

## **Class 1A Sustainability Event Rules 2009**

### Event Objective

The objectives of the Sustainability Event are:

- A. To teach the participants that environmental impact is a significant factor that must be considered in any engineering exercise, particularly at the design stage. For the 2009 event the metrics used for assessing environmental impact are restricted to embodied energy and CO<sub>2</sub> in the materials used to manufacture the vehicle.
- B. For teams to make trade off decisions between the performance advantage and environmental impact of each part and assembly.
- C. To gain experience with creating and maintaining a Bill of Material (BOM).
- D. For the participants to learn and understand the principles of Eco-Design.

### Rules Objective

The objectives of the Sustainability Event rules are:

- A. To provide a logical, simple and time-efficient rule set enabling students to achieve the event's objectives.
- B. To improve fairness by providing consistent guidelines independent of teams' geographical location by using standardized embodied energy and CO<sub>2</sub> tables.
- C. To require the minimal burden of supporting documentation such as material suppliers environmental data sheets. However, in some cases there may be unusual materials used in components such as batteries, ultra-capacitors, fuel cells and composites that are not covered in the standard tables and participants are encouraged to source the relevant embodied energy and CO<sub>2</sub> information directly from the suppliers wherever possible.

## 1.0 Event Requirements

This event is comprised of three (3) parts

- 1.1 The preparation and submission of a report (the “Sustainability Report”), which is to be sent to the Sustainability Judges prior to the competition. See 5.0.
- 1.2 A discussion at the Competition with the Sustainability Judges around the team’s vehicle. See Section 17.0. This evaluates not only the environmental impact of the car, but also the team’s ability to prepare accurate impact estimates and assessments as part of the design process.
- 1.3 A “real case” scenario where students will have to respond to a challenge related to the environmental impact of the student vehicle.

## 2.0 Definitions

The following definitions will apply throughout the Sustainability Event rules:

- 2.1 Adjusted Impact – The final score for the vehicle including penalties
- 2.2 Amended Impact – The score for the vehicle after modification by the competition addendum
- 2.3 Bill of Material – A hierarchical list of all parts of the vehicle. A BOM lists every item that is on the vehicle but also shows the relationships between these items, for example showing the parts that make up an assembly. An Impact Bill of Material (IBOM) is a standard BOM that includes embodied energy and CO<sub>2</sub> information for the materials that go into manufacturing the vehicle, a measure of the environmental impact of the components.
- 2.4 Eco-Design - The process by which items are designed for minimum environmental impact by careful consideration of form and materials selection.
- 2.5 Environmental Impact – The environmental impact for each item is simply the mass of the constituent materials that make up that item multiplied by the unit energy and CO<sub>2</sub> values for those materials from the Sustainability Materials List.
- 2.6 Initial Environmental Impact – The environmental impact of the vehicle submitted for initial judging in the Sustainability Report.
- 2.7 Purchased Parts – Also called bought in parts; where possible, for commonly used parts such as tyres, these items are listed in the Sustainability Materials List in a near as-installed condition. In some cases purchased parts may still

require additional processing before they can be assembled to the car, which may affect the final mass in the IBOM.

- 2.8 Quantity – The amount of the item
  - 2.9 Raw Materials – Materials used for manufacturing parts, such as aluminium, steel and rubber
  - 2.10 Sustainability Materials List – Lists the mass-based embodied energy and CO<sub>2</sub> values for raw materials used to manufacture parts built by the teams, bought-in components where data is available and a sliding-scale of ‘left-over’ materials to cover bought-in components that cannot be easily accounted for due to a lack of material composition data. The left-over materials are also used for calculating penalties.
  - 2.11 Sustainability Report – All materials submitted for judging
  - 2.12 Sustainability Score – Refers to the total number of points out of 100 earned in the Sustainability Event.
  - 2.13 Unit – Is the measurement system used to define the quantity of a parameter. For example millimetres and kilograms are units.
- 3.0 General Requirements
- 3.1 The Sustainability Report must:
    - A. Use the standardized Sustainability Materials List for raw materials.
    - B. List every part on the prototype vehicle. This includes any equipment fitted on the vehicle at any time during the competition. The only exceptions are that, per 17.3 “Sustainability Report Exempt Items” of the Rules.
    - C. Be based on the calculated environmental impact of materials used in the construction of the car. The impacts shall be calculated as defined in these rules.
    - D. Exclude tooling, R & D and capital (e.g. moulds, jigs, plant, machinery, hand tools and power tools).

