Introduction

The fiscal year (FY) 2019 U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program (the Program) Annual Merit Review and Peer Evaluation Meeting (AMR) was held April 29–May 1, 2019, in Arlington, Virginia. This report is a summary of comments by AMR peer reviewers about the hydrogen and fuel cell projects funded by DOE's Office of Energy Efficiency and Renewable Energy (EERE). Projects supported by other state agencies and DOE offices (including the Office of Fossil Energy Solid Oxide Fuel Cell Program [FE-SOFC)], Office of Science [Basic Energy Sciences], Office of Nuclear Energy [NE], Advanced Research Projects Agency–Energy [ARPA-E], and EERE Bioenergy Technologies Office) in areas relevant to hydrogen and fuel cells were also presented at the FY 2019 AMR. DOE uses the results of this merit review and peer evaluation, along with additional review processes, to make funding decisions for upcoming fiscal years and help guide ongoing performance improvements to existing projects.

The objectives of this meeting included the following:

- Review and evaluate FY 2019 accomplishments and FY 2020 plans for DOE laboratory programs; industry/university cooperative agreements; and related research, development, and demonstration (RD&D) efforts.
- Provide an opportunity for stakeholders and participants (fuel cell and hydrogen system manufacturers, component developers, and others) to provide input to help shape the DOE-sponsored RD&D program in order to address the highest-priority technical barriers and facilitate technology transfer.
- Foster interactions among the national laboratories, industry, and universities conducting RD&D.

The peer review process followed the guidelines in the *Peer Review Guide* developed by EERE. The peer review panel members, listed in Table 1, provided comments about the projects presented. Panel members included experts from a variety of backgrounds related to hydrogen and fuel cells, and they represented national laboratories; universities; various government and non-government organizations; and developers and manufacturers of hydrogen production, storage, delivery, and fuel cell technologies. Each reviewer was screened for conflicts of interest as prescribed by the *Peer Review Guide*. A subset of these reviewers was also asked to provide overall Program and subprogram review feedback. The results of this Program Review feedback are included in Appendix A. A complete list of the meeting participants is presented in Appendix B.

Table 1: Peer Review Panel Members

No.	Name	Organization
1	Kareem Afzal	PDC Machines, Inc.
2	Rajesh Ahluwalia	Argonne National Laboratory
3	Paul Albertus	University of Maryland
4	Ilse Alcantara	NASA
5	Shaun Alia	National Renewable Energy Laboratory
6	Laurent Antoni	CEA (French Atomic Energy and Alternative Energies Commission)
7	Mirela Atanasiu	Fuel Cells and Hydrogen Joint Undertaking (FCH JU)
8	Katherine Ayers	Proton OnSite
9	Chulsung Bae	Rensselaer Polytechnic Institute
10	Bamdad Bahar	Xergy Inc
11	Nick Barilo	Pacific Northwest National Laboratory
12	Jean Baronas	California Energy Commission
13	Olga Baturina	U.S. Navy, Naval Research Laboratory
14	Matthew Beckner	General Motors
15	Guido Bender	National Renewable Energy Laboratory
16	William Bergeson	Federal Highway Administration
17	Naveen Berry	South Coast Air Quality Management District
18	Bart Biebuyck	Fuel Cells and Hydrogen Joint Undertaking (FCH JU)
19	Bryan Blackburn	Redox Power Systems
20	Rodney Borup	Los Alamos National Laboratory

