or classes. Entire race series or categories within series may become eligible for Green Racing recognition, but can only be attributed to qualifying categories and classes referenced in the Green Racing Matrix. In order for categories or classes to be eligible to receive Green Racing recognition, at least 20 percent of the cars must have Green Racing attributes in that category or class over the course of the race season. Sanctioning bodies can include points earned from Elements allowed in their sporting regulations without any team using those technologies when calculating their Green Racing score for a period of three years. This provision is included since the Committee realizes it might take some time before competitors can develop and implement those technologies on the race track; however, if a series applies and receives credit for a technology or fuel that it later deems to be no longer advantageous or desirable, the SAE Green Racing Committee can remove those credits from the series' Green Racing score immediately. After this three year grace period, the same 20 percent provision for cars competing in a category or class to count towards eligibility for recognition. The entire race series cannot claim to be a Green Racing Series unless 50 percent or more of its competing cars qualify for Green Racing recognition over the course of the season.

Once the SAE Green Racing Committee has reviewed the materials submitted by a race series and granted recognition and award status as appropriate, that designation will remain in place until the sanctioning body modifies the sporting regulations the designation was based on or for a maximum of three years. After that time, a new application for Green Racing designation must be submitted for review by the Green Racing Committee. It is the responsibility of the sanctioning body to reapply for Green Racing designation when their sporting regulations on which its eligibility was determined have been modified at which time the race series must discontinue use of authorized Green Racing logos and stop taking advantage of other benefits provided by such recognition until recertified by the Green Racing Committee.

10. GREEN RACING RECOGNITION AND AWARDS

Four levels of recognition and two awards are established to recognize outstanding commitment of racing series to the goals and objectives of Green Racing. These represent significant commitments to fostering technologies and fuels relevant to future production vehicles and to providing a sustainable future for motorsports and personal mobility. Each of the following recognitions and awards will be based on a determination of qualification by SAE's Green Racing Committee. To be eligible for any of the four levels of recognitions, a race series must conduct at least ten percent of their races in North America during their annual race season. To be eligible for either of the two awards, a race series must conduct 50 percent of their races in North America over their annual race season. Race-specific awards and the ability to use trademarked Green Racing logos for those events may be granted to individual races in the U.S. that do not qualify for season-long awards if they otherwise meet the requirements. Individual race awards will be determined by SAE's Green Racing Committee dependent on the content and location of the race, and the data-sharing and promotional arrangements made with race organizers and promoters.

10.1 Green Racing Pathway Recognition

Many race series have already taken the first step toward becoming a full-fledged Green Racing Series. Other race series have only limited ability to embrace the Elements of Green Racing due to their format, participation, or technical or financial limitations. As incentive to strive toward higher Green Racing Commitment levels, the Pathway to Green Racing recognition was established. Racing categories or series that have a Green Racing score of 5 as determined by the SAE Green Racing Committee are entitled to receive this recognition at the time they are deemed eligible for this achievement. The Pathway recognition consists of a certificate from DOE, EPA, and SAE recognizing these actions and allowing the race series to use a unique Pathway to Green Racing logo to indicate it has taken the first steps toward making racing sustainable for the long-term.

10.2 Green Racing Series or Category Recognition

A race series or a category within a series with a Green Racing score of 8 points or above as determined by the SAE committee is classified as being a Green Racing Series or Category. Each Green Racing Series or Category will be recognized with a certificate of achievement from DOE, EPA, and SAE at the time they are deemed eligible for this recognition. Additionally, each Green Racing Series or Category is allowed to use a unique Green Racing Series recognition logo which indicates that they have taken meaningful steps toward making racing sustainable for the long-term. Their visibility may be enhanced by media releases and inclusion on websites and social media maintained by the agencies. Agency technical staff may be made available for consultation to the Green Racing Series or Category. Visits by agency leadership to key races and media events may be arranged by mutual agreement.

10.3 Green Challenge Championship

Racing series or one or more categories in a series that have a Green Racing point score of 12 or higher are qualified for a Green Challenge Championship award from DOE, EPA, and SAE at the time they are designated as being eligible for the award. Each eligible racing series must execute a partnership agreement with the agencies that ensures no conflicts of interest exist between them, and that no funds are exchanged to receive these awards. Series or categories that qualify for this Championship are allowed to use a unique Green Challenge logo which indicates it has taken meaningful steps toward making personal mobility and racing sustainable for the long-term. The visibility of the series and categories in a series may be enhanced by media releases and inclusion on websites and social media maintained by the agencies. A season-long Green Challenge Championship award by the agencies will be made to the OEM vehicle or powertrain manufacturer that demonstrates the best energy and environmental performance achieved over the course of the season in the qualifying series or categories. Visits by agency leadership to key races and media events may be arranged by mutual agreement. Agency technical staff may be made available for discussions with Green Challenge Championship series or categories on a range of technical topics.

