



# CABLE Conductor Manufacturing Prize

## Official Stage 2 Rules

The Conductivity-enhanced materials for Affordable, Breakthrough Leapfrog Electric and thermal applications (CABLE) Conductor Manufacturing Prize will identify, verify, and reward affordable breakthroughs in conductivity that will enable U.S. manufacturers to leapfrog to next-generation materials.

APRIL 2023  
Modification 6

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# Modification Summary

Date	Modifications
Revision 1 8/5/2022	<ul style="list-style-type: none"> <li>Pages 7, 9, 11, 48 added minimum threshold for critical current density <math>J_c</math> of 1 MA/cm<sup>2</sup> for superconductors to enter CABLE prize contest</li> <li>Page 12: Added clarification on critical current density for superconductors</li> <li>Page 15, 19: Stage 2 final submission due date moved from December 1 to December 8, 2022</li> <li>Page 29 and 30: Shipping information for the sample testing will be sent to eligible registered competitors following the August 25<sup>th</sup> registration deadline.</li> <li>Page 29: Updated testing sample size requirements for non-superconductors to be skinnier and longer to conform to industry practice.</li> <li>Page 47: Added additional terms and conditions – Return of Funds</li> <li>Page 50: Updated testing sample size requirements checklist for non-superconductors to be skinnier and longer to conform to industry practice.</li> <li>Page 51: Updated checklist for superconductor data (see below)</li> <li>Page 56 (Appendix D): Corrected the score card testing data temperature requirement for Superconductors' critical current measurement to be either at 77K or at 4K depending on the Superconductors' critical temperature.</li> </ul>
Revision 2 8/15/22	<ul style="list-style-type: none"> <li>Page 35: Added eligibility requirements regarding U.S. Citizenship/Permanent Residency.</li> </ul>
Revision 3 9/20/22	<ul style="list-style-type: none"> <li>Page 30: Correction of the non-superconductor testing sample size from 0.95 millimeters to 1.90 millimeters</li> </ul>
Revision 4 2/20/23 (post sample submission)	<ul style="list-style-type: none"> <li>Page 8, 10, 12, 13, 58: For superconductor submissions, lowered <math>J_c</math> requirement and added <math>J_e</math> due to testing issues.</li> <li>Page 9, 10: Lowered Stage 2 contest IACS thresholds to define “%IACS<sub>CABLE</sub>” thresholds for both the Beat Copper! and Beat Aluminum! Contests due to</li> </ul>

	<p>calibration issues with the Stage 2 testing vendor.</p> <ul style="list-style-type: none"> <li>• Page 10,11: Clarified the requirement for contests 1 and 2 that no <i>bulk sliver could be used in the Beat Copper! contest and no bulk gold</i> could be used in the Beat Aluminum contest.</li> <li>• Page 17, 21: Updated important dates for Stage 2, Phase 2 submission deadline is now March 23, 2023 at 5p.m. ET.</li> <li>• Page 30: Added footnote to clarify new results date</li> <li>• Page 39: For general submission requirements, adjusted the minimum conductivity from 10 MS/m to that of the lowest conductivity conductor in Appendix A (Carbon Fiber, <math>1.06 \times 10^{-4}</math> MS/m) as shown by Stage 2 testing.</li> <li>• Page 50, 57: Updated the RTEC formula</li> </ul>
Revision 5 4/19/2023	<ul style="list-style-type: none"> <li>• Pages 6,7, and 11: Updated anticipated number of Phase 2 awards from six to seven.</li> </ul>
Revision 6 4/25/2023	<ul style="list-style-type: none"> <li>• Pages 6, 17, and 58: Updated the prize total from \$4.5 million to \$4.8 million.</li> </ul>



# 1. Program Summary

## 1.1. Introduction

The Conductivity-enhanced materials for Affordable, Breakthrough Leapfrog Electric and thermal applications (CABLE) Conductor Manufacturing Prize (“prize”) will award a total of up to \$4.8 million in cash prizes and vouchers for testing and technical assistance to competitors (Figure 1).

As electrification grows worldwide, so too will demand grow for affordable conductivity-enhanced materials and applications—especially those with same or increased enhancement at elevated industrial process temperatures. Hence, there is a need to rapidly transition such conductivity-enhanced materials—in advanced cables as well as in anything else that uses electricity—from the lab to the marketplace. Conductivity-enhanced materials support transformational technologies, such as electric cars and planes, as well as more advanced versions of everyday technologies, including smartphones, heat pumps, and motors. For all these reasons, the U.S. Department of Energy (DOE) Advanced Manufacturing Office (AMO) launched the CABLE Conductor Manufacturing Prize to help supercharge the U.S. energy and manufacturing industries.

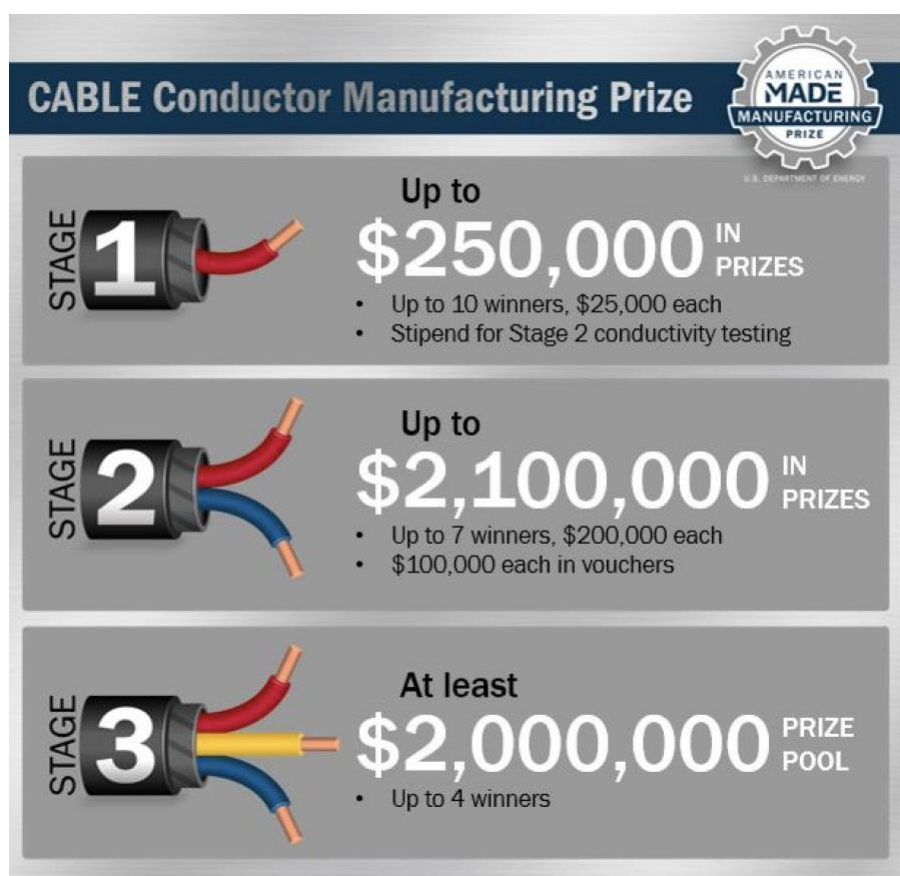


Figure 1. CABLE Conductor Manufacturing Prize stage outline

Building a clean energy economy and addressing the climate crisis is a top priority of the Biden administration. This prize will advance the administration's goals to achieve carbon-pollution-free electricity by 2035 and "deliver an equitable, clean energy future, and put the United States on a path to achieve net-zero [greenhouse gas] emissions, economy-wide, by no later than 2050" to the benefit of all Americans.<sup>1</sup>

The CABLE Conductor Manufacturing Prize will push the frontiers of science and engineering and drive American innovation for materials that can lead to the deployment of clean energy technologies that are critical for climate solutions. It will also immediately catalyze good-paying clean energy jobs through the research, development, demonstration, and deployment carried out by prize competitors.

In addition to their benefits for clean energy technologies, conductivity-enhanced materials can deliver a clean energy future by enabling affordable, cleaner, lower-impact grid expansion that ensures environmental justice and inclusion of disadvantaged communities. The competitive activities supported by this prize will enhance the governmentwide approach to the climate crisis.

The prize aims to identify, verify, and reward breakthrough materials and manufacturing methods that have the potential to affordably exceed the electrical conductor enhancement thresholds (listed in

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<sup>1</sup> Exec. Order No. 14,008. 2021. "Tackling the Climate Crisis at Home and Abroad." (January 27, 2021). <https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/>.

Table 1). In particular, competitors must document a pathway to produce their new conductivity-enhanced material so that it is economically competitive with today's leading conductors in applications that enable innovators to “leapfrog” current state-of-the-art technology.

In Stage 1, DOE awarded each of the 10 winning teams a cash award of \$25,000. In Stage 2, DOE anticipates up to **seven awards** of \$200,000 each, plus a \$100,000 voucher for each awarded team for Stage 3 technical assistance. In Stage 3, DOE anticipates up to four awards that split a total prize pool of at least \$2,000,000.

Unlike Stage 1, in which competitor's scores were determined by submission materials—especially the Technical Narrative—in Stage 2, 50% of each competitor's score will be determined directly by electrical conductivity testing (relative to related inputs in Appendix C) and 50% will be determined by reviewers based on the Technical Narrative and the other submission materials.

Because of the importance of testing in Stage 2, DOE issued a Request for Information (RFI, refer to Appendix E) through the NREL Prize Administrator in November 2021 that proposed specific testing requirements and sought input on other aspects of the Stage 2 contest, such as the inclusion of superconductors.

## 1.2. Background

Conductive materials are fundamental to nearly all energy applications. Developing manufacturing processes for conductivity-enhanced materials would enable product manufacturers to lower costs, improve performance, and allow their customers to save substantial amounts of energy. The group developing this prize concept incorporated expert advice from several DOE programs, national laboratories, universities, and companies to better understand the current research status in this area and to establish relevant prize parameters. The group noted the following:

- Greatly expanded electricity delivery systems (e.g., transmission cables) are needed to connect grids to the best renewable power resources, most of which are located far from electricity demand.
- Innovation in many CABLE-relevant fields, including metal matrix composites, nanoscience (especially carbon allotropes), and artificial intelligence/machine learning, has greatly accelerated. There is a growing body of research evidence that macroscale electrical conductivity, once thought to have a maximum upper limit, can now be further increased.
- The private sector is reluctant to invest in many existing breakthrough conductivity-enhanced materials because such materials challenge the common belief that electrical conductivity cannot be further increased; therefore, rigorous and transparent independent testing of such materials is needed.



- There is an opportunity for prize winners to help lay the foundation for one or more new, American-made material manufacturing industries.

Efforts to enhance normal conductors and conductors that have zero resistance at low temperatures, known as superconductors, are welcome in this prize.

**Conductivity metrics:** This prize uses megasiemens per meter (MS/m) (or IACS% (International Annealed Copper Standard<sup>2</sup>) as a conductivity metric. Because the bulk electrical conductivity of the most common conductors (copper [Cu] and aluminum [Al] alloys) and all non-superconductors (refer to Appendix A) have improved negligibly over the past century, even a small percentage improvement in electrical conductivity would be notable.

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<sup>2</sup> The two metrics are related as follows: 100% IACS is defined as 58.1 MS/m

Table 1, therefore, includes the minimum or threshold values for tested conductivity for: (1) general-purpose conductors (non-silver) and (2) lightweight conductors. In addition, to allow for superior conductors that compete on other properties, a third conductivity contest was added to

Table 1.

**Table 1. Stage 2 Electrical Conductivity and Other Contest Thresholds for Conductors**

Contest 1: Beat Copper!
Conductivity measured > 101% IACS <sub>CABLE</sub> <sup>3</sup> ; + No bulk silver (Ag) + Pathway to economic competitiveness with Cu + Parity with or better than Cu's nonconductivity properties
Contest 2: Beat Aluminum!
Conductivity measured > 65% IACS <sub>CABLE</sub> <sup>4</sup> ; + Density < 2,710 kg/m <sup>3</sup> + No bulk gold (Au) + Pathway to economic competitiveness with Al1350 + Parity with or better than Al1350's nonconductivity properties.
Contest 3: Beat a Conductor System!
Conductivity measured greater than the conductor system comprising a primary conductor from Appendix A: + Parity with or better than the primary conductor's nonconductivity system properties + Material that would replace an existing conductor system in a major market (refer to the example in Figure 2) involving conductor(s) in Appendix A.

Figure 2 provides an example of a potential Goal 3 competitor. For reference, the International Annealed Copper Standard (IACS) was set in 1913 as 100% IACS = 58.1 MS/m at 20°C (1 MS = 10<sup>6</sup> Siemens). By comparison, the conductivity of an aluminum alloy conductor used widely in electrical applications, Al1350, is ~62% IACS (35.8 MS/m), and the conductivity of most commercial copper wires now used for electrical applications is 101% IACS (58.6 MS/m). The highest-conductivity material, silver (Ag), achieves 108% IACS (62.9 MS/m) but costs far more per gram than electrical-grade copper and is one-third its strength at 0.1 gigapascals (10<sup>8</sup> Pascals). Gold (Au) is the most expensive conductor, with a conductivity (40.6 MS/m [69.9% IACS]) between Al1350 and copper but is still used in a few premium applications because of its other properties, such as corrosion resistance.

