APPENDIX FSA-C-1

1. General

1.1. Objective of the FSA Cost Rule Extension

When the new cost model was introduced by the FSAE in 2009, its objective was to simplify the cost process by providing standardized and parameterized materials and processes. However, when Formula Student Electric was introduced in mid-2009, the joint committee of FSAE and FSE failed to keep up with the new developments.

We THINK that the tables published by the cost committee in June 2011 are not sufficient to create a proper cost report **for an electric FS vehicle**.

Therefore, we decided to publish an additional table with the EV parts that were not covered by the FSAE materials table so teams will be able to complete their cost reports.

We tried to stay with the “spirit” of the cost process and not require the teams to submit AIRs, receipts, etc. by providing completely parameterized models.

Note that these extensions to the cost process are only valid for Formula Student Austria!

2. Materials parameterization clarification

2.1. ECU, Rapid Prototyping

This covers the dSpace microAutoBox and similar systems from ETAS and other suppliers. Those Units are differentiated by their deigned targets being Lab cars, HIL systems and prototype vehicles.

2.2. ECU, Automotive

ECU designed for small- or large series application.

2.3. ECU, Industrial

Industrial Automation – type Control units, e.g. Siemens SiMatic and similar systems from B&R and other suppliers. If you have a full system with e.g. Inverter and control modules, you will need to cost both separately (see 2.5.10)

2.4. ECU, EV, student built

Use this item if you run your vehicle control (driver wish to motor torque request) on a self-designed unit, usually some kind of microcontroller + I/O. You will have to use the ECU add-ons (e.g. Traction Control) from the materials table if you have those features.

2.5. Chassis Control Modules

Since the System Topology of each EV will probably be different, we decided to stick to the Cost Committee recommendation to cost the EV function “boxes” as Chassis Control Module (CCM) functions. This allows for individual functionality “grouping”. For each “box” in your car you need “Chassis Control Module, Baseline Enclosure” and one or more of the functionalities from the EV table. The “baseline” CCM covers whatever Power supply, MCU, PCB, wiring etc. you have in your box.

2.5.1. Chassis Control Module, + Battery Management System

Use this instead of “Chassis Control Module, +Battery Charger”.
Cost of this function is per “channel”. A channel is one “tap” into your battery pack, usually one for each cell in series. If your BMS manages a 12S1P pack, you will probably have 12 channels, if you have a 10S4P, it will probably have 10 channels (although it manages 40 cells!).

2.5.2. Chassis Control Module, + Isolation Monitoring Device

Your Bender ISO F1 or similar. See also 2.5.14

2.5.3. Chassis Control Module, + Power Distribution Module

Low voltage power switchbox. This covers “electronic fuse boxes” as well as devices that switch e.g. pumps and fans. Cost is per independently switchable output channel.

2.5.4. Chassis Control Module, + TSAL

Your tractive system active light as of FSE Rule 7.13. Covers any type, e.g. LED, strobe, regular bulbs. Includes cost for “blink” circuits but not for HV DC-DC converters described in 2.5.7

2.5.5. Chassis Control Module, + TSAS, buzzer

Your tractive system active sound as of FSE rule 7.18, if you use a piezo buzzer similar device.

2.5.6. Chassis Control Module, + TSAS, melody

Your tractive system active sound 7.18, if you use a speaker to play a melody, or a sound clip.

2.5.7. Chassis Control Module, + DCDC-Power (>1A) HV->LV

DC/DC switching type voltage converter to generate low voltage from the tractive system high voltage supply.

2.5.8. Chassis Control Module, + DCDC-Power LV->LV

DC/DC switching type voltage converter to generate a powerful low voltage supply from another low voltage, e.g. 24V or 48V control system supply from 12V. Not needed for low power sensor supplies.

2.5.9. Chassis Control Module, + Battery Charger HV

Battery charger for your HV Battery, if mounted on the car. Cost is per kW (rated) charging power

2.5.10. Chassis Control Module, + Motor Controller AC

Inverter for one AC drive motor. You will need one for every motor. Includes the cost for low capacity HV capacitors. The cost is per kW continuous power. If this figure is not available, use (peak power * 0.5)

2.5.11. Chassis Control Module, + Motor Controller DC

Controller for DC drive motors. Use one for each independently controllable motor. Includes the cost for low capacity HV capacitors. The cost is per kW continuous power. If this figure is not available, use (peak power * 0.5)

2.5.12. Chassis Control Module, + HV Insulation Relay

Single-line HV insulation relay. Does not include cost for the electronics to switch it on or off.

2.5.13. Chassis Control Module, + HV Precharge

Single HV precharge circuit, complete with low-power HV relay, power resistor(s) and wiring. If you have multiple precharge circuits in your car (e.g. multiple battery containments) you will need a matching number.

2.5.14. Chassis Control Module, + HV Housing

You will need to add this item to each CCM that has high voltage inside. This adjusts for the higher cost of insulation, shielding etc. on these modules. This includes wire glands fitted to the case. Note that the CCM costs do not include HV wiring leaving the module, this has to be costed separately as wiring + e.g. lugs.

2.5.15. Chassis Control Module, + HC-HV Fuse incl. Box

The high voltage fuse element includes fuse, fuse holder, cover, terminals.

2.6. Battery, Tractive Lithium

Tractive system battery. Cost is per kWh and includes the PCBs, rails or whatever you use to electrically connect the cells to a pack. Note that the battery containers, carrier, etc. has to be cost separately!

