## Introduction

The fiscal year (FY) 2017 U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program (the Program) Annual Merit Review and Peer Evaluation Meeting (AMR), in conjunction with DOE's Vehicle Technologies Office Annual Merit Review, was held June 5–9, 2017, at the Washington Marriott Wardman Park Hotel in Washington, DC. 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 DOE offices (including the Office of Science [Basic Energy Sciences] and Advanced Research Projects Agency – Energy [ARPA-E]) in areas relevant to hydrogen and fuel cells were also presented at the FY 2017 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 include the following:

- Review and evaluate FY 2017 accomplishments and FY 2018 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 (e.g., 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 agencies; 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 complete list of the meeting participants is presented as Appendix A.

**Table 1: Peer Review Panel Members**

| No. | Name | Organization |
|---|---|---|
| 1 | Abdel-Baset, Tarek | Fiat Chrysler Automobiles |
| 2 | Aceves, Salvador | Lawrence Livermore National Laboratory |
| 3 | Advani, Suresh | University of Delaware |
| 4 | Adzic, Radoslav | Brookhaven National Laboratory |
| 5 | Afzal, Kareem | PDC Machines, Inc. |
| 6 | Ahluwalia, Rajesh | Argonne National Laboratory |
| 7 | Ahn, Channing | California Institute of Technology |
| 8 | Albertus, Paul | ARPA-E |
| 9 | Allendorf, Mark | Sandia National Laboratories |
| 10 | Anton, Donald | Savannah River National Laboratory |
| 11 | Antoni, Laurent | Commissariat à l'énergie atomique et aux énergies alternatives (CEA) |
| 12 | Ardo, Shane | University of California, Irvine |
| 13 | Atanasiu, Mirela | Fuel Cells and Hydrogen Joint Undertaking (FCH JU) |
| 14 | Autrey, Tom | Pacific Northwest National Laboratory |
| 15 | Ayers, Katherine | Proton OnSite |
| 16 | Balbuena, Perla | Texas A&M University |
| 17 | Balema, Viktor | NASA Ames |
| 18 | Barilo, Nick | Pacific Northwest National Laboratory |
| 19 | Baronas, Jean | California Energy Commission |
| 20 | Baturina, Olga | U.S. Navy, Naval Research Laboratory |
| 21 | Benjamin, Thomas | Argonne National Laboratory |
| 22 | Biebuyck, Bart | Fuel Cells and Hydrogen Joint Undertaking (FCH JU) |
| 23 | Borup, Rodney | Los Alamos National Laboratory |

| No. | Name | Organization |
|---|---|---|
| 24 | Botta Reis, Livia Silva | Ergostech Renewal Energy Solutions |
| 25 | Bouwkamp, Nico | California Fuel Cell Partnership |
| 26 | Bouwman, Peter | Nedstack |
| 27 | Bouza, Antonio | U.S. Department of Energy |
| 28 | Bowden, Mark | Pacific Northwest National Laboratory |
| 29 | Bowman, Robert | Oak Ridge National Laboratory (Retired) |
| 30 | Boyd, Robert | Boyd Hydrogen LLC |
| 31 | Brinkman, Kyle | Clemson University |
| 32 | Brooks, Kriston | Pacific Northwest National Laboratory |
| 33 | Brouwer, Jack | University of California, Irvine |
| 34 | Brown, Craig | National Institute of Standards and Technology |
| 35 | Burgunder, Albert | Praxair, Inc. |
| 36 | Butsch, Hanno | NOW GmbH |
| 37 | Calabrese Barton, Scott | Michigan State University |
| 38 | Camiloti, Priscilla Rosseto | Ergostech Renewal Energy Solutions |
| 39 | Chapman, Bryan | Exxon Mobil Corporation |
| 40 | Chen, Shuo | University of Houston |
| 41 | Choudhury, Biswajit | DuPont |
| 42 | Collins, William | Consultant |
| 43 | Cornelius, Chris | University of Nebraska |
| 44 | Creager, Stephen | Clemson University |
| 45 | Cullen, David | Oak Ridge National Laboratory |
| 46 | Curry-Nkansah, Maria | Argonne National Laboratory |
| 47 | Danilovic, Nemanja | Lawrence Berkeley National Laboratory |
| 48 | Daum, Johannes | NOW GmBH |
| 49 | De Castro, Emory | Advent Technologies, Inc. |
| 50 | DeSantis, Daniel | Strategic Analysis, Inc. |
| 51 | Dillich, Sara | U.S. Department of Energy |
| 52 | Dobbins, Tabbetha | Rowan University |
| 53 | Dornheim, Martin | Helmholtz-Zentrum Geesthacht |
| 54 | Edwards, David | Air Liquide |
| 55 | Elrick, William | California Fuel Cell Partnership |
| 56 | Esposito, Dan | Columbia University |
| 57 | Farese, David | Air Products and Chemicals, Inc. |
| 58 | Funk, Stuart | LMI |
| 59 | Ganesan, Prabhu | Savannah River Consulting, LLC |
| 60 | Gardiner, Monterey | BMW Group |
| 61 | Garzon, Fernando | University of New Mexico |
| 62 | Ge, Qingfeng | Southern Illinois University |
| 63 | Gennett, Thomas | National Renewable Energy Laboratory |
| 64 | Gervasio, Don | University of Arizona |
| 65 | Graetz, Jason | HRL Laboratories |
| 66 | Grassilli, Leo | Consultant |
| 67 | Gross, Tom | Energy Planning and Solutions |
| 68 | Grot, Stephen | Ion Power |
| 69 | Hamdan, Monjid | Giner, Inc. |
| 70 | Hamilton, Jennifer | California Fuel Cell Partnership |
| 71 | Hanlin, Jason | Center for Transportation and the Environment (CTE) |
| 72 | Harris, Aaron | Air Liquide |
| 73 | Harrison, Kevin | National Renewable Energy Laboratory |
| 74 | Hartman, Brent | CSA Group |
| 75 | Hatzell, Kelsey | Vanderbilt University |