10.4 Green Racing Cup Championship

Racing series or categories in a series that have a Green Racing point score of 19 or above are entitled to a Green Racing Cup Championship award from DOE, EPA, and SAE at the time they are eligible for the award. This significant accomplishment is the highest achievement in Green Racing. The race series or categories will also receive a season-long Green Racing Cup Championship award from DOE, EPA, and SAE to the OEM vehicle or powertrain manufacturer that demonstrates the best energy and environmental performance achieved over the course of the season in the qualifying series or categories. Each eligible racing series must execute a partnership agreement with the agencies that ensures no conflicts of interest exist between them, and that no funds are exchanged to receive these awards. Series or categories attaining this level of achievement are allowed to use a unique Green Racing Cup logo which indicates it has reached the pinnacle of actions taken to make racing sustainable for the long-term. The visibility of the Green Racing Cup Championship series or category will be enhanced by a media event in Washington, D.C. that acknowledges the leadership and relevance to national energy and environmental policy of these series. Regular media releases and inclusion on websites and social media maintained by the agencies may accompany this award. Visits by agency leadership to key races and media events may be arranged by mutual agreement. Agency technical staff may be made available for consultations with Green Racing Cup Championship series or categories, their vehicle manufacturer participants, and headline sponsors.

TABLE 2 - SUMMARY OF GREEN RACING RECOGNITION AND AWARDS 2014 – 2016

Recognition or Award	Green Racing Points
Pathway Award	**5 - 7**
Green Racing Series or Category Recognition	**8 - 11**
Green Challenge Championship	**12 - 18**
Green Racing Cup Championship	**19 or greater**

The Committee expects that as race series understand the content of the Green Racing Protocols and evolve their sporting regulations to embrace their benefits, the number of Green Racing Points required for the recognitions and awards will gradually rise. Changes to the recognition and reward levels for 2017 and beyond will be determined by the SAE Green Racing Committee as described in Section 8 above.

11. TOWARDS SUSTAINABLE MOTORSPORTS

These Green Racing Protocols provide a template for all forms of motorsport to help in the transformation of the automotive and energy industries to achieve sustainability and increase relevance, visibility, and credibility with the public. By helping to build the technical foundation for sustainable transportation, racing also increases its attractiveness to sponsors and new fans alike.

Motorsports have been in existence for over 100 years. It has been said the first automobile race occurred when the first two cars found themselves traveling in the same direction. The human need to compete and improve is the foundation of this sport. What makes it exceptional is the marriage of man and machine to push boundaries and achieve feats never before accomplished. By the last third of the 20th century, the fast pace of racing's technological development had been reined in. This was primarily due to the simultaneous need for reducing the cost of implementing multiple advanced technologies on racing machines, and controlling speed for safety's sake. By the start of the 21st century, racing found itself so constrained by regulation that its capacity for innovation was limited to more niche areas than ever – look no further than the front wings on Formula 1 cars as a case in point. Such extensive regulation has stymied racing to the point it is becoming less relevant to the automotive and energy industries, and more distant from the public.

The fusion of advanced engineering at the cutting edge of technology with superb and courageous athletic talent is what that makes motorsports so appealing. The essence of Green Racing is that motorsports holds great potential for preserving and expanding the economic benefits and individual freedom that comes from personal mobility while ensuring its own long-term survival.

To give racing the best chance at not only surviving, but thriving in the future, we believe that these Protocols must be embraced. Motorsports can transition to relevance, flourishing in a future shaped by efficiency, diversity of energy supplies and conversion technologies, and fed by a huge demand for mobility from developing parts of the globe. Moving toward sustainable motorsports is the only winning long-term strategy for racing; the Green Racing Protocols are the best blueprint to get there.

12. NOTES

12.1 Marginal Indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE GREEN RACING COMMITTEE

APPENDIX A
WELL-TO-WHEEL ANALYSIS AND GREEN RACING

Any consideration of the impact on energy and emissions from motor sports must be made from a WTW, or Total Life Cycle, perspective. An essential part of credible energy and environmental analysis for nearly 20 years, this holistic analytical approach seeks to present the most complete and accurate assessment of the results of consuming energy and its environmental impacts.

Green Racing focuses on the GHG emissions and impact on oil use to propel racing vehicles. To accurately assess the GHG emissions and the amount of petroleum embodied in fuels used for racing, it is imperative to use a comprehensive WTW analytical approach.