**High-temperature superconductivity:** A superconductor by definition is a novel material that conducts electricity with zero resistance or infinite conductivity when cooled below its critical temperature ( $T_c$ ).

<sup>3</sup> For the purposes of Stage 2 only, we have defined 101% IACS<sub>CABLE</sub> = 56.2 MS/m as measured by the Stage 2 Prize testing vendor as that is the value they measured for an electrolytic copper standard sample we provided to them that should have measured 101% IACS (58.7 MS/m).

<sup>4</sup> For the purposes of Stage 2 only, we have defined 65% IACS<sub>CABLE</sub> = 36.2 MS/m as measured by the Stage 2 Prize testing vendor as that is the value they measured for an Aluminum standard sample we provided to them that should have measured 65% IACS (37.7 MS/m).

Superconductors have generally been considered impractical for anything but research,<sup>5</sup> because their critical temperatures are so low (near absolute zero for the first superconductors discovered) that they require super-expensive and reliable cooling. In 1988, the first of several so-called high-temperature superconductors (HTS)—which could be cooled with relatively inexpensive liquid nitrogen—was discovered. It was hoped that the relatively low cost of cooling would lead to their widespread use in energy applications, but material and manufacturability problems have prevented this to date. The CABLE Conductor Manufacturing Prize Stage 1 submission pool, however, provided evidence that ultra-low-cost, highly manufacturable HTS may now be possible.

**Comparing high-temperature superconductors to normal conductors:** Because a key requirement of the CABLE Conductor Manufacturing Prize Stage 2 is laboratory testing of a sample material's conductivity and superconductors have infinite conductivity, this prize developed a room-temperature-equivalent conductivity (RTEC) equation that includes a linear-cooling penalty and manufacturing-cost parameter for superconductors so that they can compete fairly with general-purpose conductors (i.e., copper). **Note that superconductor material submissions must have discernable critical current density  $J_c$  or engineering critical current  $J_e$  for the RTEC to be used.** The RTEC was added based on RFI responses (refer to Appendix E). Any HTS that has a  $T_c$  high enough and a manufacturing cost low enough for its RTEC to exceed the

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<sup>5</sup> Or premium nonenergy applications, such as magnetic resonance imaging (MRI) machines.

Table 1 threshold would be notable. A room-temperature superconductor with a plausible path to economic competitiveness with copper would be a breakthrough.

### **1.2.1. Conductivity and Other Thresholds for Stage 2 Contests**

With an overall goal of improving upon the performance of existing conductors, Stage 2 competitors will try to beat three conductors in the three separate contests in



Table 1:

**Contest 1: Beat Copper!** The first contest asks competitors to produce a material with a test-sample conductivity that significantly exceeds that of commercial electrolytic copper ( $>101\% \text{ IACS}_{\text{CABLE}}$ ). The material with the highest tested conductivity will get the maximum number of testing points. Other requirements include that the material contains no **bulk** silver and that the submission includes a credible description for eventual (10-years-post-commercialization) economic competitiveness with electrolytic copper as well as parity or improvement on all other relevant copper performance requirements (e.g., mechanical and anticorrosion properties).

**Contest 2: Beat Aluminum!** For the second contest, the test sample material must have significantly better conductivity than aluminum ( $>65\% \text{ IACS}_{\text{CABLE}}$ ) and a density the same as or lower than that of Al1350 (2,703 kilograms per cubic meter [ $\text{kg}/\text{m}^3$ ]). Other requirements include that the material contains no **bulk** gold and that the submission includes a credible description for eventual (10-years-post-commercialization) economic competitiveness with Al1350 as well as parity with or improvement on all other relevant Al1350 performance requirements.

**Contest 3: Beat a Conductor System Market!** For the third contest, the test sample must have significantly higher conductivity than the net conductivity of a conductor system (

Figure 2) in a *widespread* application market. It also requires a convincing description for eventual (10-years-post-commercialization) economic competitiveness with the identified baseline conductor system as well as life cycle competitiveness on all other relevant conductor system performance requirements.

The Prize Administrator anticipates distributing up to **seven** \$200,000 prizes. The number and distribution of awards under each contest, however, will be determined by the Prize Judge (DOE) according to samples' test results, the judging criteria, and program policy factors described in Section 3.13.

**Beat a Conductor System Market (Contest 3) Example:** An aluminum conductor steel-reinforced (ACSR) cable is commonly used for overhead power transmission and as a primary and secondary distribution cable. As shown in the image, ACSR comprises varying concentric layers of Al1350 wires around a steel core. The overall conductivity (using 62% IACS for Al1350 and 8% IACS for steel) of the highest conductivity type of ACSR is 43.7% IACS. Top manufacturers include Nexans, Southwire Company, LLC, and General Cable. ACSR has widespread energy applications with an estimated



global market of ~\$30 billion in 2022.<sup>6</sup> A competitive CABLE Conductor Manufacturing Prize material would have a conductivity of >44% IACS, equivalent strength and sag resistance (for part or all of ACSR), and a path to cost competitiveness in this widespread conductor application.

**Figure 2. Conductor system example: Beat an aluminum conductor steel-reinforced (ACSR) cable**

## 1.3. Conductor Material Class

All conductor materials are judged for improvement over the respective contest conductor shown in

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<sup>6</sup> MarketWatch. 2022. "Aluminum Conductor Steel-Reinforced Cable (ACSR) Market Size 2022 With CAGR of 1.1%, Top Growth Companies: Nexans, Southwire, General Cable, and, End-User, SWOT Analysis in Industry 2026." Accessed April 5, 2022. <https://www.nrel.gov/comm-standards/editorial/references-and-citations.html>.

Table 1. Based on the experience in Stage 1 and the data gathered from the RFI, Stage 2 competitors must classify their materials invention according to one of the following three technical classes of conductivity-enhanced materials:

- **Metal-based non-superconductor.** These are enhanced-conductivity materials whose bulk material comprises a composite or alloy that is predominantly metal. These may include metals whose conductivity is enhanced by nanocarbons, such as graphene, carbon nanotubes, or other carbon allotropes, or enhanced by nonmetal elements or dopants, such as rare earth elements. They may also include metal-based materials whose conductivity is enhanced through process innovations.
- **Nonmetal-based non-superconductor.** These conductors are primarily nonmetal (e.g., nanocarbon). They may also contain metal, such as nanoparticles or coatings of metallic elements, but cannot include bulk metal.
- **Superconductor.** These are materials capable of achieving zero electrical resistance below  $T_c$ . For comparison with metals and nonmetals, an RTEC is calculated based on  $T_c$  and manufacturing cost (refer to Appendix A and Appendix D) compared to copper for superconductors with a discernable critical current density  $J_c$  or engineering critical current  $J_e$ .

## 1.4. Nonconductivity Properties

The ultimate CABLE Conductor Manufacturing Prize goal is to create an affordable, manufacturable, and usable conductor. Review criteria for Stage 2 submissions will be based on electrical conductivity tests of actual material samples, as well as sample preparation data (refer to Appendix C), a competitor's Technical Narrative (which includes estimates of manufacturing volume and costs if the material is deployed at an industrial scale), and other Stage 2 submission materials as specified in Section 0 (What To Submit). In Stage 2, in addition to the part of the score derived directly from conductivity test values, Expert Reviewers will evaluate sample preparation data (Appendix C) related to affordability, the potential for breakthrough applications, and other estimated properties highlighted in the Technical Narrative.

In Stage 3, we anticipate that scores will be based partially on direct measurements of conductivity and other properties of larger material samples as well as on Expert Reviewers' evaluation of additional data on economic competitiveness and other untested nonconductivity properties. In general, breakthroughs in conductivity must not come at the expense of other vital properties required for the intended broad applications. In Stage 3, it is anticipated that conductor materials entered for the prize must also meet minimum values for other properties for specific use cases that are appropriate for one or more of the Stage 2 winners. These other potentially relevant properties may include but are not limited to:

- Mechanical-related properties, including:
  - Density
  - Tensile strength

- Yield strength
- Fracture toughness
- Creep resistance
- Wear resistance/durability/reliability/lifetime
- Conformality
- Malleability
- Thermal properties, including:
  - Operational temperature range/maximum operating temperature
  - Heat transfer rate
  - Thermal conductivity, measured directly (e.g., via a guarded hot plate or heat flow meter)
  - Thermal diffusivity (for calculated thermal conductivity)
  - Specific heat capacity (at constant pressure for measuring conductivity)
  - Thermal capacity
  - Insulation properties
- Electric properties, including:
  - Ampacity
  - Dielectric strength
  - Gravimetric power density
  - Operational voltage range/line voltage drop
  - Operational current range/line current
  - Discharge-related reliability issues
  - Power losses/leakage
  - Series resistance or shadowing
  - Energy storage charging/discharging rate
  - Energy storage density
  - Energy storage round-trip efficiency
- Superconductivity-specific properties, including:
  - Critical temperature ( $T_c$ )
  - Critical current density ( $J_c$ ) = Critical current  $I_c$ / cross-sectional superconducting area
  - Engineering critical current ( $J_e$ ) =  $I_c$ / total wire cross-section (for winding magnets)
  - Critical field ( $B_c$ )
- Other properties, including:
  - Density/specific weight (at constant pressure for conductivity measurement)
  - Size/dimensions/footprint/geometry
  - Corrosion resistance
  - Net life cycle cost

- Safety standards
- Wildfire prevention
- Ice/wind resistance
- Resistance to animal and environmental damage
- Recyclability
- Regulatory compliance
- Ease of installation
- Continuous manufacturing process
- Product cleaning interval
- Stampability

## 1.5. Contest Stages

This document includes the official rules for Stage 2. The official rules for Stage 3 will be released prior to that Stage's open date.

The CABLE Conductor Manufacturing Prize comprises three stages:

- 1) **Stage 1 (closed):** Competitors submitted their breakthrough concepts for the development and manufacture of a new, affordable, electrical-conductivity-enhanced material. An “electrical-conductivity-enhanced material” was defined as one that exceeds the minimum standard (10 MS/m) and potentially could be enhanced to meet or exceed the levels of the aspirational contest objectives in Table 2 of the Stage 1 Rules. This stage of the prize informed DOE about the minimum conductivity enhancement and other property benchmarks, as well as the types of support that competitors would likely need from DOE national laboratories or other American-Made Network providers in the next two stages of the prize. Ten winners received \$25,000 each in cash awards. DOE invited all registered prize competitors to the [2021 CABLE Big Idea Workshop](#) during Stage 1. At the workshop, prize competitors were encouraged to connect with the rest of the CABLE R&D innovation ecosystem.
- 2) **Stage 2 (open):** Any competitor—including nonwinners from Stage 1 as well as new competitors—may enter the prize in Stage 2. Competitors must submit a sample of their non-superconducting or superconducting material in the dimensions required for their respective material (refer to Section 2.5. [Sample Testing] and Appendix B).<sup>7</sup> Scores will be based half on the sample testing results for conductivity. The other half of the score will be based on Expert Reviewers' evaluation of the

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<sup>7</sup> NOTE: Based on input from the RFI conducted in Winter 2022, dimension requirements for electrical conductivity testing have replaced the earlier suggested 1-gram (g) minimum weight standard. For a copper conductor, for example, the dimensions required correspond to a 40-g sample weight, which is significantly larger than the 1-g minimum originally set for Stage 2.

Technical Narrative and the related sample commercialization estimate data in Appendix C as well as other HeroX submission documents. Because the testing results are a significant measurement of the conductivity breakthrough and the manufacturability, the HeroX submission criteria points for these goals are lower (see Table 4). The points associated with the testing results are 50% attributable to the “Breakthrough” goal and 50% attributed to the “Manufacturability” goal, so even though the HeroX submission criteria points are lower, the total weight of these goals is as indicated in Table 4 below higher than in Stage 1. Up to **seven** competitors will win \$200,000 each in cash awards and \$100,000 each in noncash voucher support to work with a DOE national laboratory or other American-Made Network Voucher Service Providers (called “Connectors”, refer to the [Voucher Guidelines](#)). In addition, DOE invited all registered prize competitors to the 2022 CABLE Big Idea Workshop (held July 20–21, 2022; refer to [HeroX](#) and the [CABLE Workshop web page](#) for copies and recordings of workshop presentations) during Stage 2.

- 3) **Stage 3 (not yet released):** Only Stage 2 winners are eligible to compete in Stage 3. Competitors will develop a larger sample of their CABLE material (anticipated ~1 kg). The Stage 3 rules will outline minimum weight and/or size requirements alongside other criteria, such as applicable standards and specifications that would enable the material to meet real-world application requirements. Competitors may also be asked to provide additional data on how the sample was made and a more detailed commercialization plan. For Stage 3, at least three testing organizations will evaluate each material sample for conductivity and other characteristics as well as for other application-specific material characteristics, manufacturability, and affordability. Up to four competitors will split a total prize pool of at least \$2,000,000.

To learn more and to sign up for the prize, go to <https://www.americanmadechallenges.org/cable>.

## 1.6. Important Dates

The important dates in the Stage 2 timeline are shown in Figure 3 and Table 2.