No.	Name	Organization
21	Nico Bouwkamp	California Fuel Cell Partnership
22	Antonio Bouza	U.S. Department of Energy
23	Ken Boyce	UL
24	Kyle Brinkman	Clemson University
25	Albert Burgunder	Praxair, Inc.
26	Susan Burke	U.S. Environmental Protection Agency
27	Jimmy Burns	University of Virginia
28	Scott Calabrese Barton	Michigan State University
29	Pietro Caloprisco	Fuel Cells and Hydrogen Joint Undertaking (FCH JU)
30	Patrick Campbell	Lawrence Livermore National Laboratory
31	Marcelo Carmo	Forschungszentrum Jülich
32	Kevin Centeck	U.S. Army, Tank Automotive Research, Development and Engineering Center (TARDEC)
33	Franklin Chang Díaz	Ad Astra Rocket Company, Costa Rica
34	Bryan Chapman	Exxon Mobil Corporation
35	Santanu Chaudhuri	Argonne National Laboratory
36	Praveen Cheekatamarla	Atrex Energy, Inc.
37	Dejun Chen	Georgetown University
38	Biswajit Choudhury	DuPont
39	Yachun Chow	California Air Resources Board
40	William Collins	Consultant
41	Hector Colon-Mercado	Savannah River National Laboratory
42	Amedeo Conti	Nuvera Fuel Cells, Inc.
43	Chris Cornelius	University of Nebraska
44	Stephen Creager	Clemson University
45	David Cullen	Oak Ridge National Laboratory
46	Ismaila Dabo	Pennsylvania State University
47	Nilesh Dale	Nissan Technical Center North America, Inc.
48	Nemanja Danilovic	Lawrence Berkeley National Laboratory
49	Timothy Davenport	United Technologies Research Center
50	Emory De Castro	Advent Technologies, Inc.
51	Daniel DeSantis	Strategic Analysis, Inc.
52	Todd Deutsch	National Renewable Energy Laboratory
53	Eric Dirschka	NASA
54	Tabbetha Dobbins	Rowan University
55	Francesco Dolci	European Commission Joint Research Centre, Energy, Transport and Climate
56	Andreas Dorda	Austrian Federal Ministry for Transport, Innovation and Technology
57	Martin Dornheim	Helmholtz-Zentrum Geesthacht
58	Mihai Dorobantu	Eaton Vehicle Group
59	David Edwards	Air Liquide
60	Glenn Eisman	Rensselaer Polytechnic Institute
61	Lior Elbaz	Israel Fuel Cells Consortium, Institute of Nanotechnology and Advanced Materials, Israel National Research Center for Electrochemical Propulsion, and Bar-Ilan University
62	William Elrick	California Fuel Cell Partnership
63	Elif Ertekin	University of Illinois
64	Sylvie Escribano	CEA (French Atomic Energy and Alternative Energies Commission)
65	Leslie Eudy	National Renewable Energy Laboratory
66	Matt Fairlie	Next Hydrogen
67	David Farese	Air Products and Chemicals, Inc.

No.	Name	Organization
68	Gary Flood	GSF Consulting
69	Nicole Forester	Commonwealth Scientific and Industrial Research Organisation, Australia (CSIRO)
70	Katrina Fritz	KM Fritz, LLC
71	Bernard Frois	CEA (French Atomic Energy and Alternative Energies Commission)
72	Livio Gambone	Nikola Motor Company
73	Prabhu Ganesan	Savannah River Consulting, LLC
74	Jürgen Garche	Ulm University
75	Mario Garcia-Sanz	ARPA-E
76	Monterey Gardiner	BMW Group
77	Thomas Gennett	National Renewable Energy Laboratory
78	Dominic Francis Gervasio	University of Arizona
79	Hossein Ghezel-Ayagh	FuelCell Energy
80	William Gibbons	University of Maryland
81	François Girard	National Research Council Canada, Energy, Mining and Environment
82	Leslie Goodbody	California Air Resources Board
83	Colin Gore	Redox Power Systems, LLC
84	Leo Grassilli	Consultant
85	Matt Gregori	Sempra Utilities
86	Ulf Groos	Fraunhofer Institute for Solar Energy Systems ISE, Fuel Cell Systems, Hydrogen Technologies
87	Tom Gross	Energy Planning and Solutions
88	Stephen Grot	Ion Power
89	Katrina Groth	University of Maryland
90	Ram Gupta	Virginia Commonwealth University
91	Jennifer Hamilton	California Fuel Cell Partnership
92	Dan Hancu	U.S. Department of Energy
93	Aaron Harris	Air Liquide
94	Alex Harris	Brookhaven National Laboratory
95	Kevin Harrison	National Renewable Energy Laboratory
96	William Harrison	Nanosonic, Inc.
97	Jason Hattrick-Simpers	National Institute of Standards and Technology
98	Andrew Haug	3M Company
99	Ethan Hecht	Sandia National Laboratory
100	Thorsten Herbert	NOW GmbH (National Organisation Hydrogen and Fuel Cell Technology)
101	Michael Hibbs	Sandia National Laboratories
102	Darren Hickey	Cummins
103	Michael Hickner	Pennsylvania State University
104	James Hinkley	Commonwealth Scientific and Industrial Research Organisation, Australia (CSIRO)
105	Jamie Holladay	Pacific Northwest National Laboratory
106	Chang Huajian	State Power Investment Corporation Research Institute
107	Kevin Huang	University of South Carolina
108	Yu Huang	University of California, Los Angeles
109	Chad Hunter	National Renewable Energy Laboratory
110	Nick Irvin	Southern Company
111	Levi Irwin	U.S. Department of Energy
112	Ian Jakupca	NASA
113	Brian James	Strategic Analysis, Inc.