For transportation fuels several powerful WTW analysis tools have been developed largely through government funding to perform comprehensive and rigorous assessments of energy pathways. These tools are essential for understanding the nature of our current energy use posture and for developing informed, appropriate policy decisions that affect kinds and quantities of energy available in the future. For example, DOE has supported the development of the GHG, Regulated Emissions and Energy in Transportation model (GREET) as the agency's primary total life cycle analysis tool for over 15 years. GREET is the most widely used and externally reviewed transportation energy total life cycle assessment tool and it has over one hundred fuel pathways. GREET is available at no cost from http://greet.es.anl.gov/greet/.

In the U.S., EPA has promulgated rules to establish a Renewable Fuels Standard (RFS). RFS was mandated by the Energy Policy Act of 2005. In 2007, the Energy Independence and Security Act of 2007 (EISA) expanded the program which included adding life cycle GHG thresholds that fuels need to meet in order to generate credits under the program. To administer the program, EPA uses a methodology that incorporates inputs from several sources, including GREET, to establish lifecycle emissions values for renewable fuels that are sold in the U.S. More information on RFS can be found at http://www.epa.gov/otaq/fuels/renewablefuels/index.htm.

In most other developed and developing nations, GREET, or a similar total lifecycle assessment program tailored to the situation in their country is employed. Natural Resources Canada has developed GHG Genius with an emphasis on fuel pathways that are applicable to Canada that works in the same way and performs the same functions as GREET. It is available at http://www.ghgenius.ca/.

Race series can adopt the most relevant WTW analysis program they have access to when calculating the GHG and oil use reductions they have achieved to meet the definitions of Green Racing in these Protocols. Additional fuel pathways are being added to these tools and GREET gives users the capability to add their own custom pathways for fuels not already covered in the model. For different blends of fuels, weighted averages composed of the proportionately correct fuel components may be constructed to suit specific fuels.

A table listing the key information needed to calculate the GHG and oil use impacts for a large number of basic fuels appears in Table 1 below. The information in this table uses the RFS methodology as discussed above, courtesy of EPA. It was compiled in March 2013.

TABLE 3 - GREENHOUSE GAS AND OIL USE IN FUEL CONSUMPTION FOR MAJOR FUELS LIKELY TO BE USED IN MOTORSPORTS FROM 2013 RFS AND GREET MODELS

Fuels	GHG Well-to-Pump (WTP) gms CO_2-Equivalent/MJ	GHG Pump-to-Wheels (PTW) gms CO_2-Equivalent/MJ	GHG Well-to-Wheels gms CO_2-Equivalent/MJ	Oil Use WTP MJ Oil/MJ Fuel	Oil Use PTW MJ Oil/MJ Fuel	Oil Use Well-to-Wheels MJ Oil/MJ Fuel
Unleaded Gasoline	18.2	74.9	93.2	0.1071	1.0	1.1071
Corn Ethanol	1.1	72.2	73.3	0.0477	Fraction of oil feedstock in fuel	Sum of WTP and PTW Oil Use
Cellulosic Ethanol	-65.1	72.2	7.1	0.0262	Fraction of oil feedstock in fuel	Sum of WTP and PTW Oil Use
Ultra-Low Sulfur Diesel	17.1	74.9	92.0	0.0986	1.0	1.0986
Gas-to-Liquids Diesel Non-North American Natural Gas	40.7	72.4	113.1	0.0211	Fraction of oil feedstock in fuel	Sum of WTP and PTW Oil Use
Biomass-to-Liquids Diesel Hydrogenated Vegetable Oil	-27.4	73.3	46.0	0.0698	Fraction of oil feedstock in fuel	Sum of WTP and PTW Oil Use
Normal Iso-Butanol	-5.9	70.1	64.2	0.0433	Fraction of oil feedstock in fuel	Sum of WTP and PTW Oil Use
Compressed Natural Gas North American Natural Gas	22.5	56.4	78.9	0.0057	0.0	0.0057
Liquefied Natural Gas North American Natural Gas	23.1	56.6	79.7	0.0126	0.0	0.0126
Electricity U.S. National Grid Mix	208.5	0	208.5	0.0619	0.0	0.0619
Electricity California Grid Mix	124.1	0	124.1	0.0300	0.0	0.0300

