USABC Systems Configuration Guidelines for Batteries

1. Background:

The United States Advanced Battery Consortium LLC (USABC) defines a set of technical and economic goals for battery systems, representative of different automotive applications. These goals are compiled in gap charts, which are used in the benchmarking of technologies, and in the definition and tracking of development programs.

2. Purpose:

The purpose of this Guidelines Document (GD) is to provide information to USABC development partners and program teams, which will allow the evaluation of the technology under investigation, in the context of a complete battery system, as defined within the requirements for the appropriate application. This GD will permit a cell or materials developer unfamiliar in the design of complete battery systems to measure their program's compliance with the USABC goals.

3. Scope:

This document defines the Battery System Bill of Materials (BOM) and its subsystem functions, as they apply to USABC-defined applications such as 12V Stop-Start (SS), 48V Hybrid Electric Vehicles (48V), Power-Assist Hybrid Electric Vehicles (HEV), Plug-in Hybrid Electric Vehicles (PHEV), and Electric Vehicles (EV). The battery systems are assumed to meet generic packaging requirements, in compliance with the goals set forth in the USABC Gap Charts. Methods for the determination of subsystem mass, volume, and cost are also provided.

These guidelines are general in nature and may be changed whenever deemed appropriate by USABC. They are not intended to alter or overrule the provisions of any purchase order issued by USABC. Any perceived inconsistency between these guidelines and the provisions of a USABC purchase order should be brought to the attention of the USABC program manager.

4. System Definition:

A battery energy storage system (BESS) is comprised of several elements, normally organized into major subsystems. Those subsystems collectively provide the BESS with the ability to perform all major functions expected for an automotive application.

4.1. High Voltage (HV) BESS:

The major subsystems typically required for an HV-BESS (voltage ≥60VDC) are illustrated in Table 1. Their respective subsystem components and potential additional (but not required) components are also shown in Table 1. An HV-BESS will contain these subsystems if it is intended to comply with the requirements/goals described in the following USABC applications: Electric Vehicle Battery, Power-Assist (PA) Battery, Plug-in Hybrid Battery, Low-Energy Energy Storage System (LEESS).

Table 1: HV-BESS Bill of Materials and Required Subsystems

Required Subsystems	Subsystem Components	Potential Additional Components
Module	Cell array Cells Cell to cell bussing Module housing Compression structure Cell voltage sensor Thermal sensor(s) Thermal interface structure	Gas vent manifold
CSC	Temperature sensor(s) Cell voltage sensors	Cell-cell balancing Current sensor(s)
BMU	Core microprocessor HV Interlock Loop (HVIL) Source 2-way communications with vehicle or charger	Fan/pump speed control Current sensor Cell-cell and/or module-module balancing
Thermal Management System	Ducting Plumbing/hoses/piping Temperature sensors	Heat sink Fan/pump/compressor Heat Exchanger Filter Heater
Battery Disconnect Hardware	Main (+/-) contactors Pre-charge relay/contactor Pre-charge resistor Current sensor Miscellaneous HV Fuses Main-pack fuse, if not in MSD	Charger (+/-) contactors
MSD		Including a main-pack fuse, if not in battery disconnect hardware
Low Voltage Wiring	High Voltage Interlock Loop (HVIL) actuators	
High Voltage Wiring	Bussing between modules Connections to BDU HV Pack Connectors	
Ducting for Vented Cells	Gas tubes and apertures	
Pack Housing	Tray Cover Fasteners Structural components	Seals/Gaskets. Thermal insulation

4.2. Medium Voltage (MV) BESS:

The required major subsystems recognized as typical for a MV-BESS (16 ≤ V DC < 60) are illustrated in Table 2, including their respective subsystem components and potential additional (but not required) components. A MV-BESS will contain these subsystems if it is intended to comply with the requirements/goals described in the following USABC applications:

- 48V HEV

Table 2: MV-BESS Bill of Materials and Required Subsystems

Required Subsystems	Subsystem Components	Potential Additional Components
Module	Cell array Cells Cell to cell bussing Module housing Compression structure Cell voltage sensor Thermal sensor(s) Thermal interface structure	Gas vent manifold
BMU	Core microprocessor Cell-cell balancing 2-way communications with vehicle Temperature sensor(s)	Fan/pump speed control
Thermal Management System	Ducting Plumbing/hoses/piping Temperature sensors	Heat sink Fan/pump/compressor Heat Exchanger Filter Heater
Battery Disconnect Hardware	Main (+) contactor/relay Current sensor Miscellaneous Fuses Main-pack fuse	Pre-charge relay/contactor Pre-charge resistor
Wiring	Bussing between modules Connections to BDU Pack Connectors	
Ducting for Vented Cells	Gas tubes and apertures	
Pack Housing	Tray Cover Fasteners Structural components	Seals/Gaskets. Thermal insulation