No.	Name	Organization
114	Will James	Savannah River National Laboratory
115	Hongfei Jia	Toyota North America
116	Qingying Jia	Northeastern University
117	Scott Jorgensen	SBC Global
118	James Kast	Toyota Motor Corporation
119	Douglass Kauffman	National Energy Technology Laboratory
120	Jay Keller	Consultant
121	Ron Kent	Southern California Gas Company
122	John Khalil	United Technologies Research Center
123	Yu Seung Kim	Los Alamos National Laboratory
124	Sarah Kleinbaum	U.S. Department of Energy
125	Shanna Knights	Ballard Power Systems
126	Tomonari Komiyama	JX Nippon Oil
127	Anusorn Kongkanand	General Motors
128	John Kopasz	Argonne National Laboratory
129	Theodore Krause	Argonne National Laboratory
130	Ahmet Kusoglu	Lawrence Berkeley National Laboratory
131	Xianglin Li	Kansas University
132	Ludwig Lipp	T2M Global
133	Shawn Litster	Carnegie Mellon University
134	Di-Jia Liu	Argonne National Laboratory
135	Gao Liu	Lawrence Berkeley National Laboratory
136	Meilin Liu	Georgia Institute of Technology
137	Miguel Maes	NASA
138	Jim Manusco	Westport Power, Inc.
139	Radenka Maric	University of Connecticut
140	Olga Marina	Pacific Northwest National Laboratory
141	Andrew Martinez	California Air Resources Board
142	Sara Marxen	CSA Group
143	David Masten	General Motors
144	Luca Mastropasqua	University of California, Irvine
145	Paul Matter	PH Matter
146	Scott Mauger	National Renewable Energy Laboratory
147	Anthony McDaniel	Sandia National Laboratories
148	Stephen McDougle	NASA
149	Noah Meeks	Southern Company
150	Nalini Menon	Sandia National Laboratories
151	Nguyen Minh	University of California, San Diego
152	Cortney Mittelsteadt	Giner, Inc.
153	Miguel Modestino	New York University
154	Mohsen Mosleh	Howard University
155	Christopher Muhich	Arizona State University
156	Rangachary Mukundan	Los Alamos National Laboratory
157	Christopher Munnings	Electrochemical Energy Systems
158	Vivek Murthi	Nikola Motor Company
159	William Mustain	University of South Carolina
160	Kenneth Neyerlin	National Renewable Energy Laboratory
161	Tien Nguyen	Independent
162	Madeleine Odgaard	IRD Fuel Cells
163	Bob Oesterreich	Air Liquide
164	Tadashi Ogitsu	Lawrence Livermore National Laboratory