Source: U.S. Environmental Protection Agency

Calculating the GHG and oil use impact of motorsports is the primary reason that fuel consumption measurement by car is in the Core level of the Emissions element in the Green Racing Protocols. The former American Le Mans Series (ALMS) used GREET results to calculate the Clean factor in its Green Challenge Scoring System from 2008 to 2013. The Clean factor is comprised of GHG emissions and reduced oil use from energy consumption during its races. For the multiple fuels used in its series, ALMS used GREET to calculate the "upstream" oil use and GHG emissions from the production and transportation of their fuels to the track per megajoule (MJ) of energy in the fuels. Oil content of the fuel and GHG emissions are based on the actual energy consumed during each race ("downstream" emissions) from each car. The GHGs and oil use are scaled appropriately and the upstream embodied results are added to the downstream race-produced results to get a total picture of the oil energy and GHG emitted from each car. ALMS also tracked the amount of oil it has saved on a race-by-race and season-long basis. The baseline for such analyses is difficult to construct given the significant changes to the racing cars, technologies, fuels, and tracks used from season to season. In the end, after attempts to reconstruct historical data from which to construct a baseline, the decision was made to work with the speed and efficiency of current cars, but compare them to operation on fuels used in years past with no renewable content; in other words, conventional gasoline and diesel fuels.

After a racing series starts down the path toward Green Racing and builds up reliable data on energy consumption using a range of different fuels, it will be possible to measure progress toward lower oil use and GHG emissions over time. Attaining this objective is a second major reason for including measurement of fuel use as a feature of the Core level of the Emissions element, as it will give the ability to reduce emissions and oil use year-to-year in the future.

APPENDIX B
ELECTRICITY AS A FUEL IN MOTORSPORTS

Electricity is an energy carrier produced through transforming other sources of energy into a form that is universal, has a multitude of uses, is easily transported, and can be recovered, stored and retrieved for future use. Its attractiveness in motorsports applications is essentially the same as for road transport; the technology used to convert electricity to motion is much more efficient than conventional heat engines, and the multitude of sources that can be used to produce it gives a wide range of attractive options to reduce critical energy and environmental issues facing individual nations and the world.

Using electricity as a fuel for motorsports presents opportunities and challenges, but given the inexorable movement toward increased efficiency for road and racing cars, its use is inevitable. This document will present some recommendations to enable the practical adoption of electricity as a fuel for motorsports.

Overview of Applications of Electricity Use in Motorsports

Electricity is so useful for multiple applications that it is already used in many ways in race cars. The advent of improved energy storage has increased its potential to include not only powering lighting, communications, thermal management, and power accessories, but also propulsion and eliminating engine-drive accessories, an added dimension that can add to performance. Vehicles that use electricity for propulsion use rechargeable energy storage systems (RESS) and fall into three broad categories. Hybrid electric vehicles (HEVs) use electricity for propulsion and are charge-sustaining. That is, they produce electrical power by converting on-board fuel into electricity directly or through recovering kinetic energy, as a result of burning fuel. HEVs do not require any other off-board electricity source to function. Plug-in hybrid electric vehicles (PHEVs) augment any on-board electricity production with electric power from external sources, typically the electric power grid; they are charge-depleting until the on-board RESS reaches a state of charge so that it functions as a charge-sustaining HEV. Fuel cell vehicles (FCVs) are a specific kind of HEV that use hydrogen as an energy carrier to produce electricity instead of a heat engine. They can be charge-sustaining (non-plug in) or a charge-depleting PHEV, and hydrogen can be produced from a secondary fuel through reformation or stored in primary from either in gaseous or liquid (cryogenic) form. As FCVs are expected to enter limited production in the next few years they present motorsport with an interesting and challenging opportunity. Battery electric vehicles (BEVs) have no on-board electricity production. They get all their energy from external sources and are completely charge-depleting.

Electricity from RESS can also be used to remove mechanical loads from the engine for improved power and efficiency. Electrifying these auxiliary loads for moving air and fluids for the car's systems, providing climate control, and operating sub-systems can be employed on vehicles with or without electric propulsion. As the technology for recovering waste heat from vehicle systems continue to improve, applications to electrify these so-called hotel loads will become increasingly attractive in motor sports.

Generating electricity for RESS applications can come from two major sources: on-board production or from external sources. Each is described below in more detail.

- On-board electricity production
    - From energy recovery: Electricity can be harvested from the kinetic energy of the vehicle by using generators or motors in operating generating mode.
    - From thermal production: Electricity can be produced directly from a heat source using a solid state device known as thermo-electric generator.
    - From mechanical production: Electricity can be produced by a generator driven by a heat engine or from its exhaust heat through a turbo compounding generator.
    - From a fuel cell: Electricity can be produced directly through a fuel cell powered by a consumable fuel. Typically these devices -have proton exchange membrane designs that use hydrogen as their fuel to make electricity.
- External sources
    - Grid connected: Connecting to the electric power grid via an RESS charger is the most typical way to use external sources. In racing applications, fast charging during competitive events is attractive, but poses significant thermal management issues for RESS that raise serious safety concerns. Fast charging also typically decreases the cycle life of electro-chemical RESSs and is far less efficient than conventional Level 2 recharging. Appendices 1 and 3 contain recommendations for how to treat grid-produced electricity on GHG and oil use.