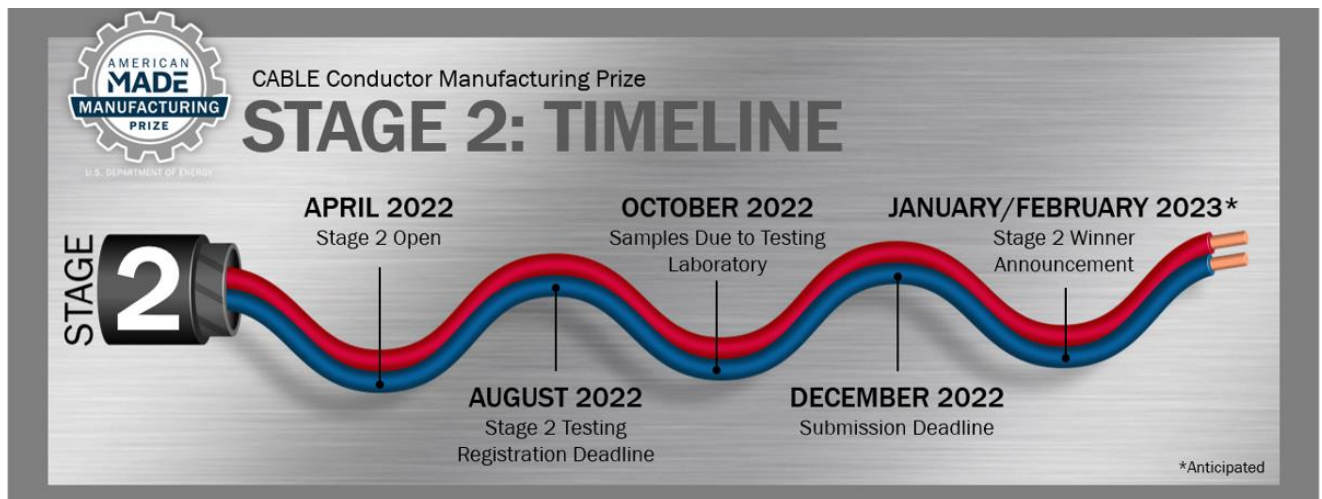


Figure 3. Stage 2 Timeline

**Table 2. CABLE Stages 2 and 3 Prize Calendar**

Date	Event
Jan. 18, 2022	CABLE RFI closes (Appendix E).
April 22, 2022 <sup>a</sup>	CABLE Conductor Manufacturing Prize Stage 2 announcement: Stage 2 contest begins.
May 17, 2022 <sup>a</sup>	<a href="#">Stage 2 Contest webinar.</a>
July 20-21, 2022 <sup>a</sup>	Second annual <a href="#">CABLE Big Idea Workshop</a> and joint CABLE Conductor Manufacturing Prize and CABLE Small Business Innovation Research Showcase event with American-Made Network voucher matchmaking.
Aug. 25, 2022, 5:00 p.m. ET <sup>b</sup>	CABLE Conductor Manufacturing Prize team HeroX registration deadline for Stage 2 testing.
Sept. 1, 2022	CABLE testing labs open for sample submissions.
Oct. 17, 2022	All sample material must be postmarked by this date and sent to an approved testing laboratory. Competitors must also email the Prize Administrator with shipping confirmation and tracking information.
March 2, 2023	Testing results are sent to competitors.
March 23, 2023 at 5 p.m. ET	Stage 2 contest submission deadline (HeroX submission).
April 2023 <sup>a</sup>	Stage 2 awards announcement.
TBD 2023	Stage 3 contest begins.
TBD 2024	Stage 3 contest submission deadline.
TBD 2024	Stage 3 awards announcement.

<sup>a</sup> Date is anticipated.

<sup>b</sup> The CABLE Conductor Manufacturing Prize will pay for all teams' Stage 2 sample conductivity testing (three samples per submission). Teams will be required to register for the Stage 2 contest by this date to be eligible for free testing. Teams who fail to complete the registration by this date can still compete but must self-pay for their Stage 2 testing with the approved testing laboratory (refer to Section 2.5. ).

## 2. Stage 2: Sample, Data, and Commercialization Plan Requirements

The CABLE Conductor Manufacturing Prize is a three-stage, \$4.8 million prize competition (refer to Table 3) designed to develop breakthrough concepts to manufacture new conductivity-enhanced materials suitable for electrical applications.

**Table 3. Stage 2 Prize Outline**

Stage 2 Contest Prizes
<ul style="list-style-type: none"><li>• Up to 6 winners</li><li>• Up to \$1,200,000 in cash prizes (\$200,000 per winner)</li><li>• Up to \$600,000 in Technical Assistance Vouchers (\$100,000 per winner)</li><li>• Stage 3 testing stipends</li></ul>

The following rules are for competitors participating in Stage 2. The rules for Stage 2 are similar to but updated from those for Stage 1 and also have more detailed requirements for: sample material size; testing logistics/requirements; data and calculations for sample material, cost, personnel, and future (10-year-post-commercialization) cost projections (relevant to economic competitiveness); and the Technical Narrative.

### 2.1. Goals for Stage 2

The CABLE Conductor Manufacturing Prize aims to catalyze the development of new materials and manufacturing methods to affordably beat one of the three major electrical conductor markets in

Table 1. These contests contribute to the development of CABLE applications. The HeroX submission criteria points for these goals are lower because the conductivity testing results are a strong measure of the conductivity breakthrough and the manufacturability of the sample material. As shown in Table 4, the goals of breakthrough and manufacturability are a high priority in Stage 2 (even with the lower HeroX submission criteria points), these two goals account for the largest two categories according to percentage of overall points. The Stage 2 contest focuses on the five following goals:

**Affordability:** The CABLE Conductor Manufacturing Prize aims to enable conductivity-enhanced materials that will be economically competitive with the copper, aluminum, and other conductor systems that they would replace. During Stage 2, Expert Reviewers will assess the 10-year economic competitiveness of competitors' materials based on their Technical Narrative as well as on their actual sample fabrication cost data, calculations, and forecasts in the submitted Appendix C.<sup>8</sup> The 10-year time frame is intended to cover the period between initial commercialization in early premium applications with first adopters and cost-reductions from learning-by-doing and economies of scale (at "industrial scale") that lead to "breakeven" and then "first revenues" in one or more application areas and, eventually, profit before taxes (positive cash flow) for various revenue streams (licensing, product sales, or other). Competitors must use the template provided in Appendix C to be responsive to these criteria. The Stage 2 Technical Narrative for this goal should describe pathways to scale up and manufacture the material, including estimates of economies of scale and learning-by-doing as the competitor's technology is deployed at an industrial scale. In Stage 3, competitors will be expected to provide detailed information on energy cost savings and greenhouse gas emissions reductions from the use of competitors' conductivity-enhanced material in a relevant application as well as data from the manufacturing process.

**Breakthrough conductor material:** In Stage 2, the extent to which a competitor's conductor material represents a breakthrough technology will be primarily evaluated via the sample's conductivity testing results relative to the electrical conductivity thresholds in

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<sup>8</sup> For comparison purposes, competitors are asked for amounts (e.g., grams, kilowatt-hours) of inputs rather than their costs so the same cost can be assumed (in \$/kg, \$/kWh) across all entries, particularly for inputs with very volatile costs, such as copper or aluminum. Any costs that are provided will be evaluated on how credible and well-documented they are as well as the documentation of the relevant baseline. For example, a conductor meant for applications in motor coils should be compared with a commercial baseline typical of that application—in this case, copper.

Table 1. As shown in Table 4, 50% of the conductivity test scoring contributes to this goal. Refer to Section 2.5. (Sample Testing) and Appendix B for more information. Competitors' data inputs from Appendix C, as well as their Technical Narrative, will also aid in determining the extent to which competitors' conductor materials demonstrate a technological breakthrough that is not only technically superior to today's conductors, but also technically feasible and eventually economically competitive. In Stage 3, this goal will be evaluated mainly by the testing results from a larger sample.

**Life cycle energy, resource, and climate impact:** In addition to the impacts on cost and economic competitiveness, Stage 2 asks for broader impact information. In particular, life cycle impacts other than cost savings are being emphasized, and so competitors are asked to provide more specifics on applications. Specifically, greenhouse gas impacts on time scales that are relevant to the Biden administration's greenhouse gas reduction goals for 2030, 2035, and 2050 are sought. A further increase in emphasis on this goal area in Stage 3 is anticipated.

**Manufacturability:** : This new goal partially replaces the technical readiness goal in Stage 1 that was evaluated based on a "paper" proposal. In Stage 2, this goal (related to your material fabrication readiness) will be evaluated primarily by the results of the sample's conductivity testing. As shown in Table 4, 50% of the test scoring contributes to this goal. In addition, in the Technical Narrative and other submission elements for this goal, competitors will be evaluated according to the reasonableness and credibility of their scale-up path/scenario. The commercialization pathway described in Stage 2 should then be used to inform the Stage 3 scale-up to an industrial-scale sample. Finally, the points associated with the quality of the Voucher plan (Table 9) submission is counted as part of this goal.

**Commercialization:** A major new goal in Stage 2 is encouraging competitors to develop a reasonable, credible, and high-quality scenario or pathway for commercializing their material and demonstrating economic competitiveness in a widespread application within 10 years of deployment. In the Stage 2 Technical Narrative, competitors are asked to describe key commercialization elements, such as market data, intellectual property, company and team, and customer discovery. These elements should lay the groundwork for Stage 3, where competitors will be asked for a far more detailed commercialization plan.

**Table 4 Maximum Points per Goal**

Goal	Criteria Points	Testing Points	Total Points	%
Affordability	24	0	24	10%
Breakthrough	6	60	66	27.5%
Lifecycle Impacts	12	0	12	5%
Manufacturability*	18	60	78	32.5%
Commercialization	36	0	36	15%

Diversity	24	0	24	10%
Total	120	120	240	100%

\*includes Voucher points from Table 9

## 2.2. Vouchers

Winners of the Stage 2 Contest will receive a \$100,000 voucher for technical assistance that they may use to fund work at national laboratories and other facilities to accelerate the production, testing, improvement, and/or validation of their conductive materials for the Stage 3 competition. [Voucher Guidelines](#) and [Voucher Capabilities](#) is posted on the [CABLE Prize HeroX website](#) and will include information for competitors as well as for entities interested in helping competitors via the voucher program. The Prize Administrator will provide competitors with opportunities to meet with potential voucher providers ahead of the Stage 2 submission deadline since the voucher provider(s) must be identified and a high-level overview of proposed work provided in the final Stage 2 submission, via the [Voucher Work Slide](#) (see Section 2.4)

## 2.3. How to Enter

To enter Stage 2, a competitor must:

- 1) Create an account on HeroX and submit a testing registration form online at <https://www.herox.com/cable> as soon as possible and no later than Aug. 25, 2022, at 5 p.m. ET. All registered eligible teams will receive free Stage 2 conductivity testing, regardless of whether or not they won Stage 1. Early registration is encouraged to receive important updates and event invitations.
- 2) Send three samples of their conductive materials to the approved testing laboratory for testing. All submission must be postmarked by Oct. 17, 2022. Refer to Section 2.5. for more details. Early sample submittal to the testing laboratory is *strongly encouraged*.
- 3) Complete a final submission package (see Section 2.4) online at <https://www.herox.com/cable> by **March 23, 2023, at 5 p.m. ET.**



## 2.4. What to Submit

All components of the submission package must be in English. Unless stated otherwise, all files must be in an unlocked, searchable PDF form and use the following file name format: **Team-**

**Name\_CABLEStage2.pdf**. For a submission package to be considered complete and eligible for this prize, the submission package for the Stage 2 Contest must include the following eight items (refer to Table 5–11 for details):

- Cover page
- Link to a 90-second video (publicly accessible online)
- Summary PowerPoint slide (which will be made public)
- Technical Narrative providing responses in five goal categories:
  - Affordability
  - Conductor Material Breakthrough
  - Life Cycle Impacts
  - Manufacturability
  - Commercialization
- Completed template for Appendix C: Quantitative Sample Data Commercialization Estimate Input
- Voucher Work Slide (refer to [Voucher Guidelines](#))
- Diversity, Equity, and Inclusion Plan
- Letters of commitment or support (optional).