| No. | Name | Organization |
|---|---|---|
| 76 | Haug, Andrew | 3M |
| 77 | Hays, Charles | Texas A&M University |
| 78 | Hennessey, Barbara | U.S. Department of Transportation |
| 79 | Herring, Andy | Colorado School of Mines |
| 80 | Hirano, Shinichi | Ford Motor Company |
| 81 | Holladay, Jamie | Pacific Northwest National Laboratory |
| 82 | Hovanski, Yuri | Brigham Young University |
| 83 | Hurst, Katherine | National Renewable Energy Laboratory |
| 84 | Ilevbare, Gabriel | Idaho National Laboratory |
| 85 | Irwin, Levi | U.S. Department of Energy |
| 86 | Jakupca, Ian J. | NASA |
| 87 | James, Brian | Strategic Analysis, Inc. |
| 88 | Jensen, Craig | University of Hawaii, Honolulu |
| 89 | Jerram, Lisa | Navigant |
| 90 | Kasab, John | AVL Powertrain Engineering, Inc. |
| 91 | Keller, Jay | Consultant |
| 92 | Kent, Ron | Southern California Gas Company |
| 93 | Kim, Sangil | University of Illinois, Chicago |
| 94 | Kim, Yu Seung | Los Alamos National Laboratory |
| 95 | Knights, Shanna | Ballard Power Systems |
| 96 | Kocha, Shyam | National Renewable Energy Laboratory |
| 97 | Kongkanand, Anusorn | General Motors |
| 98 | Kopasz, John | Argonne National Laboratory |
| 99 | Kraigsley, Alison | National Institutes of Health |
| 100 | Kuppa, Shashi | U.S. Department of Transportation |
| 101 | Lakshmanan, Balasubrumanian | General Motors |
| 102 | Linkous, Clovis | Youngstown State University |
| 103 | Lipp, Ludwig | eT2M |
| 104 | Liu, Di-Jia | Argonne National Laboratory |
| 105 | Maes, Miguel | NASA |
| 106 | Marenco, Claudia | Fuel Cells and Hydrogen Joint Undertaking (FCH JU) |
| 107 | Maric, Radenka | University of Connecticut |
| 108 | Markovic, Nenad | Argonne National Laboratory |
| 109 | Martinez, Andrew | California Air Resources Board |
| 110 | Marxen, Sara | CSA Group |
| 111 | Masten, David | General Motors |
| 112 | Matter, Paul | PH Matter |
| 113 | McKeown, Kyle | Linde |
| 114 | McWhorter, Scott | Savannah River National Laboratory |
| 115 | Meeks, Noah | Southern Company |
| 116 | Melaina, Marc | National Renewable Energy Laboratory |
| 117 | Minh, Nguyen | University of California, San Diego |
| 118 | Mittelsteadt, Cortney | Giner, Inc. |
| 119 | Moretto, Pietro | European Commission, Joint Research Centre |
| 120 | Motyka, Ted | Greenway Energy |
| 121 | Moulthrop, Larry | H2@LMDesk (dba name) |
| 122 | Mukerjee, Sanjeev | Northeastern University |
| 123 | Mukundan, Rangachary | Los Alamos National Laboratory |
| 124 | Myers, Deborah | Argonne National Laboratory |
| 125 | Nguyen, Nha | U.S. Department of Transportation |
| 126 | Nguyen, Tien | Independent |
| 127 | Oesterreich, Bob | Air Liquide |