- On-site generation: Electricity can be produced at the race track by an engine-driven generator (typically diesel-powered), through solar cells, wind turbines, or even fuel cells. The sanctioning body determines whether individual teams can provide its own electricity (see discussion in Appendix 3); these sources of power must be treated differently from the electric power grid as they have very different energy and emissions profiles. Appendix 3 also contains recommended practices to determine the impact of their use on GHG and oil use compared to the electric power grid.
- Swapping Energy Storage Devices: It is also possible to swap pre-charged RESS as a way to "refuel" electrically-powered racing cars. Reliable, safe high voltage connectors are essential for RESS swapping to work as is the RESS attachment system to the vehicle. See recommended safety requirements for fast charging in Appendix 4. Restraining movement of RESS during high G operation and potential vehicle accidents while allowing fast swapping is another engineering challenge for this approach.
- Inductive/conductive energy transfer: Wireless charging is a rapidly developing technology that could be employed when stationary during pit stops, and theoretically could occur when the vehicles are in motion at certain locations or all around a race track. On-the-fly recharging is not developed for practical use at this time, but efforts are ongoing to make this possible during this decade.

Measuring Electricity Use in Motorsports

There are multiple reasons to accurately measure electricity use in motorsports. Many sporting regulations limit RESS size and electric propulsion power, so ensuring compliance with those regulations is a primary motivation to measure electricity use for many sanctioning bodies. The committee also points out that accurate measurement is essential for calculating energy use and emissions from motorsports and understanding the system efficiency of the many ways electricity is used -on-board racing vehicles.

Measuring electricity use is straightforward with today's compact, rugged instruments that also record and/or transmit data taken from 1 to over 1000 Hz. System voltage and current (amperes) are multiplied to get power (typically in kW); most are bi-directional. Recommended locations and types of data collection are: at the input to the RESS (bi-directional); at each traction electric drive motor at the input to the power electronics module (bi-directional); at any source of electricity - generator, thermo-electrics, etc. (output only); and at any external charger (at the input; output can be assumed as the value of RESS in).

Overall electricity consumed is used to calculate the amount of GHGs attributed to the amount of electricity used (see Appendix 3 for how to perform these calculations) and oil use (see Appendix 1 for this value). Other measurements allow calculation of the efficiency of components (RESS recharger is an especially important one to watch) and to insure compliance with limits present in the sporting regulations. It is the committee's recommendation to open up sporting regulations to eliminate artificial limitations on the use of electric energy storage, and drive and focus on on-level component-based targets for RESS and total electric propulsion systems based on mass. By setting limitations at this level, improvements in RESS and electric drive energy- and power-density as well as improved thermal management of these systems can be incentivized.

APPENDIX C
EMISSIONS FROM ELECTRICITY GENERATION

It is important in a Green Racing context to properly account for emissions from electricity used by race cars but produced off-board. Any race car that uses an RESS, such as a battery or ultracapacitor, could potentially use off-board energy for some portion of its total energy consumption. In the case of a charge sustaining HEV, off-board energy would account for zero energy consumption by definition, and for an EV, that portion would be 100 percent. PHEVs would be somewhere between zero and 100 percent, depending on the design and implementation of the system. In motorsports applications, however, it is likely PHEVs would begin a race with 100 percent or near 100 percent RESS state of charge and use active blended braking – a constantly changing mix of foundation and regenerative braking – immediately after the start to maximize available electric drive power during the race.

There are two key factors to consider when accounting for electricity emissions in Green Racing. The first is how to compare upstream electricity GHG emissions with GHG tailpipe emissions from other vehicles in a fair and equitable manner. The second factor is at what level upstream emissions accounting will occur, whether local, regional, or national. These two factors are closely related in that the choices made in determining the rigor of the upstream analysis can impact the relative GHG emission impact of electricity.

Recommended Treatment of Emissions from Electricity

Generally, the committee believes that it is best to consider electricity use in EV racing in a manner similar to other fuels (see Appendix 1 on WTW Analysis and Green Racing for a discussion on that topic).. It is acknowledged that, especially for electricity, there is the potential for controversy to arise from decisions that must be made concerning the nature of electricity production in specific locations. The J2880 committee believes it is best to establish a system that is as simple and fair as possible, because of the specialized expertise in lifecycle analysis necessary to determine appropriate emissions factors for each and every location where motorsports may take place.