**Note: Content that exceeds any word, page, or time limit will not be reviewed.**

**Table 5. Cover Page Requirements**

Cover Page: List basic information about the submission. (One Page Maximum) (Editable Template)
<p>Competitors should include:</p> <ul style="list-style-type: none"><li>• Submission title</li><li>• Competitor or team name</li><li>• Official team address with nine-digit zip code</li><li>• Team leader (point of contact)</li><li>• Team leader phone number</li><li>• Short description (e.g., slogan)</li><li>• Material class of the team’s conductor according to the three categories of the conductor material class (refer to Section 1.3. )</li><li>• Link to the 90-second video online</li><li>• Key project members (names, contacts, and, if possible, links to online profiles/resumes)</li><li>• &lt;100-word abstract.</li></ul>

**Table 6. Online Public Video Requirements**

Online Public Video: What is the innovation, in 90 seconds?
<p>Competitors should make a 90-second (maximum) video showcasing their submission and emphasizing the novelty or advantage(s) of their idea and potential impact. Competitors should be creative and produce a video that conveys the information in exciting and interesting ways but not focus on time-consuming activities that only improve production value (i.e., technical elements, such as décor, lighting, and cinematic techniques). The video should be posted as “Unlisted” on YouTube, and the link should be included in the submission. Note: the video will be made public on HeroX after the submission deadline for Stage 2.</p>
<p>Competitors could include:</p> <ul style="list-style-type: none"><li>• Their proposed idea</li><li>• How their idea works</li><li>• Why their idea is innovative</li><li>• Show their sample preparation</li><li>• Who they are and why they have a competitive edge.</li></ul>

**Table 7. PowerPoint Summary Slide Requirements**

Public PowerPoint Summary Slide (One Slide) (Editable Template)
<p>Competitors should make a public-facing, one-slide summary using PowerPoint that contains technically specific details that can be understood by most people. The slide will be made public and should include:</p> <ul style="list-style-type: none"> <li>• The competitor or team name and team leader</li> <li>• Submission title</li> <li>• Description of the conductor material, application market size, and which Table 1 contest the team is competing in</li> <li>• Sample fabrication approach</li> <li>• Material image</li> <li>• Potential impact.</li> </ul> <p>Competitors should make any text readable in a standard printout and conference-room projection. A summary slide template can be found at <a href="https://www.herox.com/cable/resources">https://www.herox.com/cable/resources</a>.</p>

**Technical Narrative:** Competitors should respond to each of the five technical goals: Affordability, Conductor Material Breakthrough, Life Cycle Impacts, Manufacturability, and Commercialization. The content bullets on the left side of Table 8. Technical Narrative Requirements are only suggestions to guide their responses; competitors decide where to focus their answers. Responses must not exceed 5,000 words in total. The required template in Appendix C must also be completed (note that quantitative responses in Appendix C do not count against the 5,000-word limit of the Technical Narrative) in order to get full credit for the Affordability and Commercialization goals. Competitors may also include up to 10 supporting images, figures, or graphs integrated into the narrative. Appendices, references, annotations, and table, figure, and/or image descriptions do not count against the word limit.

**Table 8. Technical Narrative Requirements**

Technical Narrative (Editable Template) Appendix C (Editable Template)	
Goal 1: Affordability 24 points possible (Note: Appendix C must also be complete)	
<p>Competitors could:</p> <ul style="list-style-type: none"> <li>• Describe a scenario/pathway for how the sample preparation costs they provided in Appendix C will decrease as their fabrication process is scaled up to the industrial scale for commercialization; specifically, describe how much the cost must decrease from Stage 2 sample preparation to 10 years post-commercialization; describe how the manufacturing cost is reduced by learning, economies of scale, etc., compared with Table</li> </ul>	<p>Judging criteria (1–6 points per statement):</p> <ul style="list-style-type: none"> <li>• The extent to which the material’s sample preparation cost-related data (Appendix C) support the competitor’s estimate of their future manufacturing cost: Are future (industrial-scale) costs just a little (e.g., 10%) lower or a lot (e.g., 100 times) lower than sample fabrication costs?</li> </ul>

<p>15Error! Reference source not found. and Table 16 (Appendix C).</p> <ul style="list-style-type: none"> <li>Describe how the industrial-scale life cycle costs will compare to the likely conventional life cycle costs of the competing material in the application type chosen in Appendix C.</li> <li>For any energy savings and reduced climate impacts that can be monetized, provide an estimate (in dollars) of their value in the proposed application(s) according to the team's scenario.</li> <li>Detail operational cost savings in the widespread energy application(s) that justify material cost premiums (if any). These savings should exceed any of the additional costs beyond manufacturing a state-of-the-art material.</li> </ul>	<ul style="list-style-type: none"> <li>The credibility of the description of how costs are reduced during the manufacturing scale-up scenario.</li> <li>The material's life cycle potential to become economically competitive with the identified baseline conductor 10 years post-commercialization.</li> <li>The credibility of the life cycle cost estimates, including estimates of future manufacturing and operational costs and competing baseline conductor material costs.</li> </ul>
<p align="center"><b>Goal 2: Conductor Material Breakthrough</b> 6 points possible (plus additional points for testing – see Table 4)</p>	
<p>Competitors could:</p> <ul style="list-style-type: none"> <li>Provide the scientific and engineering underpinnings of the enhanced conductivity in their microscale conductor material</li> <li>Provide scientific explanation for why the enhanced conductivity at microscale will persist at industrial scale</li> <li>If the material represents a major breakthrough, describe any new scientific understanding.</li> </ul>	<p>Judging criteria (1–6 points per statement):</p> <ul style="list-style-type: none"> <li>The extent to which the competitor's explanation of their samples' enhanced conductivity relies on sound scientific and engineering principles, including the credibility of the explanation for why the enhanced conductivity observed at microscale will persist at industrial scale.</li> </ul> <p>Note: Evaluation of the actual magnitude of the enhanced conductivity (any metric) will come directly from the ranked sample testing results in Appendix D based on a curve developed by the Prize Administrator.</p>

<b>Goal 3: Life Cycle Impacts</b> 12 points total	
Competitors could describe: <ul style="list-style-type: none"> <li>Non-GHG emission and other environmental and non-economic impacts related to the material's associated energy, resource extraction, product energy use or reuse/recycling for the most likely application(s).</li> <li>How will this contribute to Biden administration climate goals of: <ul style="list-style-type: none"> <li>50% greenhouse gas emissions reductions by 2030</li> <li>Carbon-free grid by 2035</li> <li>Net-zero greenhouse gas emissions economy by 2050.</li> </ul> </li> </ul>	Judging criteria (1–6 points per statement): <ul style="list-style-type: none"> <li>The size and credibility of the non-greenhouse gas, non-cost savings positive life cycle environmental impacts (e.g. reduced air criteria pollutants and toxics emissions related to reduced energy and resource extraction impacts and/or energy use and/or recycling impacts) of the competitor's application(s) for 10 years post-commercialization.</li> <li>The size and credibility of the net greenhouse gas emissions reductions by 2030, 2035, and 2050 from the new material.</li> <li></li> </ul>
<b>Goal 4: Manufacturability</b> 12 points possible (plus additional points from Table 9 and additional points for testing; see <b>Error! Reference source not found.</b> )	
Competitors could: <ul style="list-style-type: none"> <li>Provide evidence that the sample fabrication technique (or proposed alternate technique that leads to industrial scale) is scalable. For example, describe the current technology readiness level (TRL) and pathway toward achieving the desired TRL.</li> </ul> <p>Note: Competitors should include any and all assumptions and calculations and/or references and supporting data. These can include schematics, drawings, or sketches.</p>	Judging criteria (1–6 points per statement): <ul style="list-style-type: none"> <li>The credibility and reasonableness of the manufacturing technologies and processes for the proposed manufacturing scale-up intended to make the material economically competitive in the contest market.</li> <li>The credibility and reasonableness of the magnitude of annual production in kilograms claimed 10 years post-commercialization. (Commercialization Statement 1B in Appendix C).</li> </ul>
<b>Goal 5: Commercialization</b> 36 points possible (Note: Appendix C must also be complete)	
Competitors could include: <ul style="list-style-type: none"> <li>Market data that describes: <ul style="list-style-type: none"> <li>The innovation and the market need that it is fulfilling</li> <li>How the team collected data on market needs, which may include but is not limited to customer discovery</li> <li>For Table 1 Contests 2 and 3 competitors (Beat Aluminum!; Beat a Conductor System!), how the market and application space for the</li> </ul> </li> </ul>	Judging criteria (1–6 points per statement): <ul style="list-style-type: none"> <li>The current and forecasted future market size of the conductor/conductor system that the new material would replace.</li> <li>The extent to which the market data provided are complete and credible, including examples of potential markets and partners that the team will likely pursue or already has pursued.</li> </ul>

<p>team's material differ than those for materials exceeding Contest 1 (Beat Copper!)</p> <ul style="list-style-type: none"> <li>○ The problem the team is trying to solve that isn't currently being addressed by another similar product</li> <li>○ What the Total Addressable Market, Serviceable Available Market, and Serviceable Obtainable Market are</li> <li>○ How the technology is positioned for commercial viability, private sector investments, and market impact.</li> <li>● Intellectual Property (IP) that describes: <ul style="list-style-type: none"> <li>○ Intellectual property protections and next-stage resource factors.</li> </ul> </li> <li>● Company/team that describes: <ul style="list-style-type: none"> <li>○ Why the company/team the best suited to address this market need.</li> </ul> </li> <li>● Customer discovery that: <ul style="list-style-type: none"> <li>○ Answers who the end customer is/will be</li> <li>○ Provides evaluations of expected market segments and end customers</li> <li>○ Describes how the commercialization plan was reviewed with relevant advisors and how their feedback was incorporated.</li> </ul> </li> <li>● Technology scaling data/narrative that estimates: <ul style="list-style-type: none"> <li>○</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>● The extent to which the IP information described is complete and reasonable.</li> <li>● The extent to which the company/team description supports commercialization.</li> <li>● The quality of the customer discovery and how data from potential customers are incorporated.</li> <li>● The magnitude and credibility of the manufacturing costs and industrial-scale commercialization using statements 1A and 1C in Appendix C.</li> </ul> <p>Note: The "Complete" criteria is also assessed by the completeness of data entries and calculations in the Appendix C template for commercialization estimates and sample data. The "Credible" criteria also include how reasonable the assumptions are in the template in Appendix C.</p> <p>Note: Prize Administrator will complete and provide Appendix D testing data results to the Expert Reviewer panel based on the information that the competitor provides in Appendix C. A copy of Appendix D will be provided to competitors by Nov. 18, 2022.<sup>9</sup></p>
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<sup>9</sup> Anticipated, subject to change



**Table 9. Voucher Work Slide Requirements**

Voucher Work Slide (Page limit: One slide/page per proposed voucher organization) 6 points possible ( <a href="#">Editable Template</a> )	
Competitors could describe: <ul style="list-style-type: none"><li>• How they will use their voucher funds to support their team’s work in the Stage 3 Contest, including the entities they plan to engage with and what they will do with the voucher funds. A letter of support from each entity should be submitted identifying the entity’s interest in participating as a voucher service provider organization.</li></ul>	Judging criteria (1–6 points per statement): <ul style="list-style-type: none"><li>• The proposed technical assistance will provide critical and effective support for teams in the Stage 3 Contest.</li></ul>

**Table 10. Diversity, Equity, and Inclusion Plan Requirements**

Diversity, Equity, and Inclusion Plan (Word limit: Minimum of 500 words, maximum of 1,500 words) 24 points possible (Editable Template)	
<p>Per Section 2.8. (Diversity, Equity, and Inclusion), competitors should describe how diversity and inclusion objectives will be or have been incorporated in their project. Specifically, the Diversity, Equity, and Inclusion (DEI) Plan must describe the actions that the team will take to foster a welcoming and inclusive environment, support people from underrepresented groups in science, technology, engineering, and mathematics (STEM), and encourage the inclusion of individuals from these groups in the project. In addition, the plan should include the extent to which project activities will be located in or benefit disadvantaged communities as well as specific, measurable, attainable, relevant, and time-bound (SMART) milestones supported by metrics to measure the success of the proposed actions.</p>	
<p>The competitor could describe:</p> <ul style="list-style-type: none"> <li>• How the technology would benefit lower socioeconomic status, disadvantaged communities and other underrepresented populations as described in Section 2.9. (Competitor Eligibility)</li> <li>• The steps that will be taken to minimize the negative impact on lower socioeconomic-status populations, disadvantaged communities, and other underrepresented populations</li> <li>• The partnership approaches the team is taking to foster a welcoming and inclusive environment, support people from underrepresented groups in STEM, and encourage the inclusion of individuals from these groups in the project</li> <li>• Activities that will build trust and strengthen relationships and partnerships with disadvantaged communities</li> <li>• Industries that would be positively and/or negatively impacted by the proposed technology</li> <li>• Mitigation strategies to minimize negative impacts to the environment</li> <li>• How environmental justice will be addressed</li> <li>• How good-paying jobs may be created by commercialization and deployment of the technology</li> <li>• SMART milestones and metrics for implementation of the team's DEI Plan.</li> </ul>	<p>Judging criteria (1–6 points for each statement):</p> <ul style="list-style-type: none"> <li>• The development of this technology will benefit lower socioeconomic-status populations, disadvantaged communities and other underrepresented populations as described in Section 2.8. (see footnotes 13 and 14 for additional detail).</li> <li>• The team's plan for integrating DEI goals into the project is well-considered and effective, provides reasonable SMART milestones and metrics, and is responsive to the goals described in Section 2.8. .</li> <li>• The plan describes current and/or planned partnership with Minority Serving Institutions, Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, or entities located in disadvantaged communities.</li> <li>• The degree to which the plan is likely to lead to increased opportunities and participation in clean energy and climate-smart job training and job placement/hiring within the industry.</li> </ul>

**Table 11. Letters of Commitment and Support Guidelines**

Letters of Commitment and Support (Optional)
Competitors may also attach one-page letters of support or intent from other relevant entities (e.g., potential users of the proposed innovation). Letters of support from partners or others that are critical to the success of their proposed solution will likely increase their score. General letters of support from parties that are not critical to the execution of a competitor's solution will likely not factor into their score. A Letter of Commitment must not exceed one page. All letters must be combined into a single PDF document.

Please read and comply with the additional submission requirements in Section 3.

Additional Terms and Conditions. COMPETITORS THAT DO NOT COMPLY WITH THESE REQUIREMENTS MAY BE DISQUALIFIED.

## 2.5. Sample Testing

This section provides testing requirements for Stage 2, in which all competitors are required to submit samples of their material to an approved testing laboratory for electrical conductivity testing. The approved testing laboratory for non-superconductors and for superconductors are [NTS](#) and the **Materials Science Division at Argonne National Laboratory (Argonne)**, respectively. These testing laboratories have been chosen to ensure fairness and comparability across all submissions.