| No. | Name | Organization |
|---|---|---|
| 128 | Ohma, Atsushi | Nissan Motor Co., Ltd. |
| 129 | Olson, Gregory | Consultant |
| 130 | Ott, Kevin | Los Alamos National Laboratory |
| 131 | Paczkowski, Benjamin | U.S. Army Tank Automotive Research Development and Engineering Center (TARDEC) |
| 132 | Parilla, Phil | National Renewable Energy Laboratory |
| 133 | Parks, George | FuelScience, LLC |
| 134 | Patel, Pinakin | Fuel Cell Energy, Inc. |
| 135 | Penev, Michael | National Renewable Energy Laboratory |
| 136 | Perry, Mike | United Technologies Research Center |
| 137 | Petitpas, Guillaume | Lawrence Livermore National Laboratory |
| 138 | Petri, Randy | Fuel Cell Energy, Inc. |
| 139 | Pintauro, Peter | Vanderbilt University |
| 140 | Pivovar, Bryan | National Renewable Energy Laboratory |
| 141 | Prasad, Ajay | University of Delaware |
| 142 | Quackenbush, Karen | Fuel Cell & Hydrogen Energy Association (FCHEA) |
| 143 | Ramsden, Todd | National Renewable Energy Laboratory |
| 144 | Renner, Julie | Case Western Reserve University |
| 145 | Rice, Brian | University of Dayton Research Institute |
| 146 | Rinebold, Joel | Connecticut Center for Advanced Technology, Inc. |
| 147 | Rohatgi, Aashish | Pacific Northwest National Laboratory |
| 148 | Rufael, Tecle | Chevron Corporation |
| 149 | Semelsberger, Troy | Los Alamos National Laboratory |
| 150 | Serre-Combe, Pierre | Commissariat à l'énergie atomique et aux énergies alternatives (CEA) |
| 151 | Siegel, Donald | University of Michigan, Ann Arbor |
| 152 | Simmons, Kevin | Pacific Northwest National Laboratory |
| 153 | Smart, John | Idaho National Laboratory |
| 154 | Snyder, Joshua | Drexel University |
| 155 | Sofronis, Petros | University of Illinois, Urbana-Champaign |
| 156 | Soto, Herie | Shell Oil Company |
| 157 | Spendelow, Jacob | Los Alamos National Laboratory |
| 158 | Stamenkovic, Vojislav | Argonne National Laboratory |
| 159 | Stavila, Vitalie | Sandia National Laboratories |
| 160 | Steinbach, Andy | 3M |
| 161 | Steiner, Nadia | Université de Franche-Comté |
| 162 | Stottler, Gary | General Motors |
| 163 | Studer, Sarah | U.S. Department of Energy |
| 164 | Sutherland, Ian | General Motors |
| 165 | Swartz, Scott | NexTech Materials LTD |
| 166 | Swider-Lyons, Karen | U.S. Navy, Naval Research Laboratory |
| 167 | Tchouvelev, Andrei | A.V. Tchouvelev & Associates Inc. |
| 168 | Tisack, Monica | University of Southern Mississippi |
| 169 | Tong, Jianhua (Joshua) | Clemson University |
| 170 | Toughiry, Mark | U.S. Department of Transportation |
| 171 | Trocciola, John | SRA International, Inc. |
| 172 | Udovic, Terry | National Institute of Standards and Technology |
| 173 | Ulsh, Michael | National Renewable Energy Laboratory |
| 174 | Vacin, Gia Brazil | California Governor's Office of Business and Economic Development |
| 175 | Vanderborgh, Nicholas | Los Alamos National Laboratory |
| 176 | Veenstra, Mike | Ford Motor Company |