The simplest and recommended method for GHG accounting is to identify a national average grid emissions factor that is applied to every vehicle that uses grid electricity in units of g of CO_2 equivalent (CO_2e) per kWh or MJ used. In EPA's Renewable Fuels Standard 2 rule (RFS2[1]), the national grid average GHG emission level is 750.1 g CO_2e/kWh or 208.5 gCO_2e/MJ. This value is derived from the GREET[2] model and is consistent with upstream factors applied to other fuels in Green Racing. The upstream electricity emission factor includes losses for transmission and distribution, which are generally assumed to be around 7 percent, but does not account for losses in battery chargers. Because charger losses can be quite variable depending on charger and battery technology, rate of charge, and cell balancing strategies, it is strongly recommended that measurement of electrical energy use be made at the input to the charger. An additional measurement of energy input to the car can be made in order to measure charger efficiency.

In order to capture the entire amount of energy used during the race, each RESS must be charged to the teams' desired state of charge at the beginning of the race and again to that same state of charge at the end of the race, under the supervision of race officials. Alternatively, a sanctioning body may decide to measure energy consumption in real-time using an appropriate on-board current shunt.

While applying a single national average number is simple and convenient, the committee does recognize that actual upstream emissions could be much higher or lower than the national average value would indicate. Electricity cannot practically be produced and shipped to an event from a central facility with known and controllable emissions impacts as other fuels such as E85R. According to RFS2, cars fueled with electricity produced in California would have average emissions of 446 g CO_2e/kWh or 124.1 g CO_2e/MJ — considerably lower than the national average. In some circumstances, it is possible that the electricity used comes from sources that produce zero CO_2 such as dedicated solar arrays at race tracks. It is up to the race series to decide whether adjusting the upstream GHG production for electricity for each location is desirable. If a sanctioning body wishes to adopt full lifecycle analysis for upstream electricity emissions and is able to perform the analysis in a rigorous manner, the committee supports and applauds the effort. If the grid electricity contribution is relatively minor, the simplified approach using national average electricity would likely have little impact on scoring, rather than having separate calculations from a variety of electricity sources.

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[1] EPA's RFS2 rule sets a standard for the renewable content of motor vehicle fuels in the U.S. The analysis underpinning this rule is the basis for fuel lifecycle numbers used in Green Racing.

[2] GREET is a fuel lifecycle model developed by Argonne National Laboratory, sponsored by the Department of Energy. It is the leading lifecycle analysis model used in the U.S. It calculates the total energy use and emissions from the production and distribution of a wide variety of fuels. http://greet.es.anl.gov/greet/

Some race tracks do not have access to grid electricity for RESS and rely on electricity produced on-site with diesel generators. Electricity produced in this manner will have an emissions factor much higher than national grid average. To calculate the GHG impact of this fuel the committee recommends the following procedure:

The sanctioning body needs to determine the amount of diesel fuel it takes to produce a unit of electricity (typically in kWh) from that specific equipment under conditions of the day. Several methods can be used to obtain this data. The most straightforward is to use a fuel flow sensor like those used on some racing cars installed on the genset's fuel line and a shunt and meter on the alternating current (AC) or direct current (DC) output of the generator. Alternatively, if the fuel tank geometry is known a tank level sensor could suffice with generator output measurement. Still another acceptable approach is to "T" into the fuel line and connect a small fuel tank of known volume and run the genset until it consumes all the fuel and make the calculation from the amount of electricity produced. The diesel consumed produces 2,982.84 gCO_2e/l of GHG emissions (from RFS2 results); this number should be divided by the number of kWh produced by the genset and applied to the electricity required by RESS use for the race in question. Genset efficiency varies widely but is typically in the 35 percent range. No additional loss factors should be applied to the power produced from gensets. In addition, for the purposes of calculating the oil use impact for this way of producing electricity, a factor of 102.11 percent should be added to the amount of diesel consumed for the kWh used by the RESS and added to any fuel use factor of the car in question and for the series as a whole plus any calculation of a "Clean" factor as discussed in Appendix 1. On-site generation using other fuels should use a similar procedure, but with fuel-specific emission factors.

