This RFI is closed for responses.

Request for Information (RFI)

Electrical Conductivity Testing for New Conductor Materials

December 6, 2021

Purpose

The National Renewable Energy Laboratory (NREL) is issuing a request for information (RFI) on behalf of the U.S. Department of Energy (DOE). This RFI is intended for the CABLE Conductor Manufacturing Prize community and broader material testing industry to provide feedback on CABLE Prize Stage 2 documentation, testing requirements, and specifications as well as on potential vendors for the testing itself. CABLE is an acronym for Conductivity-enhanced materials for Affordable, Breakthrough, Leapfrog Electric and thermal applications, wherein the letters C, A, B, and L represent CABLE goals. In Stage 2, the focus will be on quantitative verification of electrical conductivity enhancement (or the equivalent) through testing and detailed documentation of costs and affordability.

Introduction

The CABLE Conductor Manufacturing Prize is made up of three stages and includes up to $4.5 million in cash prizes and vouchers for testing and technical assistance to competitors.

In Stage 1, 22 teams submitted their breakthrough concepts for development and manufacture of a new, affordable, electrical conductivity-enhanced material. In Stage 1, an "electrical-conductivity-enhanced material" was defined as exceeding the minimum standard (10 MS/m) and potentially could be enhanced to or above the levels of the aspirational electrical conductivity enhancement goals: exceeding 65 MS/m conductivity or 14 kSm^2/kg conductivity by density.[1] In October of 2021, DOE selected and announced 10 winners who each received $25,000 in cash awards and a stipend for third-party testing of their material in Stage 2 of the prize.

In Stage 2, competitors will be asked to submit a sample of their material to an approved laboratory for electrical conductivity testing according to prize requirements. Although the Stage 1 rules stated there would be a 1 gram minimum for these samples, the proposed dimension requirements provided in this document would imply a somewhat heavier sample, and we also are proposing multiple samples be produced. At the conclusion of Stage 2, DOE anticipates up to six awards of $200,000 each.

Through the prize DOE aims to identify, verify, and reward new materials and manufacturing methods that have the potential to achieve the aforementioned electrical conductivity enhancement goals that would indicate a breakthrough material that would be affordable and have widespread energy applications.

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[1] MS is 10^6 Siemens, kS is 10^3 Siemens, m is meters, m^2 is square meters, and kg is kilogram

More information on the CABLE Prize can be found in the official rules document.

Proposed Stage 2 manufacturing cost documentation requirements include:

Initial feedback from Stage 1 judges suggests the need for more detailed information on manufacturing costs of the material. Because the competitors will actually have to manufacture a sample in Stage 2, DOE suggests requesting documentation of the actual material quantities in the sample and manufacturing cost of the sample. Of course, this is not the final manufactured cost for the material, as there would be economies of scale and a learning curve that would reduce this cost. Therefore, DOE plans to solicit information on what reasonable scaling factors should be applied for calculating the ultimate manufactured cost of an enhanced conductivity material. Further, DOE plans to compare costs to the cost of electrolytic copper, which DOE proposes competitors take to be $15/kg (101% IACS C10100) for the purposes of comparison.

Proposed Stage 2 testing and documentation requirements for superconductors include:

By definition, below their critical temperature (Tc), the electrical resistance of superconductors is zero with infinite electrical conductivity. However, because the Stage 1 rules did not explicitly rule out superconductors, one of the Stage 1 winners had a superconducting material because its Tc was sufficiently high so that its cooling cost was low and its manufacturing cost—including raw material cost—was asserted to be significantly lower than that of copper. Because the purpose of Stage 2 is to quantitively compare conductors through testing, DOE is proposing a "Room Temperature Equivalent Conductivity" (RTEC) calculation for superconductors to compare them with non-superconductors. DOE designed the following RTEC equation to serve three purposes:

1) Yield a finite, appropriate conductivity in MS/m
2) Penalize superconductors proportionately for Tc that are below defined room temperature (i.e., 25°C)
3) Penalize/reward superconductors for material/manufacturing costs that are above/below that of electrolytic copper.

$$RTEC\ (MS/m) = 72.6 + 26*(1\text{-}fraction) - \Delta T/11.1(K)$$

where "fraction" is the aforementioned manufacturing cost of the superconductor in $/kg divided by $15/kg.

and

$\Delta T = 295.15\text{-}Tc$, where Tc is the superconductors' critical temperature in Kelvin.

Note that the penalty for cooling below 25°C vanishes at this temperature, but not the cost factor, so using this equation, even a room temperature superconductor would not meet the minimum 65 MS/m goal if its ultimate cost were more than 30% higher than that of electrolytic copper. Potential competitors with superconducting and non-superconducting materials are especially encouraged to comment on this proposed equation and the proposed testing protocol shown in the next section to determine Tc. Additional questions include the following:

1) Should affordable electric current capacity (i.e., $/kA.m) be included in the RTEC equation, and/or should there be a minimum value for this metric[2]?
2) Should something other than Tc be measured for superconductors? For example, is magnetization a better or additional measure than Tc for comparing superconducting and non-superconducting materials?