The CABLE Conductor Manufacturing Prize will provide a testing stipend to *all competitors*, regardless of if they won Stage 1 or not. This stipend will cover the cost of conductivity testing of three samples of their conductivity-enhanced material at the approved CABLE Conductor Manufacturing Prize laboratories. Teams who wish to take advantage of the Stage 2 testing stipend must submit a [registration form on HeroX](#) no later than Aug. 25, 2022, at 5 p.m. ET. Multiple submissions from the same lead organization will be accepted; however, the team captain and individual team members as well as the sample material itself must be distinct for each entry (i.e., slight variations on the same material will not be accepted, and the team captain and the majority of the team must be different). Competitors who do not submit a registration form by the deadline may still compete; however, they may be required to self-fund their sample testing at an approved CABLE Conductor Manufacturing Prize laboratory.

For both types of samples, results are anticipated to be provided to the competitor via the Prize Administrator within approximately 1 month following the sample submission deadline, which is Oct. 17, 2022.<sup>10</sup>

It is the responsibility of the respective testing vendor to examine the sample upon receipt to determine if it is obviously untestable (e.g., broken, too small, or too large). It is the responsibility of the competitor to confirm that the vendor received the sample, and if the sample is NOT received or is obviously untestable, it is the competitor's responsibility to send a new set of samples by the sample submission deadline.

**Early submission of samples is highly encouraged, as sample submissions postmarked after the sample submission deadline of Oct. 17, 2022, will not be accepted.** If, for any reason, the competitor determines they would like a test of additional samples, those tests must be self-funded. The CABLE Conductor Manufacturing Prize will pay for the testing of three samples per registered, eligible (i.e., met the HeroX registration deadline and overall prize eligibility; refer to Section 2.9. ) competitor. Final results of the

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<sup>10</sup> March 2023 Update: Due to challenges with the Stage 2 testing vendor, results are now anticipated to be sent to competitors in early March 2023.

testing will be sent directly to the Prize Administrator, who will share individual results privately with each competitor.

Competitors are responsible for the cost of shipping their sample to the test laboratory; however, the Prize Administrator will pay for the return shipping of samples to competitors following testing. It is the intention of the Prize Administrator to ensure that all samples are returned to competitors.

Each competitor (regardless of material type) shall submit **three samples** that meet the requirements in the following subsections. The testing vendor cannot test samples that fall outside of these parameters.

### 2.5.1. Non-Superconducting (Metal and Nonmetal) Submissions

**Sample size requirements:** The sample must:

- Minimum 6 inches long (longer is preferred, up to 12 inches), with a cross sectional area of at least 0.0044 square inches (equivalent to .075 inches in circular diameter) or square dimensions of at least 0.0664 inches long on each side (2.85 square millimeters with a diameter of 1.90 millimeters or square sides of at least 1.69 millimeters in length)
- Be a uniform cross section, where the cross-sectional area may not vary more than  $\pm 2\%$  along the length
- Have a minimum electrical resistance of 20 microohms ( $\mu\Omega$ ).

**Mailing instructions:** Competitors should package samples appropriately to shield against damage during shipping. Once shipped, competitors must email the testing laboratory (see below) and copy the Prize Administrator ([prize@cableprize.gov](mailto:prize@cableprize.gov)) with confirmation of shipment, team name, submission title, team captain name and contact, and tracking number. Contact and shipping information for the testing laboratory will be provided to registered eligible competitors after the registration deadline (August 25, 2022). If registering after August 25, 2022, please email [prize@cableprize.gov](mailto:prize@cableprize.gov) for instructions.

Competitors should also provide their return mailing information in order to have their samples returned to them following testing, including:

**Name:**

**Company:**

**Address:**

**State:**

**Zip-Code:**

**Phone Number:**

Please note that neither are DOE or NREL responsible for any damage to the sample, nor are they responsible should the sample be unable to be tested for any reason.

## 2.5.2. Superconducting Submissions

**Sample size requirements:** The submission must be a round or square sample where one face of film is 5 square millimeters or less in area.

**Mailing instructions:** Competitors should package samples appropriately to shield against damage during shipping. Once shipped, competitors must email the testing laboratory (address given below) and copy the Prize Administrator ([CablePrize@NREL.gov](mailto: CablePrize@NREL.gov)) with confirmation of shipment, team name, submission title, team captain name and contact, and tracking number. Contact and shipping information for the testing laboratory will be provided to registered eligible competitors after the registration deadline (August 25, 2022). If registering after August 25, 2022, please email [CablePrize@NREL.gov](mailto: CablePrize@NREL.gov) for instructions.

Competitors should also provide their return mailing information in order to have their samples returned to them following testing, including:

**Name:**

**Company:**

**Address:**

**State:**

**Zip-Code:**

**Phone Number:**

Note for superconducting submissions: refer to Appendix D to learn how testing data will be used.

## 2.5.3. Other Testing Information

By submitting samples, competitors agree to have their samples tested by NTS or Argonne. The testing vendor may need to manipulate samples to achieve the most accurate electrical conductivity data; neither are DOE, NREL, Argonne, or NTS responsible for any damage to the sample, nor are they responsible should the sample be unable to be tested for any reason. It is up to the competitor to ensure that enough time is available to mail additional samples to the testing lab before the submission deadline in the event of a lost or otherwise untestable sample. The Prize Administrator may, at their sole discretion, allow late samples to be submitted due to laboratory testing failure. Competitors are allowed to request nondisclosure agreements (NDAs) between themselves and the testing laboratories; however, these agreements must be finalized no later than the sample submission deadline. NDAs between the competitor and the testing laboratory are the sole responsibility of the competitor.

## 2.6. How Stage 2 Is Scored

Stage 2 will be scored based on two submission components: the HeroX submission (refer to Section 2.4. [

What to Submit]) and the conductivity testing of the submitted Stage 2 sample material (refer to Appendix D and Section 2.5. [Sample Testing]).

The HeroX submission judging statements (from all scored submission documents, including the Technical Narrative; refer to Appendix C) will comprise 50% of a competitor's total score (with the other 50% coming from testing results). The maximum score for the Stage 2 contest is 240, 120 for the final written submission package and 120 for the sample testing results.

**Scoring of testing results:** Points for testing will come directly from the ranked sample testing results in Appendix D based on a curve developed by the Prize Administrator. The number of points for qualifying entries will be determined by rank, with the top conductivity for Table 1 Contests 1 and 2 and the top market for Contest 3 receiving the maximum 120 points for testing.

**Scoring of HeroX final submission package:** The Expert Reviewers will score the HeroX submission judging criteria questions (see Section 2.4. ) based on the content provided in the Technical Narrative and other submission elements, including the data inputs for Appendix C.

Expert Reviewers will score submissions by agreeing or disagreeing with assigned statements on a 1–6 scale, as shown in



Table 12.

**Table 12. Expert Reviewers Scoring Guide**

1	2	3	4	5	6
Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree

## 2.7. How Winners Are Selected

### 2.7.1. HeroX Submission Scoring

All items in the submission package, with the exception of the cover page, will be considered when scoring each submission. After reviewing all elements of the submission package, Expert Reviewers will assign a score between 1 and 6 (refer to

Table 12) for each of the judging criteria statements, taking into account the entirety of the submission package. Each criterion is weighted equally.

The scoring of submissions will proceed as follows:

**Review criteria scoring:** Each bullet listed in the review criteria in Section 0 (

- What to Submit) will receive a score between 1 and 6. Each bulleted criterion statement has equal weight. The final score from an individual reviewer for a submission package equals the total of the scores for all the bullets ( $20 \times 6 = 120$ ). All Expert Reviewers' scores will be averaged for a final review score for the submission package. Note: Expert Reviewers will also provide comments on the submissions they review. The Prize Administrator intends to provide comments to competitors after the winners are announced. These comments are intended to help competitors continue to improve and iterate on their submissions. The comments are the opinions of the Expert Reviewers and do not represent the opinions of DOE.
- **Conductivity test scoring:** Competitors will submit their Stage 2 materials for conductivity testing (refer to Section 2.5. [Sample Testing]). The number of points for qualifying entries will be determined by rank, with the top conductivity for contests 1 and 2 and the top market for Contest 3 receiving the maximum 120 points for testing. To qualify for a prize, Stage 2 submissions must meet or exceed the requirements for one the three contests (Beat Copper!, Beat Aluminum!, Beat a Conductor System!) in Table 1.
- **Interviews:** The Prize Administrator, at their sole discretion, may decide to hold a short interview with a subset of the Stage 2 competitors. The interviews will be held prior to the winner announcement and will serve to clarify questions the Prize Judge may have. Attending interviews is not required, and interviews are not an indication of winning.

**Overall scoring and prize winning:** The Prize Judge will consider review scores, ranked testing results (Appendix D), and program policy factors when deciding the winners of the prizes. The size of the prize is equal for each contest in Table 1. The number of awards under each contest, however, will be determined by the Prize Judge according to sample test results, judging criteria, and program policy factors described in Section 3.13.

The final determination of winners will take into account reviewer scores, testing results, interview findings (if applicable), and program policy factors listed in Section 3.13.

## 2.8. Diversity, Equity, and Inclusion

It is the policy of the Biden administration that:

[T]he Federal Government should pursue a comprehensive approach to advancing equity for all, including people of color and others who have been historically underserved, marginalized, and adversely affected by persistent poverty and inequality. Affirmatively advancing equity, civil rights, racial justice, and equal opportunity is the responsibility of the whole of our government. Because advancing equity requires a systematic approach to embedding fairness in decision-making processes, executive departments and agencies (agencies) must recognize and work to redress inequities in their policies and programs that serve as barriers to equal opportunity. By advancing

equity across the Federal Government, we can create opportunities for the improvement of communities that have been historically underserved, which benefits everyone.<sup>11</sup>

As part of this approach, the CABLE Conductor Manufacturing Prize seeks to encourage the participation of disadvantaged communities and underrepresented groups. As recognized in Section 305 of the American Innovation and Competitiveness Act of 2017, Public Law 114-329:

(1) [I]t is critical to our Nation's economic leadership and global competitiveness that the United States educate, train, and retain more scientists, engineers, and computer scientists; (2) there is currently a disconnect between the availability of and growing demand for science, technology, engineering, and math (STEM)-skilled workers; (3) historically, underrepresented populations are the largest untapped STEM talent pools in the United States; and (4) given the shifting demographic landscape, the United States should encourage full participation of individuals from underrepresented populations in STEM fields.<sup>12</sup>

Competitors are highly encouraged to include individuals from groups historically underrepresented in STEM on their teams.<sup>13</sup> As part of the prize application, competitors are required to describe how diversity and inclusion objectives will be incorporated in the project. Specifically, competitors are required to submit a Diversity, Equity, and Inclusion Plan that describes the actions the competitor will take to foster a welcoming and inclusive environment, support people from underrepresented groups in STEM, and encourage the inclusion of individuals from these groups in the project. In addition, the plan should include the extent to which project activities will be located in or benefit disadvantaged communities as well as specific, measurable, attainable, relevant, and time-bound (SMART) milestones supported by metrics to measure the success of the proposed actions.

Further, Minority Serving Institutions, Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, or entities located in a disadvantaged community that meet the eligibility

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<sup>11</sup> Exec. Order No. 13985. 2021. "Advancing Racial Equity and Support for Underserved Communities Through the Federal Government." (Jan. 20, 2021). <https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/20/executive-order-advancing-racial-equity-and-support-for-underserved-communities-through-the-federal-government/>.

<sup>12</sup> 114<sup>th</sup> U.S. Congress. 2017. "American Innovation and Competitiveness Act of 2017." Washington, D.C.: U.S. Congress. Pub. L. No. 114-329 (2017). <https://www.congress.gov/bill/114th-congress/senate-bill/3084/text/enr>

<sup>13</sup> "Historically, minorities and women have been vastly underrepresented in the STEM (science, technology, engineering and math) fields that drive the energy sector. In the U.S., Hispanics, African Americans and American Indians make up 24 percent of the overall workforce, yet only account for 9 percent of the country's science and engineering workforce. DOE seeks to reverse this troubling trend by working to inspire underrepresented Americans to pursue careers in energy and supporting their advancement into leadership positions." (Pierce, Erin. 2013. "Introducing the Minorities in Energy Initiative." U.S. Department of Energy. <https://www.energy.gov/articles/introducing-minorities-energy-initiative>.)

requirements (refer to Section 2.9. are encouraged to apply.<sup>14</sup> As described in Section 3.13. , the Selection Official may consider the inclusion of these types of entities as part of the selection decision.

## 2.9. Competitor Eligibility

To compete in this prize, competitors must comply with the eligibility requirements provided here. Eligibility is subject to verification before prizes are awarded. The registered competitor is the individual or entity that registers to compete in HeroX. Once registered, any eligible competitor can participate in and provide a submission package (multiple submissions from the same lead organization will be accepted and each may be considered for prize awards; however, individual team members and sample material must be distinct) to compete in Stage 2 of the prize. Note: Only winners of Stage 2 will be eligible to participate in Stage 3.