2.7. Motor, Tractive AC

Cost per kW continuous power. Use peak power * 0.5 if this figure is not available.

2.8. Motor, Tractive DC

Cost per kW continuous power. Use peak power * 0.5 if this figure is not available.

2.9. Wiring HV (> 12 mm²)

HV wiring, any style ((non) shielded, solid/stranded, etc..). Cost per mm² conductive cross section and meter length.

2.10. Conduit incl. Nuts, Elbows etc.

HV wiring conduit as required by FSE rule 7.11. Any type, color and diameter. Includes cost for small parts to connect the conduit, e.g. elbows, nuts, plastic glands etc.

2.11. Connector, HC-HV Lug Type

Single-wire lug type connector for HV wiring as described in 2.9. Any size and style.

2.12. Connector, HC-HV incl. Interlock

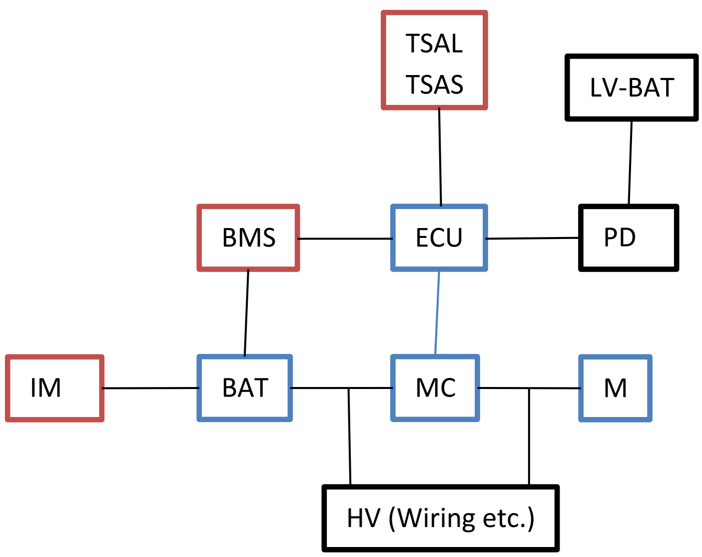
Insulated HV connector, any style, cost per HV Pin. Includes cost for small pilot/interlock/grounding pins and casing.

3. Electric vehicle cost model example

3.1. Abstract & Terminology

Here we will provide you with a simple example of how the tractive system of an electric vehicle could be costed using the provided table. Fig.1 shows the principal layout of that vehicle. *Note that this vehicle may not fulfill the FSE rules!*

Fig. 1: Simplified FSE Race Car Model



BAT… Tractive System Battery

BMS… Battery Management System

ECU… Electronic Control Unit

HV…. High Voltage – Wiring etc.

IMD… Isolation Monitoring Device

LV-BAT… Low Voltage Battery

M… Tractive Motor

MC… Motor Controller

PDU… Power Distribution Unit

TSAL… Tractive System Active Light

TSAS… Tractive System Active Sound

3.2. Battery

The battery of this vehicle consists of 72x 45Ah Lithium Cells connected in series but split into 6 containers. The overall capacity is *therefore 6 x 12 x 45Ah x 3,7V = 11,98 kWH* which will cost *$600/kWh x 11,98 kWh = $7188*

3.3. Battery Management

Each one of the six battery containers has one BMS board inside, which monitors the 12 cells and therefore has 12 channels. In the cost report:

6x Chassis Control Module, baseline enclosure = 6 x $25
6x Chassis Control Module + Battery Management System (12 ch.) = $20 x 12 = 6x $240

3.4. Electronic Control Unit

The car uses a dSpace MicroAutoBox as ECU, which qualifies as a Rapid Prototyping System and will therefore *cost $5000.*

3.5. IMD and TSAL/TSAS

On this car the IMD is integrated with the HV relay and TSAL/TSAS driver into one device.

In the cost report, this would look like this

Chassis Control Module, baseline enclosure	*$25*
Chassis Control Module, + IMD	*$300*
Chassis Control Module + PDU (4ch.)	*$28 (3 for the relays, 1 for the TSAL+TSAS)*
Chassis Control Module + TSAL	*$10*
Chassis Control Module + TSAS, buzzer	*$5*
Chassis Control Module + HV housing	*$25*

3.6. Motors

The car has dual DC motors, which are rated at 20 kW continuous power each:

2x Motor, Tractive DC	*20x $50 = $1000*	*2x $1000*

3.7. Motor Controller

The car uses a two-channel DC power stage which is rated at 25kW continuous power per channel:

1x Chassis Control Module, baseline enclosure	*$25*
2x Chassis Control Module, + Motor Controller DC	*2x $562,5 (=25x $22,5)*
1x Chassis Control Module + HV housing	*$25*

3.8. PDU

The PDU is a stand-alone device acting as an electronic fuse box and providing the ECU, and 4 other systems with power

Chassis Control Module, baseline enclosure	*$25*
Chassis Control Module, + PDU (5ch.)	*$35*

3.9. LV-Battery

The LV Battery is a low-performance LiIon 13,2V pack weighing about 1,2 kg.

Battery, advanced Chemistry	*$65/kg * 1,2kg*	*$78*

3.10. HV Wiring & systems

The wiring is not explained here, the standard harness process applies.
The battery containment houses the 6 battery packs as well as the precharge circuit and HV Fuse:

Chassis Control Module, baseline enclosure	*$25*
Chassis Control Module, +HV Fuse	*$100*
Chassis Control Module, + HV Precharge	*$50*

4. Document history

12.06.2011	Initial Release