| No. | Name | Organization |
|---|---|---|
| 177 | Verduzco, Laura | Chevron Corporation |
| 178 | Wachsman, Eric | University of Maryland |
| 179 | Wagner, Frederick T. | Retired |
| 180 | Walchuk, George | Exxon Mobil Corporation |
| 181 | Waldecker, James | Ford Motor Company |
| 182 | Warren, C. David | Oak Ridge National Laboratory |
| 183 | Weber, Adam | Lawrence Berkeley National Laboratory |
| 184 | Wheeler, Douglas | DJW Technology, LLC |
| 185 | Williams, Mark | National Energy Technology Laboratory |
| 186 | Woods, Stephen | NASA |
| 187 | Xie, Jian | Indiana University–Purdue University Indianapolis |
| 188 | Xu, Hui | Giner, Inc. |
| 189 | Xu, Ye | Louisiana State University |
| 190 | Xue, Jisan | National Highway Traffic Safety Administration/ U.S. Department of Transportation |
| 191 | Yan, Yushan | University of Delaware |
| 192 | Yandrasits, Michael | 3M |
| 193 | Zelenay, Piotr | Los Alamos National Laboratory |

## 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 sub-program. Comments about sub-program management are provided in Appendix B.

### Analysis Methodology

A total of **141** Fuel Cell Technologies Office (FCTO) projects were reviewed at the meeting. As shown in Table 1, **193** review panel members participated in the AMR process, providing a total of **848** 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 Production and Delivery; Hydrogen Storage; Fuel Cells; Manufacturing R&D; Safety, Codes and Standards; and Systems Analysis sub-programs, scores were based on the following five criteria and weights:

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.

For the Market Transformation and Technology Validation sub-programs, scores were based on the following five criteria and weights:

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

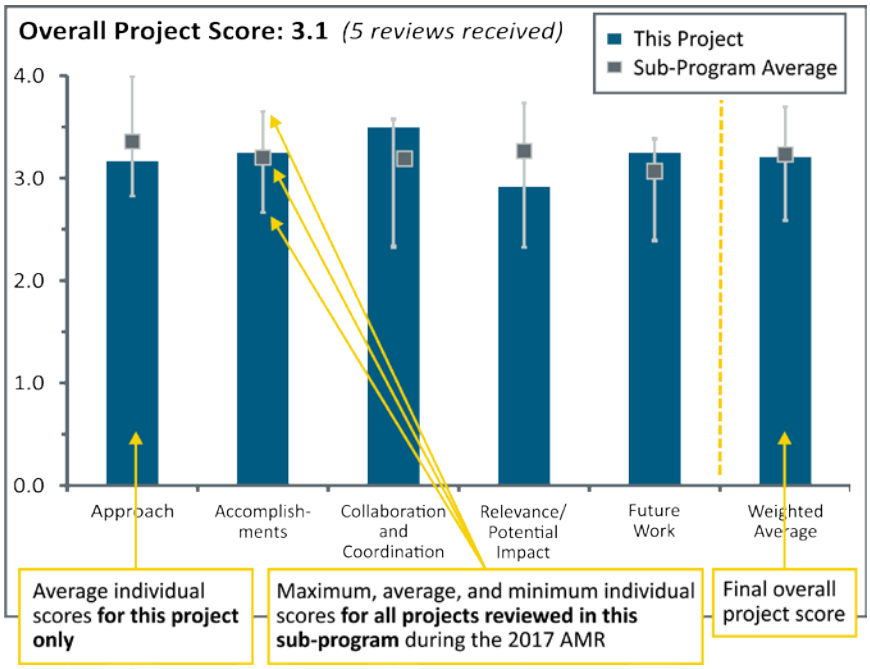
For all sub-programs, reviewers were also asked to provide qualitative comments regarding the five criteria, specific strengths and weaknesses of the project, and any recommendations relating to the work scope. These comments were also entered into the private online database for easy retrieval and analysis.

## Organization of the Report

The project comments and scores are grouped by sub-program (Hydrogen Production and Delivery; Hydrogen Storage; Fuel Cells; Manufacturing R&D; Technology Validation; Safety, Codes and Standards; Market Transformation; and Systems Analysis) in order to align with FCTO's planning scheme. 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 2017 AMR. The report also includes a summary of the qualitative comments for each project, as well as a graph showing the overall project score and a comparison of how each project aligns with all of the other projects in its sub-program. A sample graph is provided in Figure 1.

Projects are compared based on a consistent set of criteria. 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 sub-program.

**Figure 1: Sample Project Score Graph with Explanation**



For clarification, consider a hypothetical review in which only five projects were presented and reviewed in a sub-program. 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 this 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 sub-program (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**