The Prize Administrator must conclude that all of the following statements are **true** when applied to a competitor:

- Individuals, private entities (for-profits and nonprofits), and nonfederal government entities (such as states, counties, tribes, municipalities, and academic institutions) are subject to the following requirements:
  - An individual prize competitor (who is not competing as a member of a group) must be a U.S. citizen or a permanent resident.
  - A group of individuals competing as one team may win, provided that the online account holder of the submission is a U.S. citizen or a permanent resident. Individuals competing as part of a team may participate if they are legally authorized to work in the United States.
  - Private entities must be incorporated in and maintain a primary place of business in the United States with majority domestic ownership and control.
    - If a private entity seeking to compete does not have domestic ownership and control, the DOE Office of Energy Efficiency and Renewable Energy (EERE) may consider issuing a waiver of that eligibility requirement where the entity: submits a compelling justification; demonstrates the entity is incorporated in and maintains a primary place of business in the United States; and the entity

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<sup>14</sup> DOE defines “disadvantaged communities” to be areas that most suffer from a combination of economic, health, and environmental burdens, such as poverty, high unemployment, air and water pollution, and the presence of hazardous wastes as well as a high incidence of asthma and heart disease. Examples include but are not limited to: economically distressed communities identified by the Internal Revenue Service as Qualified Opportunity Zones; communities identified as disadvantaged communities by their respective States; communities identified on the Index of Deep Disadvantage (Wadley, Jared and Lauren Slagter. 2020. Index of Deep Disadvantage. University of Michigan. Last updated: Jan. 30, 2020. <https://news.umich.edu/new-index-ranks-americas-100-most-disadvantaged-communities/>), and communities that otherwise meet the DOE definition of a disadvantaged community.

otherwise meets the eligibility requirements. Entities seeking a waiver should include a justification along with their submission. EERE may require additional information before making a determination on the waiver request. There are no rights to appeal DOE's decision on the waiver request. Refer to Section 3.16. (Request To Waive the "Domestic Ownership and Control" Eligibility Requirement) for details and instructions on seeking a waiver.

- Academic and nonfederal government entities must be based in the United States.
- Individuals who worked at DOE (federal employees or support service contractors) within 6 months prior to the submission deadline of any stage of this contest are not eligible to participate.
- Non-DOE federal entities and federal employees are not eligible to win any prize contests in this program.
- Employees of an organization that cosponsors this program with DOE are not eligible to participate in any prize contests in this program.
- NREL employees directly involved in the administration of this prize are not eligible to participate in any prize contest in this program; however, NREL and other national laboratory employees, including laboratory researchers, may participate. They can also win a prize contest, provided they are not competing in their official capacity.
- Entities and individuals publicly banned from doing business with the U.S. Government, such as entities and individuals debarred, suspended, or otherwise excluded from or ineligible for participating in federal programs, are not eligible to compete.
- Entities identified on a U.S. Department of Homeland Security Binding Operational Directive as an entity publicly banned from doing business with the United States government are not eligible to compete. See Cybersecurity Directives: <https://cyber.dhs.gov/directives/>.
- Entities and individuals identified as a restricted party on one or more screening lists of the departments of Commerce, State, and the Treasury are not eligible to compete. See Consolidated Screening List: [https://2016.export.gov/ecr/eg\\_main\\_023148.asp](https://2016.export.gov/ecr/eg_main_023148.asp).
- This prize competition is expected to positively impact U.S. economic competitiveness. Participation in a foreign government talent recruitment program<sup>15</sup> could conflict with this objective by resulting in the

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<sup>15</sup> A foreign government talent recruitment program is defined as an effort directly or indirectly organized, managed, or funded by a foreign government to recruit science and technology professionals or students (regardless of citizenship or national origin, and whether having a full-time or part-time position). Some foreign-government-sponsored talent recruitment programs operate with the intent to import or otherwise acquire from abroad, sometimes through illicit means, proprietary technology or software, unpublished data and methods, and intellectual property to further the military modernization goals and/or economic goals of a foreign government. Many, but not all, programs aim to incentivize the targeted individual to physically relocate to the foreign state for the above purpose. Some programs allow for or encourage continued employment at U.S. research facilities or receipt of federal research funds while concurrently working at and/or receiving compensation from a foreign institution, and some direct competitors not to disclose their participation to U.S. entities. Compensation could take many forms including cash, research funding, complimentary foreign travel, honorific

unauthorized transfer of scientific and technical information to foreign government entities; therefore, individuals participating in foreign government talent recruitment programs of foreign countries of risk are not eligible to compete. Further, teams that include individuals participating in foreign government talent recruitment programs of foreign countries of risk<sup>16</sup> are not eligible to compete.

- As part of their submission to this prize program, competitors will be required to sign the following statement:

*I am providing this submission package as part of my participation in this prize. I understand that I am providing this submission to the Federal Government. I certify under penalty of perjury that the named competitor meets the eligibility requirements for this prize competition and complies with all other rules contained in the Official Rules document. I further represent that the information contained in the submission is true and contains no misrepresentations. I understand false statements or misrepresentations to the Federal Government may result in civil and/or criminal penalties under 18 U.S.C. § 1001 and § 287.*

- Submission content sufficiently confirms the competitor's intent to commercialize early-stage technology and to establish a viable U.S.-based business in the near future.

## 2.10. General Submission Requirements

Only submissions relevant to the goals of this program are eligible to compete. The Prize Administrator must conclude that all of the following statements are **true** when applied to a competitor's submission:

- The conductor material must have an electrical conductivity at least **as high as the lowest conductivity conductor<sup>17</sup> in Appendix A** as shown by Stage 2 testing.
- The proposed effort does not involve the lobbying of any federal, state, or local government office.
- The proposed effort is not dependent on new, pending, or proposed federal, state, or local government legislation, resolutions, appropriations, measures, or policies.
- The proposed effort is based on fundamental technical principles and is consistent with a basic understanding of the U.S. market economy.

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titles, career advancement opportunities, promised future compensation, or other types of remuneration or consideration, including in-kind compensation.

<sup>16</sup> Currently, the list of countries of risk includes Russia, Iran, North Korea, and China.

<sup>17</sup> Carbon Fiber,  $1.06 \times 10^{-4}$  MS/m conductivity



## 2.11. Additional Requirements

Competitors must read and comply with additional requirements in Section 3. (Additional Terms and Conditions). COMPETITORS THAT DO NOT COMPLY WITH THESE REQUIREMENTS MAY BE DISQUALIFIED.

## 3. Additional Terms and Conditions

### 3.1. Universal Contest Requirements

A competitor's submission for the Stage 1, Stage 2, or Stage 3 contest is subject to the following terms and conditions:

- The competitor must complete registration at [www.herox.com/cable](http://www.herox.com/cable) to participate in the prize by the registration deadline.
- The competitor must post the final content of their submission or upload the submission form online at [www.herox.com/cable](http://www.herox.com/cable) before the Stage 1, Stage 2, and Stage 3 contests close. Late submissions or any other form of submission do not qualify.
- The video submission, summary slide, and cover page will be made public.
- The technical narrative is not intended to be made public; however, refer to Section 3.10. Records Retention and Freedom of Information Act regarding the Freedom of Information Act (FOIA).
- The competitor agrees to release their submission video under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/) (see <https://creativecommons.org/licenses/by/4.0/>).

The competitor must include all the required submission package components; refer to Section 0

- What to Submit. The Prize Administrator may disqualify a submission after an initial screening if it fails to provide all required submission elements. Competitors may be given an opportunity to rectify submission errors due to technical challenges.
- The competitor submission must be in English and, except for the video, in an unlocked, searchable PDF form. Scanned handwritten submissions will be disqualified.
- Submissions will be disqualified if they contain any matter that, in the sole discretion of the Prize Administrator, is indecent, obscene, defamatory, libelous, lacking in professionalism, or demonstrates a lack of respect for people or life on this planet.
- If the competitor click “Accept” on the HeroX platform and proceed to register for any of the contests described in this document, these rules will form a valid and binding agreement between them and DOE and are in addition to the existing HeroX Terms of Use for all purposes relating to these contests. Competitors should print and keep a copy of these rules. These provisions only apply to the contests described here and no other contests on the HeroX platform or anywhere else.
- The Prize Administrator, when feasible, may give competitors an opportunity to fix nonsubstantive mistakes or errors in their submission packages.

## 3.2. Verification for Payments

The Prize Administrator will verify the identity and the role of a competitor potentially qualified to receive the prizes. Receiving a prize payment is contingent upon fulfilling all requirements contained herein. The Prize Administrator will notify winning competitors using provided email contact information after the date that results are announced. Each competitor will be required to sign and return to the Prize Administrator, within 30 days of the date the notice is sent, a completed NREL Request for ACH Banking Information form (for a copy please email [Cableprize@nrel.gov](mailto: Cableprize@nrel.gov)) and a completed W-9 form (<https://www.irs.gov/pub/irs-pdf/fw9.pdf>). In the sole discretion of the Prize Administrator, a winning competitor will be disqualified from the competition and receive no prize funds if: (i) the person/entity cannot be contacted; (ii) the person/entity fails to sign and return the required documentation within the required time period; (iii) the notification is returned as undeliverable; or (iv) the submission or person/entity is disqualified for any other reason.

## 3.3. Teams and Single-Entity Awards

The Prize Administrator will award a single dollar amount to the designated primary submitter (team leader) whether a team consists of a single entity or multiple entities. The primary submitter is solely responsible for allocating any prize funds among member competitors as they deem appropriate. The Prize Administrator will not arbitrate, intervene, advise on, or resolve any matters between team members.

## 3.4. Submission Rights

By submitting materials for the Stage 2 contest and consenting to the rules of the CABLE Conductor Manufacturing Prize, each competitor is granting a Creative Commons Attribution 4.0 International License (see <https://creativecommons.org/licenses/by/4.0/>) to the U.S. Government, the Prize Administrator, and any other third party supporting the contest for the U.S. Government or the Prize Administrator in the submission components intended to be public pursuant to the requirements and rules of the contest, including, but not limited to, the video submission, summary slide, and cover page.

To the extent not already provided for in the above Creative Commons License, each competitor is granting to the U.S. Government, the Prize Administrator, and any other third party supporting the prize for the U.S. Government or the Prize Administrator, a license to display publicly and use the submission components package that are intended to be public pursuant to the requirements and rules of the prize. This license includes posting or linking to the public portions of the submission on the Prize Administrator websites, including the contest website, DOE websites, and partner websites, and the inclusion of the submission in any other media worldwide.

Each competitor acknowledges and agrees that the entire submission package and any other information provided by the competitor for the prize may be viewed by the U.S. Government, the Prize Administrator, any other third party supporting the contest for the U.S. Government or the Prize Administrator, and the reviewers for purposes of the contests, including, but not limited to, evaluation purposes. The Prize Administrator and any third parties acting on its behalf will also have the right to publicize indefinitely a competitor's name and, as applicable, the names of the competitor's team members and organization on the prize website.

As appropriate and to further the goals of this prize competition, DOE may request a competitor's written consent to use intellectual property (IP) (e.g., inventions) developed by a competitor in this prize competition, if any. The prize rules for Stage 2 will provide further guidance on any rights the government will seek in such competitor IP to advance the goals of the competition, such as a license to use the IP for government purposes.

By entering, a competitor represents and warrants that:

- 1) Competitor's entire submission is an original work by the competitor and the competitor has not included third-party content (such as writing; text; graphics; artwork; logos; photographs; dialogue from plays; likeness of any third party; musical recordings; or clips of videos, television programs, or motion pictures) in or in connection with the submission, unless (i) otherwise requested by the Prize Administrator and/or disclosed by competitor in the submission and (ii) competitor has either obtained the rights to use such third-party content or the content of the submission is considered in the public domain without any limitations on use.

- 2) Unless otherwise disclosed in the submission, the use thereof by Prize Administrator, or the exercise by Prize Administrator of any of the rights granted by competitor under these rules, does not and will not infringe or violate any rights of any third party or entity, including, without limitation, patent, copyright, trademark, trade secret, defamation, privacy, publicity, false light, misappropriation, intentional or negligent infliction of emotional distress, confidentiality, or any contractual or other rights.
- 3) All persons who were engaged by the competitor to work on the submission or who appear in the submission in any manner have:
  - a) Given competitor their express written consent to submit the submission for exhibition and other exploitation in any manner and in any and all media, whether now existing or hereafter discovered, throughout the world.
  - b) Provided written permission to include their name, image, or pictures in or with the submission; competitor may be asked by Prize Administrator to provide permission in writing.
  - c) Not been and are not currently under any union or guild agreement that results in any ongoing obligations resulting from the use, exhibition, or other exploitation of the submission.

## 3.5. Copyright

Each competitor represents and warrants that: the competitor is the sole author and copyright owner of the submission; the submission is an original work of the competitor or that the competitor has acquired sufficient rights to use and to authorize others, including the Prize Administrator, to use the submission, as specified throughout the rules; the submission does not infringe upon any copyright or upon any other third-party rights of which the competitor is aware, or should be aware; and the submission is free of malware.

## 3.6. Contest Subject to Applicable Law

All contests are subject to all applicable federal laws and regulations. Participation constitutes each competitor's full and unconditional agreement to these Official Contest Rules and administrative decisions, which are final and binding in all matters related to the contest. This notice is not an obligation of funds; the final awards are contingent upon the availability of appropriations.

## 3.7. Resolution of Disputes

DOE is solely responsible for administrative decisions, which are final and binding in all matters related to the contest.

Neither DOE nor the Prize Administrator will arbitrate, intervene, advise on, or resolve any matters between team members or among competitors.