**Note:** There is no maximum environmental impact value.

#### 4.0 Scoring

The points for the Sustainability Event will be broken down as follows:

$30 \times \frac{\text{kg}_{\min}}{\text{kg}_{\text{your}}}$ $30 \times \frac{\text{MJ}_{\min}}{\text{MJ}_{\text{your}}}$	60	Lowest energy/CO <sub>2</sub> - each of the participating schools will be ranked by total adjusted embodied energy and CO <sub>2</sub> from the IBOM and given 0-30 points for CO <sub>2</sub> and energy respectively, based on the formulae on the left.
	20	The Sustainability Report – written, professional presentation of embodied energy and CO <sub>2</sub> data. The report score will be given based on the quality of the report, its accuracy and thoroughness. The range for the report score is 0 –20 points.
	20	Event Day/Materials Selection - The teams must be prepared to discuss in detail the reasoning behind their materials selection and how they balanced technical performance against ecological impact.
Total	100 Points	

Where:

$\text{kg}(\text{or MJ})_{\text{your}}$  is the adjusted CO<sub>2</sub>/energy value of your car (with penalties)

$\text{kg}(\text{or MJ})_{\min}$  is the adjusted value of the car with the lowest embodied CO<sub>2</sub>/energy (with penalties).

## 5.0 Sustainability Report

5.1 The Sustainability Report consists of a full vehicle IBOM with environmental impact data derived from the Sustainability Materials List and supporting documentation where appropriate. The Sustainability Report must be submitted in Excel spreadsheet (.xls or .xlsx) format only and must be identified as follows:

Carnumber\_schoolname\_competitioncode\_SR.xls using the assigned car number, the complete school name and the competition code.

Example: 087\_University of FSAE\_FSAEV\_SR.xls

Competition Codes are listed in Rule A – 2.6

## 5.2 Sustainability Report Identification

The front page of the Sustainability Report must include the following:  
(a) university name, (b) competition name, and (c) vehicle number.

## 5.3 The Sustainability Report must consist of the following:

- A Cover sheet
- An Environmental Impact Summary sheet listing each section's and the total vehicle's embodied energy and CO<sub>2</sub>.
- Nine (9) commodity report sections on separate worksheets with the parts placed in the sections as specified in Appendix S1.

## 6.0 Impact Bill of Materials (IBOM)

The IBOM is a parts list for every vehicle part. It also shows the relationships between the items.

6.1 The following terminology will be used when referring to the IBOM.

- The overall vehicle is broken down into nine (9) Systems which are defined in Appendix S1.
- Systems are made up of Assemblies.
- Assemblies are made up of Parts.
- Parts consist of materials.

6.2 An example IBOM structure is shown below:

- Engine & Drivetrain..... System
  - Engine..... Assembly
  - Differential..... Assembly
    - Housing..... Part
      - Aluminum..... Material
      - Needle Bearing..... Material
      - M6x1.25 Grade 8.8..... Fastener
    - Internals..... Part
    - End Cap..... Part

The IBOM must follow the format given above. There must be no other IBOM levels added or any removed. Deviations from the structure published will be penalized per Section 14.0.

**Note:** Manufacturing processes are currently not considered for the Sustainability Report.

6.3 All assemblies, parts and fasteners in the IBOM must use the standard numbering convention explained in FSAE Appendix C-2.

## 7.0 The Sustainability Materials List

- 7.1 All environmental impact figures in the Sustainability Report come from the standardized Sustainability Materials List. This list has been compiled to represent the average embodied energy and CO<sub>2</sub> values for raw materials and a limited number of bought-in components used in the manufacture of the vehicle.
- 7.2 Requests to alter the embodied energy and CO<sub>2</sub> values of materials in the list because of changing technologies and processes will not be approved. The list is intended to provide a fair, unchanging (within a given competition year) environmental impact for materials and to reduce regional variations that may help or hurt certain teams. All teams must use the embodied energy and CO<sub>2</sub> values given in the list. If a team wishes to use any materials not included in the list an “Add Material Request” must be submitted to the Formula Student rules committee, see section 10.0.
- 7.3 The list represents embodied energy and CO<sub>2</sub> based on material mass.

**Note:** For bought-in items, such as tyres, the data is still presented on a unit-mass basis, not per component.

**Note:** To simplify the process of assessing the environmental impact of the vehicle it may be assumed that an IC engine/gearbox assembly is made of 50% aluminium and 50% steel by weight. Any team that wishes to individually assess the actual weight of the engine components may do so.