No.	Name	Organization
165	Gregory Olson	Consultant
166	Kevin Ott	Los Alamos National Laboratory, retired
167	Benjamin Paczkowski	U.S. Army, Tank Automotive Research, Development and Engineering Center (TARDEC)
168	Andrew Park	Chemours
169	George Parks	FuelScience, LLC
170	Pinakin Patel	Fuel Cell Energy, Inc.
171	Tapan Patel	U.S. Army
172	Mike Perry	United Technologies Research Center
173	Michael Peters	National Renewable Energy Laboratory
174	Guillaume Petitpas	Lawrence Livermore National Laboratory
175	Aaron Petri	U.S. Army
176	John Pietras	Saint-Gobain
177	Peter Pintauro	Vanderbilt University
178	Bryan Pivovar	National Renewable Energy Laboratory
179	Olga Polevaya	Nuvera Fuel Cells, Inc.
180	Karen Quackenbush	Fuel Cell & Hydrogen Energy Association
181	Glenn Rambach	SiGNa Chemistry Inc.
182	Jeffrey Reed	University of California, Irvine
183	Brian Rice	University of Dayton Research Institute
184	Denzel Robertson	Air Liquide
185	Aashish Rohatgi	Pacific Northwest National Laboratory
186	Subir Roychoudhury	Precision Combustion, Inc.
187	Tecle Rufael	Chevron Energy Technology Company
188	Antonio Ruiz	Nikola Motor Company
189	Christian Sattler	German Aerospace Center (DLR)
190	Birgit Schwenzer	National Science Foundation
191	Alexey Serov	Pajarito Powder, LLC
192	Godwin Severa	University of Hawaii
193	Stephen Sikirica	U.S. Department of Energy
194	Kevin Simmons	Pacific Northwest National Laboratory
195	Prabhakar Singh	University of Connecticut
196	Joshua Snyder	Drexel University
197	Grigorii Soloveichik	U.S. Department of Energy
198	Xueyan Song	West Virginia University
199	Herie Soto	Shell Oil Company
200	Jacob Spendelow	Los Alamos National Laboratory
201	Vojislav Stamenkovic	Argonne National Laboratory
202	Andy Steinbach	3M Company
203	Nadia Steiner	Université de Franche-Comté
204	Gary Stottler	General Motors, retired
205	Ian Sutherland	General Motors
206	Scott Swartz	NexTech Materials LTD
207	Karen Swider-Lyons	U.S. Navy, Naval Research Laboratory
208	Andrei Tchouvelev	A.V. Tchouvelev & Associates Inc.
209	Pascal Tessier	Air Liquide
210	David Tew	ARPA-E
211	Michael Toney	SLAC National Accelerator Laboratory
212	Jianhua Tong	Clemson University
213	John Trocciola	CSRA
214	Hiroyuki Usuda	New Energy and Industrial Technology Development Organization

No.	Name	Organization
		(NEDO)
215	Mike Veenstra	Ford Motor Company
216	David Viano	Commonwealth Scientific and Industrial Research Organisation, Australia (CSIRO)
217	James Waldecker	Ford Motor Company
218	Jia Wang	Brookhaven National Laboratory
219	Adam Weber	Lawrence Berkeley National Laboratory
220	Marcel Weeda	TNO innovation for life
221	Douglas Wheeler	DJW Technology, LLC
222	Mark Williams	AECOM
223	Brandon Wood	Lawrence Livermore National Laboratory
224	Stephen Woods	NASA
225	Ryszard Wycisk	Vanderbilt University
226	Jian Xie	Indiana University–Purdue University Indianapolis
227	Hui Xu	Giner, Inc.
228	Michael Yandrasits	3M Company
229	Fuming Yang	State Power Investment Corporation Research Institute, China
230	Eleni Zafeiratou	Fuel Cells and Hydrogen Joint Undertaking (FCH JU)
231	Piotr Zelenay	Los Alamos National Laboratory
232	Xiao-Dong Zhou	University of Louisiana at Lafayette
233	Jonathan Zimmerman	Sandia National Laboratories
234	Barr Zulevi	Pajarito Powder, LLC

Summary of Peer Review Panel's Crosscutting Comments and Recommendations

AMR panel members provided comments and recommendations regarding selected DOE hydrogen and fuel cell projects, overall management of the Hydrogen and Fuel Cells Program, and the AMR peer evaluation process. The project comments, recommendations, and scores are provided in the following sections of this report, grouped by subprogram. Comments about Program and subprogram management are provided in Appendix A.

Analysis Methodology

A total of **129** Fuel Cell Technologies Office (FCTO) projects were reviewed at the meeting. As shown in the table above, **234** review panel members participated in the AMR process, providing a total of **677** project evaluations. These reviewers were asked to provide numeric scores (on a scale of 1–4, including half-point intervals, with 4 being the highest) for five aspects of the work presented. Sample evaluation forms are provided in Appendix C. Scores and comments were submitted using laptops (provided on site) to a private online database, allowing for real-time tracking of the review process. A list of projects that were presented at the AMR but not reviewed is provided in Appendix D.

For the Hydrogen Fuel R&D; Fuel Cell R&D; Infrastructure and Systems R&D; and Safety, Codes and Standards subprograms, scores were based on the five criteria and weights provided below. The Hydrogen Fuel R&D subprogram includes two project categories—Hydrogen Production R&D and Hydrogen Storage R&D—that were similarly evaluated. The Infrastructure and Systems R&D subprogram includes three project categories: Hydrogen Infrastructure R&D, Technology Acceleration, and Systems Analysis; these were similarly evaluated.