Vehicles that receive a portion of their propulsion energy from the grid such as PHEVs introduce another accounting problem. These vehicles use both the electricity and another consumable fuel and, necessarily, GHG emissions from electricity and the other fuel will need to be combined. In this case, the sanctioning body must make a determination of the expected electricity use compared to impact of the use of other fuels. In reality, the impact of any electricity from a PHEV's RESS on total GHG emissions is likely to be very small – likely small enough to be negligible. For example, the largest RESS system allowed by 2014 Automobile Club de l'Ouest (ACO) Le Mans Prototype 1 (LMP1) regulations is 8 MJ. That level of electricity consumption from the national grid amounts to 1668 gCO2e; less than 15 percent of the GHGs in *one gallon* of E10 using first generation ethanol (11,291 gCO2e). Over the course of a typical two hour race it is likely that over 40 gallons of E10 would be consumed by a typical race car, meaning the 8 MJ represents less than 0.4 percent of the energy consumed over the course of the race; measurement error in the fuel consumption apparatus is likely greater than that;[3] however, the committee supports inclusion of all GHG emission sources in the tabulation of results and tracking of a series Green Racing status to maintain transparency in all Green Racing results.

Sanctioning bodies will also have to decide if they will allow teams to use their own on-site generation to provide electricity for their team's cars and if they want to account for these GHG emissions on an individual basis. For example, a team could bring a portable hydrogen-powered fuel cell or solar panels to charge their vehicles with low or zero emissions. Compared to other cars running on grid electricity, these electricity sources would be demonstrably cleaner, but if a single upstream factor is used by the series there would be no incentive for teams to do this. If the sanctioning body allows teams to produce their own electricity, they may choose to perform a full upstream accounting to encourage this approach using RFS2, GREET, or another Total Life Cycle model; however, the sanctioning body must then consider a full upstream accounting for each event as well, since the emissions advantage of the on-site fuel cell generation would be less in a cleaner-grid venue such as in California. A series should use the same general approach as described for the diesel generator, but use the appropriate GHG values for the fuel in question. Because of the complexity and cost of allowing teams to generate their own electricity on-site, the committee recommends the sanctioning body supply all electricity from the same source, but to make that source as clean as possible by using electricity supplied by the grid.

[3] In 2014, Formula E, an all-electric racing series, allows a maximum of a 30 kWh RESS for their entire race (or half the race given two cars will be used per race). That level of electricity consumption from the U.S. national grid amounts to 22,503 gCO_2e, the equivalent of two gallons of E10 using first generation ethanol, a small fraction of the fuel that would have been burned over this distance using an internal combustion engine. The resulting reduction in GHGs compared to those that would have been emitted using conventional fuels in an engine is significant, in the range of 80 percent.

APPENDIX D
HIGH VOLTAGE ELECTRICAL SAFETY CONSIDERATIONS IN MOTORSPORTS

INTRODUCTION

The objective of this document is to establish the key guidelines for high voltage safety for vehicles with electric powertrains competing in Green Racing competitions. This document summarizes the minimal high voltage (HV) safety guidelines to be followed to safeguard competitors, officials, and spectators in motorsports. Refer to the documents listed below and those in the References above for more details and comprehensive discussion of these important topics.

HV DESIGN REQUIREMENTS

In the contents of this document, HV is defined as any voltage of 60V or greater.

Exposed HV Contact Points

Accidental contact with any portion of an HV electrical system shall be avoided at all times, except when the vehicle is being serviced and the system is de-energized. All portions of an electrical system must be protected against accidental contact with the human body. International Electrotechnical Commission (IEC) 60529 (Finger safe IP2X protection) must be met, specifically the section specifying that a 12mm diameter jointed “test finger” cannot make contact to any HV electrical terminal or conductor.

All portions of an electrical system must be protected against loose or dropped items, such as a wrench or bolt.

HV Markings

All HV conductors, connectors, and terminals must be insulated and properly labeled with HV warning labels or covered with orange coloring of 8.75R 5.75/12.5, according to SAE J1128 or equivalent color standard.

All HV components shall be marked with a HV warning triangle with lightning bolt according to ISO 3864-2 or equivalent standard.

Weather Proofing

All connection points of HV casings shall provide adequate weather-proofing to avoid moisture and water contact with any HV bus connections and shall follow the recommendations of ISO 20653.

Manual and Automatic Disconnect Safety Switch

There shall be a disconnect safety switch that fully disconnects the energy source(s) from the HV bus and immediately turns off any engine and fuel pump when engaged. The energy source(s) shall be disconnected by opening the HV contactor(s). Any source that could place energy on the HV bus – including a spinning Permanent Magnet motor – must be disconnected or shorted to ground. In the case of a Permanent Magnet motor, a three-phase ground short to ground is required when the contactor(s) is opened to prevent dangerous current on the HV bus.