## 8.0 Make Versus Buy

Every part on an individual car can be classified as “made” or “bought”. This designation does refer to whether a team actually purchased or fabricated a part.

- A. Made (or manufactured) parts must be assessed as if the company manufacturing the vehicle was going to make the part internally by purchasing and processing raw materials and into a finished product. Note, raw material left over from the manufacturing process, e.g. machining swarf, is not accounted for in the Sustainability Report, it is assumed that this material is collected and recycled.
- B. Bought parts must be assessed by determining the proportions of principal materials that make up the part and applying the appropriate figures from the Sustainability Materials List. It is assumed that these parts would be received by the vehicle manufacturer in a relatively finished state. Where the component supplier is able to provide documented evidence of embodied energy and CO<sub>2</sub> for the product used by the vehicle constructor these figures may be used. Copies of the supplier documentation must be included in the Sustainability Report.

## 9.0 Add Material Request

9.1 The Sustainability Materials List is intended to include all materials needed by the teams to accurately reflect the construction of their vehicle. However, it will be necessary to add materials to the list to suit individual team requirements. To do this an “Add Material Request” must be submitted to the Rules Committee at [fsrules@imeche.org](mailto:fsrules@imeche.org). After review the material will be added to the list with the next list update. The list will be updated throughout the competition year as required.

**Note:** Since all teams work off the same list once a team requests an item or material be added to the list all teams will see the addition. Any team using the newly added item will use the same CO<sub>2</sub> and energy figures. The identity of the school that made the request will not be published.

## 10.0 Report Submission and Deadline

- A. The Sustainability Report must be submitted in the designated format.
- B. Submission Address and Deadline – The submission requirements and deadline will be released on the Formula Student website.

## 11.0 Late Submission of the Sustainability Report

It is imperative that the Sustainability Judges have the Sustainability Reports in enough time for proper evaluation. Teams that submit reports late will be penalized 10 points per day late, with a maximum penalty of 80 points. Teams that do not submit a Sustainability Report will receive negative 100 points for the Sustainability Event. Penalties will be applied based on official upload date and time for electronic submission and by post mark for printed submissions.

## 12.0 Addenda

12.1 An addendum that reflects any changes or corrections made after the submission of the Sustainability Report must be submitted at Registration when the Team registers on-site at the Event. It will not be accepted at any other time or place. The addendum document must follow the template format specified in Appendix S2, a blank spreadsheet version will be posted on the Formula Student website. No other format will be accepted.

12.2 Any items added to the Sustainability Report through addenda will be included at 1.25 times the list values. Any items removed through addenda will only be credited 0.75 times the list values.

**Note:** Late changes to designs affect environmental impact in the real world. The scaling factors for the addenda capture this as well as encourage teams to submit full and accurate information with the initial Sustainability Report.

## 13.0 Sustainability Report Judging and Penalties Process

13.1 The following procedure will be used in determining penalties:

1. Penalty A based on IBOM accuracy will be calculated first using procedure 14.0
2. Penalty B based on mass accuracy will then be calculated using procedure 15.0
3. Both of the two penalties will be applied against the Sustainability score
  - a. Penalty A expressed in points will be deducted from the Accuracy score
  - b. Penalty B expressed in MJ & kg will be added to the Adjusted Impact score
4. If no additional points remain to be deducted from the Accuracy score the team will score zero for that part of the Sustainability Event.

13.2 Any error that results in a team over-reporting an impact in their Sustainability Report will not be further penalized. For example, when the Sustainability Report is prepared the weight of the brake discs has not yet been determined. The team conservatively estimates the discs at 1kg each. The final mass is 0.8kg and no change is made in the addendum. The team disc weight is higher than necessary but no further penalty is applied.

**Note:** The penalty system is intended to reward accuracy and minimize workload at the competition for students and judges.

**Note:** Any instance where a team's score benefits by an intentional or unintentional error on the part of the students will be corrected on a case by case basis.

#### 14.0 Penalty Method A- Fixed Point Penalty

14.1 From the Bill of Material, the Sustainability Judges will determine if all parts have been included in the analysis. In the case of any omission or error the judges will add a penalty proportional to the IBOM level of the error. The following standard points deductions will apply:

- Missing/inaccurate material, fastener..... 1 pt.
- Missing/inaccurate part..... 2 pt.
- Missing/inaccurate assembly..... 3 pt.