### 3.8. Publicity

The winners of these prizes (collectively, “winners”) will be featured on the DOE and Prize Administrator websites.

Except where prohibited, participation in the contest constitutes each winner’s consent to DOE’s and its agents’ use of each winner’s name, likeness, photograph, voice, opinions, and/or hometown and state information for promotional purposes through any form of media worldwide, without further permission, payment, or consideration.

### 3.9. Liability Considerations

Upon registration, all competitors agree to assume any and all risks of injury or loss in connection with or in any way arising from participation in this contest. Upon registration, except in the case of willful misconduct, all competitors agree to and, thereby, do waive and release any and all claims or causes of action against the federal government and its officers, employees, and agents for any and all injury and damage of any nature whatsoever (whether existing or thereafter arising, whether direct, indirect, or consequential, and whether foreseeable or not), arising from their participation in the contest, whether the claim or cause of action arises under contract or tort.

In accordance with the delegation of authority to run this contest delegated to the director of AMO, the director has determined that no liability insurance naming DOE as an insured will be required of competitors to compete in this competition per 15 USC 3719(i)(2). Competitors should assess the risks associated with their proposed activities and adequately insure themselves against possible losses.

### 3.10. Records Retention and Freedom of Information Act

All submission package components and any other materials submitted for the prize will likely be considered DOE records and subject to the Freedom of Information Act. The following applies only to components of the submission package not intended to be public according to the prize requirements and rules. If a submission includes trade secrets or information that is commercial or financial, or information that is confidential or privileged, it is furnished to the Government in confidence with the understanding that the information shall be used or disclosed only for evaluation purposes. Such information will be withheld from public disclosure to the extent permitted by law, including the Freedom of Information Act. Without assuming any liability for inadvertent disclosure, DOE will seek to limit

disclosure of such information to its employees and to outside reviewers when necessary for review of the submission package or as otherwise authorized by law. This restriction does not limit the Government's right to use the information if it is obtained from another source.

Confidential, proprietary, or privileged information in a nonpublic submission package component must be marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information and may use or disclose such information for any purpose.

The submission must be marked as follows and identify the specific pages containing trade secrets or confidential, proprietary, or privileged information:

Notice of Restriction on Disclosure and Use of Data:

Pages [list applicable pages] of this document may contain trade secret, confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for evaluation purposes. [End of Notice]

The header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Trade Secret, Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure." In addition, each line or paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets.

Competitors will be notified of any Freedom of Information Act requests for their submissions in accordance with 29 C.F.R. § 70.26. Competitors may then have the opportunity to review materials and work with a FOIA representative prior to the release of materials.

## 3.11. Privacy Considerations

If competitors choose to provide HeroX with personal information by registering or completing the submission package through the contest website, they understand that such information will be transmitted to DOE and may be kept in a system of records. Such information will be used only to respond to them in matters regarding their submission and/or the contest unless they choose to receive updates or notifications about other contests or programs from DOE on an opt-in basis. DOE and NREL are not collecting any information for commercial marketing.

## 3.12. General Conditions

DOE reserves the right to cancel, suspend, and/or modify the contest, or any part of it, at any time. If any fraud, technical failures, or any other factor beyond DOE's reasonable control impairs the integrity or

proper functioning of the contests, as determined by DOE in its sole discretion, DOE may cancel the contest.

Although DOE may indicate that it will select up to several quarterfinalists, semifinalists, finalists, and winners for each contest, DOE reserves the right to only select competitors that are likely to achieve the goals of the program. If, in DOE's determination, no competitors are likely to achieve the goals of the program, DOE will select no competitors to be quarterfinalists, semifinalists, finalists, or winners and will award no prize money.

ALL DECISIONS BY DOE ARE FINAL AND BINDING IN ALL MATTERS RELATED TO THE CONTEST.

### 3.13. Program Policy Factors

Although the scores of the Expert Reviewers will be carefully considered, it is the role of the Prize Administrator and DOE to maximize the impact of contest funds. Some factors outside the control of competitors and beyond the independent Expert Reviewer scope may need to be considered to accomplish this goal. The following is a list of such factors. In addition to the reviewers' scores, the following program policy factors may be considered in determining prize winners:

- The extent to which the submission intended application(s) reduce climate change impacts
- The inclusion of Minority Serving Institutions, Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, or entities located in a disadvantaged community that meet the eligibility requirements (refer to Section 2.9. [Competitor Eligibility])
- Representation of diverse types and sizes of competitor organizations
- Geographic diversity and potential economic impact of projects
- Whether the use of additional DOE funds and provided resources are nonduplicative and compatible with the stated goals of this program and the DOE mission generally
- The degree to which the submission exhibits technological or programmatic diversity compared to the existing DOE project portfolio and other competitors
- The level of industry involvement and demonstrated ability to accelerate commercialization and overcome key market barriers
- The degree to which the submission is likely to lead to increased employment and manufacturing in the United States or provide other economic benefit to U.S. taxpayers
- The degree to which the activities described in the submission have been or will be performed in the United States
- The degree to which the submission will accelerate transformational technological, financial, or workforce advances in areas that industry by itself is not likely to undertake because of technical or financial uncertainty



- The degree to which the submission supports complementary DOE-funded efforts or projects that, when taken together, will best achieve the goals and objectives of DOE
- The degree to which the submission expands DOE’s funding to new competitors and recipients who have not been supported by DOE in the past
- The degree to which the submission enables new and expanding market segments
- Whether the project promotes increased coordination with nongovernmental entities for the demonstration of technologies and research applications to facilitate technology transfer
- Whether submission content sufficiently confirms the competitor’s intent to commercialize technology.

### 3.14. National Environmental Policy Act (NEPA) Compliance

DOE’s administration of the CABLE Conductor Manufacturing Prize is subject to National Environmental Policy Act (NEPA) compliance (42 USC 4321, et seq.). NEPA requires federal agencies to integrate environmental values into their decision-making processes by considering the potential environmental impacts of their proposed actions. For additional background on NEPA, please see DOE’s NEPA website at <http://nepa.energy.gov/>.

Although NEPA compliance is a federal agency, responsibility and the ultimate decisions remain with the federal agency, all competitors in the Stage 2 contest will be required to assist in the timely and effective completion of the NEPA process in the manner most pertinent to their participation in the prize competition. Competitors may be asked to provide DOE with information on fabrication and testing of their device such that DOE can conduct a meaningful evaluation of the potential environmental impacts.

### 3.15. Return of Funds

As a condition of receiving a prize, competitors agree that if the prize was made based on fraudulent or inaccurate information provided by the competitor to DOE, DOE has the right to demand that any prize funds or the value of other noncash prizes be returned to the government.

### 3.16. Request To Waive the “Domestic Ownership and Control” Eligibility Requirement

If an entity seeking to compete as the registered competitor does not have domestic ownership and control, the entity should include a waiver request that addresses the following waiver criteria and content requirements along with their submission. EERE may consider issuing a waiver of that eligibility requirement where the entity submits a compelling justification; the entity is incorporated in and

maintains a primary place of business in the United States; and the entity otherwise meets the eligibility criteria. There are no rights to appeal EERE's decision on the waiver request.

**Waiver criteria:** Entities seeking a waiver must demonstrate to the satisfaction of EERE that its participation: (1) has a high likelihood of furthering the objectives of this prize competition and (2) aligns with the best interest of the U.S. industry and U.S. economic development.

**Content for waiver request:** A waiver request must include the following information:

0. Entity's name and place of incorporation
1. The location of the entity's primary place of business
2. A statement describing the extent the entity is owned or controlled by a foreign government, agency, firm, corporation, or person who is not a citizen or permanent resident of the United States, including the applicable percentage of ownership/control
3. A compelling justification that addresses the waiver criteria stated above
4. A description of the project's anticipated contributions to the U.S. economy
5. A description of how the entity has benefited U.S. research, development, and manufacturing, including contributions to employment in the United States and growth in new U.S. markets and jobs
6. A description of how the entity has promoted domestic manufacturing of products and/or services.

Requests should be submitted through the HeroX portal.

## 3.17. Voucher Pairing System

The Prize Administrator coordinates with other DOE national laboratories and cultivates relationships with private facilities that are willing to work with competitors. Stage 2 Contest competitors include their planned use of voucher funds as part of the Stage 2 Contest submissions. Finalists of the Stage 2 Contest are then able to negotiate specifics with either their lab partner or private facility and quickly begin voucher work. The Prize Administrator assists in making connections, identifying relevant organizations and their expertise. Winners can choose where they spend their voucher funding but is limited to organizations that are part of the American-Made Network, or DOE national laboratories. In the case of a national laboratory, the funds are provided directly to the lab on behalf of the winner to conduct a mutually agreed upon scope of work between the lab and the winner. When vouchers are used at a non-national-laboratory facility, the winners are reimbursed after the voucher work is complete. Voucher funds

may not be redeemed for cash or transferred. See [CABLE Conductor Manufacturing Prize Voucher Guidelines](#) for more information.

## 3.18. Definitions

**Prize Administrator:** Prize Administrator means both the Alliance for Sustainable Energy LLC operating in its capacity under the Management and Operating Contract for the National Renewable Energy Laboratory (NREL), and the U.S. Department of Energy's Advanced Manufacturing Office (AMO). When the Prize Administrator is referenced in this document, it refers to staff from both the Alliance for Sustainable Energy LLC and AMO. Ultimate decision-making authority regarding contest matters rests with the director of AMO.

**Connector or Connector Organization:** Connector or Connector Organization means an entity that seeks to support the efforts of the competitors. These must be United States-based organizations that have the capacity to connect competitors to mentoring, business resources, manufacturing resources, or introduce them to possible sources of funding. This definition is intentionally broad so that many different types of entities are able to participate. Connectors earn recognition rewards based upon their support of the competitors. Further details can be found at: <https://americanmadechallenges.org/network.html>.

**Expert Reviewer:** Expert Reviewer means the panel of DOE and industry subject matter experts who are responsible for scoring submission materials and providing feedback to help inform the final winner determination by the Prize Judge.

**Prize Judge:** Prize Judge means the DOE AMO selection official who will make the final determination of winners for the CABLE Conductor Manufacturing Prize. The judge will take the competitor's scores, sample test results any interview findings, and the Expert Reviewer's feedback into account when making final winner selections.

**Voucher Funding:** Vouchers are part of the prizes for the Stage 2 Contest. In the case of a national laboratory, the funds are provided directly to the lab on behalf of the winner to conduct a mutually agreed upon scope of work between the lab and the winner. When vouchers are used at a non-national laboratory facility, the winners are reimbursed after the voucher work is complete. Further details about the voucher process are provided on the CABLE Conductor Manufacturing Prize website.

## 3.19. Return of Funds

As a condition of receiving a prize, competitors agree that if the prize was awarded based on fraudulent or inaccurate information provided by the competitor to DOE, DOE has the right to demand that any prize funds or the value of other non-cash prizes be returned to the government.

# Appendix A. Updated Electrical Conductivity Table

To enable comparisons among enhanced conductivity materials, these values are required to be used as a standard reference when completing the calculations required for Stage 2 submission.

**Table 13. Electrical Conductivity and Densities of Common Conductors**

Material	Conductivity (megasiemens per meter [MS/m])	International Annealed Copper Standard (IACS) %	Density (kilogram per cubic meter [kg/m <sup>3</sup> ])
Silver	62.9	108%	10,490
Copper (Electrical)	58.6	101%	8,960
Copper (International Annealed Copper Standard) =100% IACS	58.1	100%	8,960
Gold	40.6	70%	19,320
Aluminum	37.7	65%	<b>2,710</b>
Al 1350	35.8	62%	<b>2,705</b>
Calcium	29.8	51%	<b>1,550</b>
Al 6061	24.6	42%	<b>2,700</b>
Magnesium	22.4	39%	<b>1,738</b>
Tungsten	17.9	31%	19,280
Zinc	16.9	29%	7,130
Brass, Yellow	15.7	27%	8,470
Nickel	14.3	25%	8,902
Lithium	10.8	19%	<b>534</b>
Carbon Nanotubes (CNT)	10.9	19%	<b>1,300</b>
Iron	10.4	18%	7,874
Carbon Fiber	$1.06 \times 10^{-4}$	0.0002%	<b>1,750</b>

## Section 1. Superconductor Room-Temperature Equivalent Conductivity

For superconductors with a discernable critical current density  $J_c$  or engineering critical current  $J_e$  the room-temperature-equivalent conductivity (RTEC, in units of MS/m) calculation is used to enable comparison of a superconductor with a general purpose non-superconducting conductor in Contest 1: (Beat Copper!) and is found using the following relation:

$$RTEC = 70 + (26 \times (1 - f)) - (\Delta T / 11.1) \quad (A.1)$$

where  $f$  is the manufacturing cost 10 years post-commercialization of the superconductor (do *not* include relative cooling costs for high-temperature superconductors versus copper, as cooling already is penalized with the  $T_c$  factor) in \$/kA m divided by \$50/kA m, and

$$\Delta T = 295.15 - T_c \quad (\text{A.2})$$

where  $T_c$  is the superconductor's critical temperature in Kelvin.