Score 1: Approach to performing the work (20%)
Score 2: Accomplishments and progress toward overall project and DOE goals (45%)
Score 3: Collaboration and coordination with other institutions (10%)
Score 4: Relevance/potential impact on DOE Program goals and RD&D objectives (15%)
Score 5: Proposed future work (10%)

For each project, individual reviewer scores for each of the five criteria were weighted using the formula in the box below to create a final score for each reviewer for that project. The average score for each project was then calculated by averaging the final scores for individual reviewers. The individual reviewer scores for each question were also averaged to provide information on the project's question-by-question scoring. In this manner, a project's final overall score can be meaningfully compared to that of another project.

Final Overall Score = [Score 1 x 0.20] + [Score 2 x 0.45] + [Score 3 x 0.10] + [Score 4 x 0.15] + [Score 5 x 0.10]

A perfect overall score of "4" indicates that a project satisfied the five criteria to the fullest possible extent; the lowest possible overall score of "1" indicates that a project did not satisfactorily meet any of the requirements of the five criteria.

The Hydrogen Fuel R&D category also includes a subcategory for Hydrogen Production R&D: HydroGEN Seedling projects. The evaluation form for these projects (included in Appendix C) was modified to address their unique features; the scores for these projects were based on the following five criteria and weights:

Score 1: Approach to performing the work (20%)
Score 2: Relevance/potential impact on DOE Program goals and RD&D objectives and the HydroGEN Consortium mission (15%)
Score 3: Accomplishments and progress toward overall project and DOE goals and the HydroGEN Consortium mission (30%)
Score 4: Collaboration effectiveness with HydroGEN and, as appropriate, other institutions (25%)
Score 5: Proposed future work (10%)

The 2019 AMR also included some recently awarded projects that were placed in a separate scoring panel with modified scoring criteria and weights. The evaluation form for these projects is included in Appendix C. The scores for new projects were based on the following five criteria and weights:

Score 1: Approach to performing the work (40%)
Score 2: Accomplishments and progress toward overall project and DOE goals (10%)
Score 3: Collaboration and coordination with other institutions (15%)
Score 4: Relevance/potential impact on Hydrogen and Fuel Cells Program goals (15%)
Score 5: Proposed future work (20%)

For this new projects panel, reviewers were given the option not to evaluate Score 2: Accomplishments. (In such instances, the other criteria were re-weighted to total 100%.) Scores for new projects were then included in their respective panels—Fuel Cell R&D or Hydrogen Infrastructure R&D—after the weighted averages for each panel were computed using normal weighting. The minimum, average, and mean scores were then computed for the entire panel (new projects included).

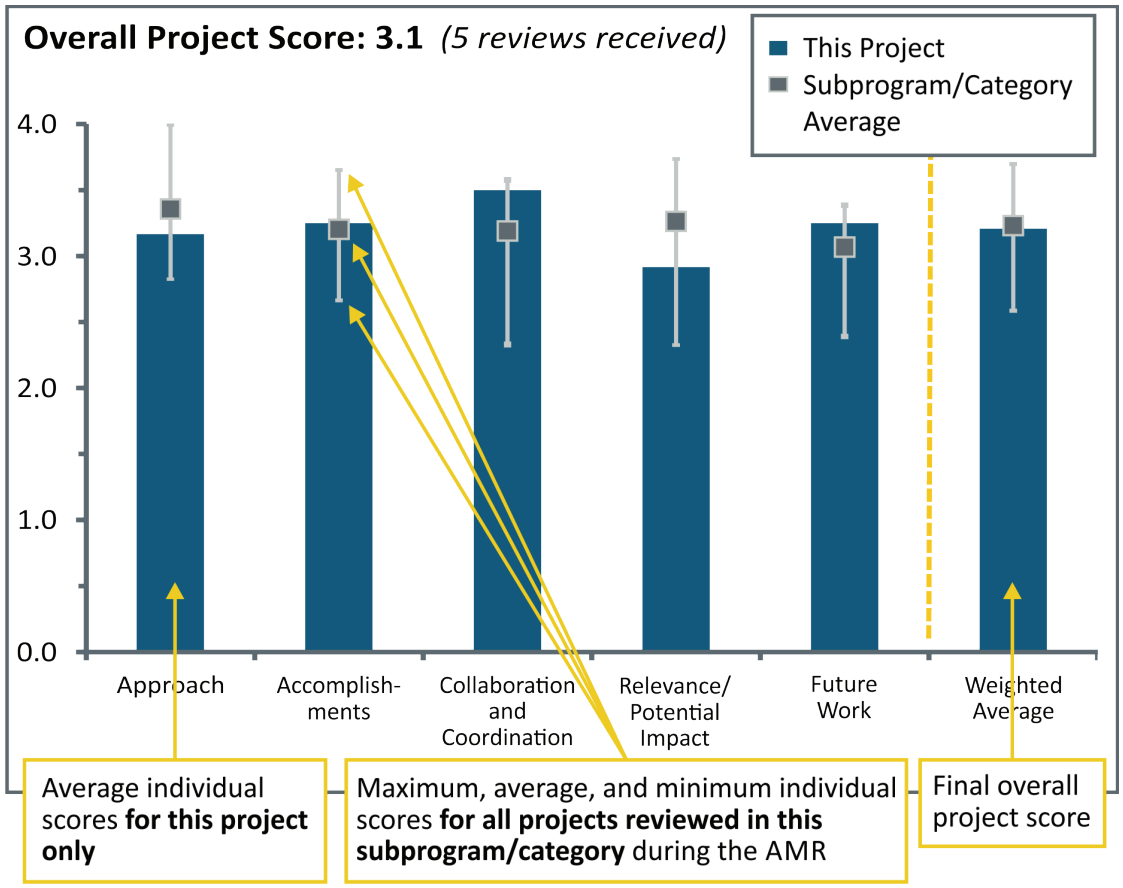
For all projects, reviewers were also asked to provide qualitative comments regarding the five criteria, specific strengths and weaknesses of the project, and any recommendations relating to the work scope. These comments were also entered into the private online database for easy retrieval and analysis.