**Note:** Each of the penalties listed above supersedes the previous penalty. If a 3 point deduction is given for a missing assembly the missing parts are ignored for Method A. Method B would include the environmental impact of the missing parts in the calculation.

14.2 Differences other than those listed above will be deducted at the discretion of the Sustainability Judges.

Examples of errors leading to points deductions:

- Upright shown in IBOM as aluminium but actual part is steel – 1 pt.
- 5 taper-roller bearings listed, 6 used – 2 pt.
- Pneumatic shifter not included on IBOM – 3 pt.

#### 15.0 Penalty Method B – Adjusted Impact Penalty

15.1 The penalty will be calculated using the mass of the vehicle as measured at technical inspection with no fuel or water (assuming the car requires water). Drivetrain lubricating oil, hydraulic oil such as brake fluid, damper oil etc does not need to be drained and should be accounted for in the IBOM.

15.2 If the IBOM total mass is higher than that measured at technical inspection the IBOM figure is used unchanged.

15.3 If the IBOM total mass is lower than that measured, the difference will be added to the IBOM value and the 'left-over' materials categories from the Sustainability Materials List will be used to establish appropriate energy and CO<sub>2</sub> values.

15.4 It is anticipated that the team will have to make use of the 'left-over' material categories to account for some bought-in components where the material composition cannot be accurately determined. At the event the Sustainability Judges will continue to use the sliding scale of 'left-over' material allocation as a continuation of what is presented in the Sustainability Report.

## 16.0 Penalty Calculation Example

1. For example the pneumatic shifter was inadvertently left off the Sustainability Report. As this is an assembly the standard error is 3 points off the accuracy score.
2. The car is weighed at technical inspection at 200kg, but the IBOM total mass is 195kg. The team has already used up 7kg of 'left-over' material in the IBOM, 5kg of 0-5 material and 2kg of 5-10 material. Consequently the 5kg difference between IBOM and measured mass is added to the total impact using energy and CO<sub>2</sub> values from the remaining 3kg of 5-10 material and 2kg of 10+ material.

## 17.0 Discussion at the Competition

17.1 At this discussion, the Sustainability Judges will:

- A. Review whether the specification of the vehicle in the Sustainability Report accurately reflects the vehicle brought to the Competition.
- B. Assess penalties for missing or incorrect information in the Sustainability Report compared to the vehicle presented at inspection.
- C. Challenge the team to explain their design methodology in the context of the Sustainability Event.

17.2 The team must present their vehicle at the designated time to the Sustainability Judges for review of the Sustainability Report. Teams that miss their Sustainability Event appointment will potentially lose all Sustainability points for that day. The schedule for these appointments will be in the registration packets and/or posted on the website.

## 17.3 Sustainability Report Exempt Items

The Sustainability Report will account for all parts fitted to the car. The IBOM should be an accurate reflection of the car in a ready-to-run condition, with three exceptions:

- Plumbed-in fire extinguisher system
- Cooling system water (if utilised)
- Fuel

**Note:** On-board fire extinguisher systems do not have to be removed for vehicle weighing at technical inspection. Teams are expected to provide an accurate weight for the extinguisher system, to be subtracted from the overall vehicle weight. If the Sustainability Judges consider the declared weight to be inaccurate teams may be requested to remove the system from the car for independent weighing.

**Note:** Data logging equipment and systems are to be included in the IBOM. A category is given in the Sustainability Materials List to cover small bought-in electrical items, such as hand-held GPS receivers and sensors, which cannot easily be taken apart for constituent part weighing.

**Note:** Any fuel on board at technical inspection weighing will be counted towards the overall vehicle weight and impact score.

## 18.0 Unit Systems

The 'currency' of the Sustainability Report will be referred to as megajoules (MJ) of energy and kilograms (kg) of CO<sub>2</sub>.

18.1 The Sustainability Materials List is presented using metric units.

18.2 The comment section for each IBOM item may, at the student's discretion, refer to the specific part by actual local designation. For example a 6.35mm bolt is assessed but the comments would say "¼ inch A-arm bolt".

18.3 Because the Sustainability Report reflects an environmental impact for 1000 units per year all materials and components are assumed to be available for the necessary volume without embodied energy or CO<sub>2</sub> penalty.

## 19.0 Examples

An example IBOM will be posted to the Formula Student website

## **APPENDIX S1 - ORGANIZED LIST OF SYSTEMS & ASSEMBLIES**

The 2009 Formula Student Class 1A Sustainability Report must follow the organized list of systems and assemblies/parts outlined below. Any questions as to the correct location of the specific items must be submitted to the rules committee by June 1, 2009.