4.3. Low Voltage (LV) BESS:

The required major subsystems recognized as typical for a LV-BESS (VDC <16) are illustrated in Table 3, including their respective subsystem components and potential additional (but not required) components. A LV-BESS will contain these subsystems if it is intended to comply with the requirements/goals described in the following USABC applications:

- 12V Start-Stop Battery

Table 3: LV-BESS Bill of Materials and Required Subsystems

Required Subsystems	Subsystem Components	Potential Additional Components
Module	Cell array Cells Cell to cell bussing Module housing	Gas vent manifold Compression structure Cell voltage sensor Thermal sensor(s) Thermal interface structure
BMU	Core microprocessor	Fan/pump speed control 2-way communications with vehicle or charger Current sensor Cell-cell balancing
Thermal Management System		Heat sink Fan/pump/compressor Heat Exchanger Ducting Plumbing/hoses/piping Temperature sensors Filter Heater
Battery Disconnect Hardware	Main terminals (+/-) (24V) Overcharge protection	Main (+/-) contactors Current sensor Miscellaneous LV Fuses Main pack fuse
Ducting for Vented Cells	Gas tubes and/or apertures	
Pack housing	Tray Cover Fasteners Structural components	Seals/gaskets. Thermal insulation

5. Subsystem Definitions and Major Functions:

5.1. Module:

A grouping of interconnected cells in a single mechanical and electrical unit. The module contains all elements required for the mechanical and electrical integration of the cells, and facilitates all functional interfaces to the balance of the BESS, and associated subsystems.

5.2. CSC:

A cell supervision circuit (CSC) is secondary battery control unit, responsible for a subset of cells or modules. The CSC monitors and communicates cell/module voltages and temperatures and can support individual cell balancing.

5.3. BMU:

A battery management unit (BMU) is the primary battery control unit, responsible for BESS control and communication. The BMU can contain the functions of the CSC.

5.4. Thermal Management System:

A system responsible for the transfer of thermal energy to and from the pack, individual modules and/or cells, in order to facilitate optimal electrochemical performance and battery life. The TMS can use one or more media for the purposes of thermal conduction and transfer.

5.5. Battery Disconnect Hardware:

The power interface to the vehicle, containing contactors, relays and sensors required for the management of battery power to/from the external application.

5.6. Manual Service Disconnect:

A device that allows for the physical breaking of the battery power circuit, often containing the high current fuse and high voltage interlock loop (HVIL) connections.

5.7. Low Voltage Wiring:

Wire harnesses internal to the BESS, providing the ≤12V low power signals and communication.

5.8. High Voltage Wiring:

Wire harnesses and bus bars that form the connections between all high power (including all high voltage subsystems), and provide the means of transferring energy (including high voltage) from within the BESS to the external Interface.

5.9. Ducting for Vented Cells:

Gas management systems dedicated to the handling of vent products generated by cells, under abusive or (for non-lithium) extended operation conditions.

5.10. Pack Housing:

The BESS enclosure, which contains and supports all major subsystems, and provides all interfaces to the external interfaces.

6. Sizing of Subsystems:

6.1. Mass Calculation

The mass of each subsystem component shall be documented in the spreadsheet below. The total mass of the battery pack is the sum of the constituent parts. Where subsystems are consolidated, care should be taken not to double-count the mass contribution of components.

Cell mass should only include the mass of the smallest unit of energy storage. Termination hardware (screws, welds, bus-bars, etc.) that is not integral to the cells, should be counted as part of high power wiring or module subsystems. Also, any structural or spacing hardware that is not integral to the cell should be counted as part of the module.

The mass of any coolant or refrigerant contained within the thermal management system of the pack should be counted as part of the thermal management system, if included in the total pack mass determination. It should be explicitly noted if the coolant or refrigerant mass is not included within the pack mass determination.

The following ratios are important for comparison purposes and should be readily calculated, per the spreadsheet: (Cell Mass)/(Total Mass), and (Module + Cell Mass)/(Total Mass)

6.2. Volume Calculation

The volume contribution of each constituent component shall be documented in the spreadsheet below. In the case of nested components (for instance cells within modules), the subcomponent volume of the nested component shall be specified, but also noted as part of a higher level of assembly.

The total volume of the battery pack shall be computed as that of the major primary dimensions of the final pack assembly. This may be defined as the outer (x, y, z) dimensions of the pack enclosure. Exceptions can be made with respect to any extra volume required for mounting brackets, connectors or fittings protruding from the extents of the enclosure.

When specifying the component volumes, both the simple material volume (equal to mass/density) should be noted, as well as the smallest prismatic (x, y z) volume that can contain the component.