For example, for REBaCuO where  $f = 50\%$  and  $T_c = 90 \text{ K}$ :

$$RETC = 70 + (26 \times (1 - 0.5)) - ((295.15 - 90) / 11) = 63 \text{ MS/m} \quad (\text{A.3})$$

# Appendix B. Testing Data Checklist: Sending Samples for Testing

Using the following checklist for sending samples for testing, competitors should:

- ☐ Confirm each of the three samples meets the following parameters:

Non-superconductors:

- ☐ Minimum 6 inches long (longer is preferred, up to 12 inches), with a cross sectional area of at least 0.0044 square inches (equivalent to .075 inches in circular diameter) or square dimensions of at least 0.0664 inches long on each side (2.85 square millimeters with a diameter of 0.95 millimeters or square sides of at least 1.69 millimeters in length)
- ☐ Uniform cross section, where the cross-sectional area may not vary more than  $\pm 2\%$  along the length
- ☐ Minimum electrical resistance of 20 microohms ( $\mu\Omega$ )

Superconductors:

- ☐ Round or square sample where one face is 5 mm<sup>2</sup> or less in area
- ☐ Include three samples
- ☐ If possible, affix the samples to the sample container so that they do not move in transit. Tightly seal the sample container(s)
- ☐ Address the package to NTS or Argonne National Laboratory's address
- ☐ Send the package and *do* purchase tracking on the package
- ☐ Email [cableprize@nrel.gov](mailto:cableprize@nrel.gov) and testing laboratory with the estimated arrival date, tracking number, and return shipping information which will serve as confirmation that samples have been submitted.

# Appendix C. Quantitative Sample Data

## Commercialization Estimate Input Template

**Purpose:** This checklist and template are designed to ensure CABLE Conductor Manufacturing Prize competitors provide comprehensive and comparable commercialization forecasts and sample data to enable the Prize Administrator and Expert Reviewers to make fair comparisons among competitors for Stage 2 of the contest and to prepare them for Stage 3, which will ask for a much more detailed commercialization plan and forecasts. The CABLE Conductor Manufacturing Prize Administrator will use the data provided in this template by competitors to calculate metrics for the scorecard in Appendix D.

**Instructions:** Competitors are *required* to use the Appendix C template for their responses. Responses in Appendix C should all be quantitative; any narrative descriptions of numbers provided should be included in the Technical Narrative. An [editable version of the template](#) can be found on the CABLE Conductor Manufacturing Prize HeroX page.

**Checklist:** Competitors should ensure they have provided inputs for each of the sections in this template:

Section 1:

- ☐ Commercialization application statements (1A, 1B, 1C)

Section 2:

Table 14

- ☐ materials data
- ☐ Table 15, energy data
- ☐ Table 16, nonmaterial/nonenergy costs

Section 3:

- ☐ Selection of goal metric input questions (questions 1–7, as applicable)
- ☐ Table 17, material density
- ☐ Sample preparation data
- ☐ Superconductor critical current density or engineering critical current at 77 Kelvin (or 4K if  $T_c < 77K$ ) if applicable

Competitors should complete all required questions and tables using the Appendix C template provided. Competitors may augment Appendix C with additional spreadsheets to show their work and calculations if needed. Please note that all qualitative information and analysis related to the data in Appendix C should be included in the Technical Narrative only.

# Section 1. Commercialization/Application Statements

**Instructions:** A competitor's summary commercialization statement assumes that unlike the sample preparation costs documented in Section 2, their net costs (which determine their likely commercialization success) will benefit from economies of scale, learning by doing, and other process innovations at the industrial scale that the competitor reaches when they begin their first 10 years of commercialization.

**Competitors should complete the following statements (1A, 1B, and 1C):**

**Statement 1A:** (COMPANY NAME HERE) estimates that during the first 10 years of commercialization of (MATERIAL NAME HERE), cumulative sales revenues would be \$\_\_\_\_\_ and cumulative licensing revenues would be \$\_\_\_\_\_.

**Statement 1B:** (COMPANY NAME HERE) estimates that after the first 10 years of commercialization of (MATERIAL NAME HERE), annual materials production would be \_\_\_\_\_ kilograms (kg).

**Statement 1C:** (MATERIAL NAME HERE) is intended for application in the following categories (check all that apply):

- ☐ High-conductivity, high-strength, moderate-cost applications such as motor windings
- ☐ Moderate-conductivity, moderate-cost, low-weight, high-strength applications such as overhead power lines
- ☐ Ultra-high-conductivity, ultra-low-weight applications such as electric aviation
- ☐ High-corrosion-resistance, high-conductivity, moderate-cost applications such as undersea or underground power lines
- ☐ Highest conductivity applications where cost is not a factor such as premium electronics
- ☐ OTHER (provide example applications and properties that are maximized, moderate, or not a factor).



## Section 2. Sample Preparation Data

**Instructions:** Competitors should complete the three tables below and include any and all assumptions and calculations and/or references, supporting data, and literature. These can include schematics, drawings, or sketches.

**Table 14. Materials Data: Template for Type and Amount of Material for Sample Preparation**

Material	Element	Amount (Grams)	Notes: (e.g. If element is Carbon, Indicate Nano-Allotrope (e.g. Graphene, CNT etc.)
A: Primary material:			(Appendix A must be used for primary material)
B: Secondary material (if applicable):			
C: Other materials (if applicable (add rows for D, E, F, etc. if needed):			
TOTAL	Formula or nickname:		

**Table 15. Energy Data**

Description	Input
Electricity source (grid or type of on-site generation or % of each)	
Total electricity used (kilowatt-hours [kWh])	
Other energy used (British Thermal Units [BTU]) (add rows if necessary)	

For comparison purposes, the Prize Administrator will use the same material cost data (e.g., \$15/kg for electrolytic copper (including cost for materials and manufacturing), \$13/kg for aluminum, and energy cost data (e.g., \$0.10/kWh) to compare and contrast the Commercialization Plans of different competitors on an equivalent basis.

**Table 16. Actual Sample Preparation Nonmaterial/Nonenergy Costs (Fraction of Capital and Operating Costs; for Equipment/Hardware Cost (Including Everything Above ~5%)**

Equipment/Hardware Costing (Process and Non-process)	First Cost of Equipment	Expected Equipment Lifetime	Time (Fraction) Used for Sample Preparation
Equipment 1			
Equipment 2			
Equipment 3			
Equipment 4			

## Section 3. Goal Metric Inputs

**Instructions:** Unlike the other inputs in this template, these inputs are used for the testing-based scoring of the competition. A competitor should answer each applicable question as directed.

All competitors should answer:

- 1) What class of conductor are you entering into the competition (select only one)?
  - a. Metal non-superconductor—go to question (2)
  - b. Nonmetal, non-superconductor—go to question (2)
  - c. Superconductor—go to question (5).
- 2) What Table 1 Contest are you competing in:
  - a. Competing only in Contest 1 (Beat Copper!)—you are done.
  - b. Competing in Contest 2 (Beat Aluminum!)—go to question (3).
  - c. Competing in Contest 3 (Beat a Conductor System!)—go to question (4).

If competing in Contest 2: Beat Aluminum!

- 3) What is your sample density \_\_\_\_\_ kilograms per cubic meter ( $\text{kg/m}^3$ )? (It is recommended you cross-check your density using densities in Table 17 and Equation (2) or equivalent.) After answering this question and filling in Table 17, you are done with this template.

Question 3.3 and 3.4 (density check). Note: Please ensure that you fill in Table 17, the cells for A, B, C, etc. for the same elements you provided in Table 14 so that the Prize Administrator can calculate %A, %B, %C, etc. from the weights in Table 15 divided by the total weight in the last row of Table 14. To cross-check your sample density, the Prize Administrator will use Equation (C1)—rule of mixtures weighted mean—to calculate the density to be used for calculation of conductivity by density of your sample. The testing lab also will provide density and weight information.

If competing in Contest 3: Beat a Conductor System!

- 4) What is the:
  - a) Baseline conductivity of your commercial system \_\_\_\_ megasiemens per meter ( $\text{MS/m}$ )
  - b) Sample density \_\_\_\_\_  $\text{kg/m}^3$  (Please complete Table 17 below)
  - c) Other properties (e.g., strength) that are key for this commercial system
  - d) Commercial system's current world market size \*\*B/[indicate data year]
  - e) CAGR for your commercial system between 2025 and 2035 (to any year within this range)

(Note: The information in

Figure 2 is an example of how to answer 4a–d.)

For superconductor submissions only:

- 5) What is the manufacturing cost and weight for a 100-m-long, 10,000-A cable that delivers 50 megawatts (MW) of power at 65 K?
- 6) What are the inputs for room-temperature-equivalent conductivity (RTEC): Specifically,  $f$  = ratio of the 10-year-post-commercialization manufacturing cost of the superconductor in \$ per kiloampere (kA) m versus that of copper = \$50/kA m, and  $T_c$ ?
- 7) What is the value of RTEC (in MS/m)? (No need to fill in further data.)

**Table 17. Weight Percentage and Density Data for Sample (To Be Used in Equation C.1)**

Element (same as Table 14)	% <sup>a</sup>	Density
A:		Primary material must use density data from Appendix A
B:		
C:		
Sample density cross-check (to be calculated by the Prize Administrator)		

<sup>a</sup> Must be calculated from corresponding element row A, B, C weight divided by total sample weight (last row) in Table 14

## Equations

$$\text{Sample density} = (\text{density A} \times \%A) + (\text{density B} \times \%B) + (\text{density C} \times \%C) \quad (\text{C.1})$$

**Section 3 (questions 3.5–3.7) Instructions:** For superconductors, in addition to filling out Table 14–Table 16, The requested values for  $f$ ,  $T_c$  need to be calculated for question 3.6 at the beginning of this section. Also, a competitor should calculate and fill in the RTEC value in question 3.7 using Equation C.2:

$$\text{RTEC} = 70 + (26 \times (1 - f)) - (\Delta T / 11.1) \quad (\text{C.2})$$

where  $f$  is the ratio of the 10-year post commercialization manufacturing cost of the superconductor (in \$/kA.m) to that for copper (\$50/kA.m)

# Appendix D. Sample Testing Data and Calculations Scorecard

Expert Reviewers will be provided the testing data solely for the purpose of assessing the extent to which the scientific and manufacturing explanations of the entries they are scoring are credible. Points scored based on testing and sample preparation data will be assessed by the Prize Administrator based on a ranking curve so that the competitor with the highest overall conductivity (above the minimum) gets the maximum score for that Table 1 goal. Refer to Section 2.6. for more information.

**Table 18. Sample Scorecard**

Sample Testing Data and Calculations Scorecard (To be filled in and used by Prize Administrator to rank/score submissions)	
<b>Testing-Vendor-Provided Data</b>	
<p>For non-superconductors, the testing data will be the:</p> <ul style="list-style-type: none"> <li>Average value of conductivity <math>\pm</math> delta for highest and lowest.</li> </ul>	<p>For superconductors, the testing data will be the:</p> <ul style="list-style-type: none"> <li>Average value of critical temperature, <math>T_c</math>, <math>\pm</math> delta for highest and lowest</li> <li>Average value of critical current density <math>J_c</math>, <math>\pm</math> delta for highest and lowest at 77 K. Samples with a <math>T_c</math> below 77K will be tested for engineering critical current density <math>J_e</math> instead.</li> </ul>
<b>Prize-Administrator-Calculated Values</b>	
<ul style="list-style-type: none"> <li>There will be no calculated values for Goal 1.</li> <li>For Goals 2 &amp; 3, sample density will be calculated as a cross-check of the density submitted by competitor using density baseline from Appendix A and Equation (A.1)</li> </ul>	<ul style="list-style-type: none"> <li><math>f</math> is the ratio of the 10-year post commercialization manufacturing cost of the superconductor (in \$/kA.m) to that for copper (\$50/kA.m)</li> <li>RTEC = ____MS/m based on <math>f</math>, <math>T_c</math>, and Appendix C Equation (C.2) for superconductors. Note: critical current density <math>J_c</math> or engineering critical current density must be measurable. NOTE since that RTEC cannot be calculated without written application input on costs, Superconductors only need to have discernable critical current in testing to qualify for contest.</li> </ul>
<b>Prize-Administrator-Ranked Values</b>	
<ul style="list-style-type: none"> <li>Ranking of all materials will be done by conductivity (or RTEC).</li> <li>Either separate rankings by secondary goals or development of equations for “equivalent” conductivity for secondary goals will be depending on entries received.</li> </ul>	

# Appendix E. Stage 2 Request for Information

**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 **\$4.8 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<sup>2</sup>/kg conductivity by density.<sup>18</sup> 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

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<sup>18</sup> MS is 10<sup>6</sup> Siemens, kS is 10<sup>3</sup> Siemens, m is meters, m<sup>2</sup> is square meters, and kg is kilogram

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.

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 ( $T_c$ ), 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  $T_c$  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 quantitatively 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  $T_c$  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.

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

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

and

$\Delta T = 295.15 - T_c$ , where  $T_c$  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  $T_c$ . 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<sup>19</sup>?
- 2) Should something other than  $T_c$  be measured for superconductors? For example, is magnetization a better or additional measure than  $T_c$  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  $T_c$  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.

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<sup>19</sup> kA is  $10^3$  Amperes of electrical current,

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.

For superconductors:

By definition, below their critical temperature ( $T_c$ ), 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,  $T_c$ , 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<sup>2</sup>/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  $T_c$ ?
  - b. Is it fair and reasonable to include a linear cooling penalty that is proportional to the difference between  $T_c$  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,  $T_c$ -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 ( $20\ \mu\Omega$  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  $T_c$  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?



U.S. DEPARTMENT OF ENERGY