The disconnect safety switch shall be automatically engaged in the event of a crash. Additionally, the disconnect safety switch shall be engaged manually by an emergency switch.

The manual emergency switch shall be easily accessible by the driver when seated normally behind the wheel with the safety belt fastened. Additionally, the manual emergency switch shall be located in a place which can be reached easily from outside for first responders. The switch must be clearly marked.

High Voltage Interlock Loop

All HV cables, both DC and AC, shall have a low voltage signal passing through each connector such that if the cable is removed, the HV contactor to the energy source(s) is opened.

High Voltage Isolation Detection System

All vehicles with an HV system must be equipped with an active ground-fault detection system that alerts the operator of the vehicle to any HV isolation faults on the vehicle, indicated by a lamp on the dashboard that is visible to the driver when seated normally behind the steering wheel, as well as outside observers. The system must monitor the isolation of the HV bus after the battery contactor to the vehicle chassis ground. The ground-fault detection systems must reliably detect when electrical isolation becomes less than 500 Ω/V, in accordance with FMVSS 305.

To properly allow the ground-fault detection system to work, all HV components enclosed by conductive casings must have equipotential (conductive) bonding between other conductive enclosed casing and vehicle chassis. The maximum allowable resistance of the bonding is 0.1 Ohms, as defined in Economic Commission for Europe (ECE)-R100.

Active and Passive High Voltage Discharge System

All vehicles must provide an indication to the driver when HV is present on the system. It shall be clearly visible even when an HV fault is present.

A passive discharge path is required to discharge the HV bus from maximum voltage to less than 60 V within two minutes after the HV contactor has been opened.

An active discharge path is required to discharge the HV bus from maximum voltage to less than 60 V within five seconds. The active discharge must be activated at each key-off event, any shutdown related fault, a crash event, activation of the manual emergency switch, opening of the HV interlock loop, and loss of the low voltage bus. Refer to SAE J1766 for further information.

Unintentional Propulsion

Competing vehicle designs must prevent high-power components, such as the electric motor, from carrying out unintentional propulsion that may cause a hazardous situation. If a power component receives an erroneous signal from a control device that has failed, the control hardware for the propulsion system or regenerator system must have a fail-safe system that prevents unintended operation of the drive system. The regulating requirement for erroneous propulsion is stated in the former ECE-R100 standard: “Unintentional acceleration, deceleration, and reversal of the drive train shall be prevented. In particular, a failure (e.g., in the power train) shall not cause more than 0.1 m movement of a standing un-braked vehicle.” Additionally, erroneous propulsion shall be prevented in the event of loss of low voltage power to the electric motor controller.

HV Battery Swapping Safety

In race events where HV battery swapping is performed, the following minimum HV safety measures should be addressed:

1. All quick disconnect connectors are finger proof when connected and not connected. Refer to the requirements in *Exposed HV Contact Points*.

2. When any cable from the HV battery is removed, the HV interlock loop shall be opened and the HV contactors shall open to the energy source(s).

3. The enclosure of the HV battery shall also meet the finger proof requirements in **Exposed HV Contact Points** above when installed in the vehicle and when out of the vehicle.

HV Battery Charging Safety

In race events where HV battery charging is performed, the following minimum HV safety measures should be addressed:

1. The connector from the charger shall have a pilot line such that it can only allow HV at the connector terminals when it is properly connected to the vehicle charger receptacle.

2. When the charger is connected to the vehicle, all vehicle propulsion shall be disabled. Propulsion is only allowed after the connector has been safely removed.

Inspection

Prior to the race event, the organizers may choose to inspect the HV safety integrity of the vehicle. The following are recommended inspection items:

1. Ground-fault detection system: Place a resistor between one of the high voltage legs and chassis ground to simulate a ground current large enough to trigger the ground-fault/isolation monitor. The dashboard ground-fault detection indicator light should illuminate. The threshold on the ground-fault monitor should be set to trip the warning light at, or near, 500 Ω/V.

2. Active discharge: Using a multi-meter, measure the voltage of the HV positive and negative bus. Engage the active discharge in all possible conditions described in *Active and Passive Discharge System*. Verify the HV bus discharges from the nominal HV voltage to less than 60 V in less than five seconds.

3. Visual inspection: Inspect all HV components, cables, and connectors for proper HV markings and proper finger proofing to prevent accidental contact to an HV conductor. The visual inspection should include reviewing the HV schematics.

4. Disable safety switch: With the vehicle running, verify that engaging the manual emergency switch discharges the HV bus to less than 60 V in less than five seconds, and the engine and fuel pump turns off, if applicable.