The following ratios are important for comparison purposes as should be readily calculated, per the spreadsheet: (Cell Volume)/(Total Volume), and (Module Volume)/(Total Volume).

7. Cost Estimations:

The USABC sets cost targets for complete systems. The annual volumes to be used for the estimation of battery system costs are illustrated in Table 3.

The total battery system cost is a rolled-up cost for the sum of the subsystems for that battery. The battery cost model used for systems analysis can be constructed, using the USABC Battery Cost Model Tool, referenced in Section 10. If the developer provides its own cost analysis, that analysis will need to account for all fixed and variable costs captured with the USABC Battery Cost Model tool.

Table 3: USABC Cost-Volume Goals

System	Annual Volume k units/yr	Cost Metric
12V Stop-start	250	$/unit
48V HEV	250	$/unit
Power-assist HEV	100	$/unit
Plug-in HEV	100	$/unit
Electric Vehicle	100	$/kWh

8. Exceptions and Deviations:

Developers participating within a USABC development program may deliver innovative technical solutions, which may render a portion of the standard BESS unnecessary. In this case the developer and the Program Manager must agree to the content of the BESS BOM that will be used in the determination of the goal values, to be published in the Program Gap Chart.

If system design decisions would require compensatory features that would not normally be included, the associated burdens (cost, volume and mass) should be accounted for. An example of this would be selection of a cell capacity/BSF that would dictate voltage conversion for normal system operation and power electronics compatibility.

9. Examples:

The table below provides a representative example of a completed partner query sheet (also see Appendix), for an EV battery. In this case, the example did not have some of the specific volume information, but instead had volumes lumped into one value, apart from cell and module components.

Subsystem	Contents	Mass	Volume	Cost
		kg	l	$
Cell	Individual cells	210.24	107.14	$7,520.00
Module H/W	Bussing, module housing, compression structure, voltage sensors, thermal sensor, thermal interface	28.76	33.96	$284.67
CSC	Thermal and voltage sense and management	3.90		
BMU	Core micro, HVIL, isolation detection, 2-way comm.. (e.g.: CAN)			$550.00
TMS	Ducting, plumbing, hosing, T sensors, cooling plates, Fans	2.00		
BD HW	Contactors, relays, resistors, current sensor, fuses	6.90		$310.50
MSD	Including main pack fuse	0.20		$64.00
LV Wiring	Circuits between modules, sensing, actuators, HVIL, Includes all LV connectors	5.60		$95.57
HV Wiring	Bussing between modules, connections to BDU, including connections to vehicle interface	11.20		$291.15
Cell Ducting for vented gasses	Gas tubes and apertures, exhaust ducting from battery compartment			$96.00
Pack Housing	Tray, cover, and all gaskets/seals, hardware	64.5	95.9	$193.98
	Total	333.30	237.00	$ 9,405.87

Commonly Encountered Cell Fractions Within a BESS

	Mass	Volume	Cost
12V S/S	0.60 – 0.85	0.60 – 0.80	0.60 – 0.90
HEV	0.30 – 0.50	0.25 – 0.50	0.55 – 0.75
PHEV	0.60 – 0.75	0.40 – 0.70	0.50 – 0.75
BEV	0.60 – 0.80	0.40 – 0.70	0.70 – 0.85

10. References:

The associated systems goals may be found at:

http://www.uscar.org/guest/article_view.php?articles_id=85

The associated USABC manuals, for use in the determination of battery performance may be found at:

http://www.uscar.org/guest/article_view.php?articles_id=86

The associated USABC cost models, for use in the determination of a battery system cost structure may be found at:

http://www.uscar.org/guest/article_view.php?articles_id=143

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Appendix:

Excel file:

Partner Query sheet.xlsx

USABC Partner System Request for Information

Partner Name: ______________________________

Program Title: ______________________________

System Description:

The Partner is requested to provide approximate values for each of the following, for the represenative battery system

Sub-System	Contents	Mass	Volume	Cost
		kg	l	$
Cell	Individual cells			
Module H/W	bussing, module housing, compression structure, voltage sensors, thermal sensor, thermal interface			
CSC	thermal and voltage sense and mngmt			
BMU	Core micro, HVIL, isolation detection, 2-way comm (e.g.: CAN)			
TMS	Duscting, plumbing, hosing, T sensors, cooling plates			
BD HW	Contactors, relays, resistors, current sensor, fuses			
MSD	Including main pack fuse			
LV Wiring	Circuits between modules, sensing, actuators, HVIL, Includes all LV connectors			
HV Wiring	Bussing between modules, connections to BDU, including connections to vehicle interface			
Cell Ducting for vented gasses	Gas tubes and apertures, exhaust ducting from battery compartment			
Pack Housing	Tray, cover, and all gaskets/seals, hardware			
	Total	0.00	0.00	$ -