Proposed Stage 2 Testing Requirements and Logistics

Stage 2 Testing Logistics, Schedule, and Estimated Costs

Stage 2 is open to anyone who wishes to compete, including non-Stage 1 winners and new competitors who did not participate in Stage 1. Stage 1 winners will be awarded a testing stipend to cover the cost of testing; however, all other Stage 2 competitors will need to self-fund their testing with the approved vendor. NREL anticipates that the cost of self-funded electrical conductivity testing will be $300–$450 per submission (for testing of three samples) except for superconducting materials, in which the test to confirm Tc using the proposed sampled size is estimated to cost ~$100 per submission. Comments on or proposed vendor prices that are competitive with these values are especially welcome.

We anticipate asking Stage 2 teams to submit three testing samples (see sample requirements next) to an approved laboratory approximately **1 month before the submission deadline** (see anticipated Stage 2 milestone dates as follows). This would allow competitors enough time to resubmit a sample should it be damaged during shipping or to fix any other issues that would prevent a sample from being tested.

Stage 2 **Anticipated** Schedule

Stage 2 Open for Sample Submissions: March 2022

Stage 2 Deadline for Samples Postmarked to Approved Laboratory: August 2022

Stage 2 HeroX Submission Deadline: September 2022

Testing Sample Requirements

All competitors (Stage 1 winners, non-Stage 1 winners, and new competitors who did not participate in Stage 1) will be required to submit at least three samples.

For non-superconductors:

NREL and DOE anticipate that a single laboratory will be approved for Stage 2 testing of electrical conductivity. These competitors will be required to submit samples with a length of at least 1.5” and a uniform cross section, wherein the cross-sectional area does not vary more than +/- 0.75% along the length. The sample must be a circular or rectangular cross section of at least 0.21” diameter or at least 0.18” width by 0.18” thickness. All testing (except for superconductivity) should occur at “room temperature”; defined here as 25°C.

[2] kA is 10^3 Amperes of electrical current,

For superconductors:

By definition, below their critical temperature (Tc), the electrical resistance of superconductors is zero with infinite electrical conductivity. Hence, for the superconductor, it is proposed that instead of conductivity testing, samples be tested for their critical temperature, Tc, with the following sample dimension requirements:

A length of at least 5 mm and a uniform cross section with a diameter of 7 mm, wherein the cross-sectional area does not vary more than +/- 0.75% along the length.

Request for Information:

The purpose of this RFI is to solicit feedback from industry, academia, research laboratories, government agencies, testing vendors, and other stakeholders on CABLE Conductor Manufacturing Prize Stage 2 documentation, testing requirements and specifications as well as potential sources for the testing itself.

NREL is interested in learning the following from stakeholders:

1. Overall Conductivity Goals
    a. Is 65 MS/m a fair and reasonable conductivity goal?
    b. Is 14 kSm^2/kg also reasonable?
    c. Are there other conductor-related metrics that should be considered?
2. Material/Manufacturing Cost Documentation
    a. Is it reasonable to request sample material/manufacturing costs?
    b. Is it reasonable to specify factors for economies of scale, and learning by doing for all materials?
    c. Is it fair and reasonable to specify a baseline electrolytic copper material/manufacturing cost?
    d. Should a cost for electrical Al alloy also be specified?
3. Superconductivity Testing
    a. Is it fair and reasonable to require testing to confirm Tc?
    b. Is it fair and reasonable to include a linear cooling penalty that is proportional to the difference between Tc and room temperature?
    c. Is it fair and reasonable to include an explicit cost credit/penalty only for superconductors?
    d. Are there other metrics that should be required for superconductors, including for testing?
4. Testing Logistics
    a. Are the proposed Stage 2 testing logistics fair and reasonable?
    b. If you are a non-Stage 1 winner and wish to compete in Stage 2, do the logistics described earlier present any undue hardship that would prevent you from competing in Stage 2? If so, what can the prize team do to alleviate your concerns?
    c. For superconductors, please comment on any logistics issues related to superconductivity, Tc-related, or other types of testing.
    d. If you plan to compete in Stage 2, how long do you think it will take your team to manufacture a sample for testing given the information presented in this RFI?
5. Testing Requirements
    a. Are the Stage 2 testing requirements comprehensive, fair, and reasonable?

    b. What is a reasonable requested minimum resistance to achieve accurate measurements for non-superconductors (20 μΩ has been suggested)?
    c. If you are a non-Stage 1 winner and wish to compete in Stage 2, do the testing requirements described earlier present any undue hardship that would prevent you from competing in Stage 2?
    d. If the testing requirements described earlier would prevent you from competing in Stage 2, what changes would help alleviate your concerns?
6. Please provide information on potential vendors for non-superconductor electrical conductivity testing and superconductor Tc testing.
7. Overall feedback: Are there any other concerns or items not covered in the questions above that you would like the CABLE Manufacturing Prize Administration team to be aware of?

Response Requirements:

This RFI is closed for responses.