### 1) Brake System – BR

- Brake Fluid
- Brake Master Cylinder
- Fasteners
- Brake Lines
- Brake Discs
- Brake Pads
- Balance Bar
- Callipers
- Proportioning Valve

### 2) IC Engine and Drivetrain – EN

- Air Filter
- Axles
- Carburettor
- Chain / Belt
- Coolant Lines
- CV Joints/U Joints
- Differential
- Differential Bearings
- Differential Mounts
- Engine
- Engine Mounts
- Engine/Diff Oil
- Exhaust Manifold
- Fuel Filter
- Fuel Injectors
- Fuel Lines/Rails
- Fuel Pressure Reg.
- Fuel Pump
- Fuel Tank
- Fuel Vent/Check Valve
- Hose Clamps
- Ignition Coil / Wires
- Intake Manifold
- Muffler
- Oil Cooler
- Overflow Bottles
- Radiator
- Radiator Fans

- Restrictor
- Shields
- Sprocket/Pulleys
- Throttle Body
- Turbo/Super Charger
- Mechanical Accumulator (Flywheel/hydraulic)

3) Frame & Body – FR

- Aerodynamic Wing (if used)
- Body Attachments
- Body Material
- Clutch
- Floor Pan
- Frame / Frame Tubes
- Mounts Integral to Frame
- Pedals
- Shifter
- Shifter Cable/Linkage
- Throttle Controls

4) Electrical – EL

- Energy Storage (Battery/Capacitor)
- Brake Light
- Bulbs
- Dash Panel
- ECM/Engine Electronics
- Fuses
- Indicator Lights
- Kill Switch
- Oil Pressure Gage/Light
- Relays
- Solenoids
- Starter Button
- Tachometer
- Water Temperature Gage
- Wire Harness/Connectors

5) Miscellaneous, Finish and Assembly – MS

- Driver's Harness
- Fire Wall
- Headrest / Restraints
- Mirrors
- Paint – Body
- Paint – Frame

Seats  
Shields

6) Steering System – ST

Steering Rack  
Steering Shaft  
Steering Wheel  
Steering Wheel Quick Release  
Tie Rods

7) Suspension System – SU

Bell Cranks  
Front A/Arms or Equivalent  
Front Uprights  
Pushrods/Pullrods  
Rear A/Arms or Equivalent  
Rear Uprights  
Rod Ends  
Shocks  
Front Springs  
Suspension Mechanism

8) Wheels, Wheel Bearings and Tyres – WT

Front Hubs  
Lug Nuts  
Rear Hubs  
Tires  
Valve Stems  
Wheel Bearings  
Wheel Studs  
Wheel Weights  
Wheels

9) Electrical Drivetrain – ED

Fuel Cell  
Accumulator (Battery/Capacitor)  
Electric Motor(s)  
Power Controller  
HV Harness

**APPENDIX S2 - 2009 Formula Student Class 1A Sustainability Event Addendum**

Car Number/Class: \_\_\_\_\_  
University: \_\_\_\_\_

(Please indicate decreases using bracketed numbers)

Section	Original Energy Total	New Energy Total	Energy Difference	Original CO2 Total	New CO2 Total	CO2 Difference
1 Brake System						
2 IC Engine and Drivetrain						
3 Frame and Body						
4 Instruments, Wiring & Accessories						
5 Miscellaneous, Finish and Assembly						
6 Steering System						
7 Suspension and Shocks						
8 Wheels, Wheel Bearings and Tyres						
9 Electrical Drivetrain						
<b>Total Vehicle</b>	MJ	MJ	MJ	kg	kg	kg

Judge  
Initials

Explanation of Differences Listed Above:

**1 Brake System**

**2 IC Engine and Drivetrain**

**3 Frame and Body**

**4 Instruments, Wiring & Accessories**

**5 Miscellaneous, Finish and Assembly**

**6 Steering System**

**7 Suspension and Shocks**

**8 Wheels, Wheel Bearings and Tyres**

**9 Electrical Drivetrain**

Accepted by: \_\_\_\_\_  
Date: \_\_\_\_\_

Entered by: \_\_\_\_\_  
Date/Time: \_\_\_\_\_

**Addenda will be accepted only at time of registration!**

These forms will then be forwarded to the sustainability event judges the morning of the Sustainability Event.