Organization of the Report

The project comments and scores are grouped by subprogram (Hydrogen Fuel R&D; Fuel Cell R&D; Infrastructure and Systems R&D; and Safety, Codes and Standards). In the case of Hydrogen Fuel R&D, project comments and scores are grouped by category (Hydrogen Production R&D, Hydrogen Production R&D: HydroGEN Seedling, and Hydrogen Storage R&D). Infrastructure and Systems R&D projects are also grouped by category (Hydrogen Infrastructure R&D, Technology Acceleration, and Systems Analysis). Each of these sections begins with a brief description of the general type of research and development or other activity being conducted. Next are the results of the reviews of each project presented at the 2019 AMR, including the qualitative comments for each project.

Each individual project report also includes a graph showing the overall project score and a comparison of how each project aligns with all of the other projects in its subprogram or category. Projects are compared based on the consistent set of criteria described above. Each project report includes a chart with bars representing that project's average scores for each of the five designated criteria. The gray vertical hash marks that overlay the blue bars represent the corresponding maximum, average, and minimum scores for all of the projects in the same subprogram or category. A sample graph is provided.

Sample Project Score Graph with Explanation



For clarification, consider a hypothetical review in which only five projects were presented and reviewed in a subprogram. Table 2 displays the average scores for each project according to the five rated criteria.

Table 2: Sample Project Scores

	Approach (20%)	Accomplishments (45%)	Collaboration and Coordination (10%)	Relevance/ Potential Impact (15%)	Future Work (10%)
Project A	3.4	3.3	3.3	3.2	3.1
Project B	3.1	2.8	2.7	2.7	2.9
Project C	3.0	2.6	2.7	2.8	2.9
Project D	3.4	3.5	3.4	3.2	3.3
Project E	3.6	3.7	3.5	3.4	3.4
Maximum	3.6	3.7	3.5	3.4	3.4
Average	3.3	3.2	3.1	3.0	3.1
Minimum	3.0	2.6	2.7	2.7	2.9

Using these data, the chart for Project A would contain five bars representing the values listed for that project in Table 2. A gray hash mark indicating the related maximum, average, and minimum values for all of the projects in Project A's subprogram or category (the last three lines in Table 2) would overlay each corresponding bar to facilitate comparison. In addition, each project's criteria scores would be weighted and combined to produce a final, overall project score that would permit meaningful comparisons to other projects. Below is a sample calculation for the Project A weighted score.

Final Score for Project A = [3.4 x 0.20] + [3.3 x 0.45] + [3.3 x 0.10] + [3.2 x 0.15] + [3.1 x 0.10] = 3.3