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Renewable Energy - Renewable Chemicals - BioBased Products - Alternative Fuels - Advanced Technologies

Federal Funding Opportunities for Each of the Nine Technology Readiness Levels (TRLs)

By CJ Evans, Managing Director, American Diversified Enterprises LLC

Many promising ideas, concepts, and innovations that could improve, add to, and make game-changing breakthroughs in energy, sustainability, and the bioeconomy – and create new jobs, bring economic growth to U.S. communities, and catapult the U.S. into a global lead in innovation – wind up languishing, losing steam, and ultimately falling silent, never to be heard from again, for one simple reason: *lack of sufficient capital*.

At whatever point on the path to commercialization that a bioenergy or bioeconomy project might be, federal funding, grants, and incentives are available ... at least, for those who know where to look and how to meet the requirements.

A significant element of seeking out and receiving financial support is recognizing at what stage the project is, identifying likely funding sources, and meeting the requirements necessary to apply for and receive that money.

The Technology Readiness Level (TRL) scale is a method for ascertaining the technology maturity of an idea, concept, or innovation. It uses a scale of 1 to 9 with 9 being the most mature technology. (There also is a similar scale to measure each Manufacturing Readiness Level, or MRL.)

TRLs and MRLs are used by multiple entities – including federal agencies such as the departments of energy and defense and the National Aeronautics and Space Administration (NASA) and Federal Aviation Agency (FAA), the oil and gas and biomedical industries, the European Union, the European Space Agency, and research and development agencies, among others.

The use of these scales enables different agencies, industries, and disciplines – including scientists, researchers, analysts, and innovators from different fields of endeavor – to have consistent, uniform discussions of the technical maturity, capabilities, and steps necessary to move an idea, concept, or innovation to the next level of development, and toward full realization.

With this information it is possible to define the funding needs for each level of development and to match it up with a list of funding opportunities targeted to that development level that are available from the private sector and federal government. This article focuses on federal funding opportunities for the nine TRL levels.

While the definitions for TRLs are consistent across all entities, different industries, agencies, and disciplines include additional elements in their definitions to address specific needs consistent with their missions.

The definitions used in the following table incorporate as many of these elements as possible. They also include a set of more finely tuned and targeted definitions developed by DWH Processing Consultant and Lee Enterprises Consulting (LEC) allied member Dave Humbird that list the marketing and business development materials that need to be prepared along with the necessary technical data to progress from one TRL level to the next.



Technology Readiness Levels (TRLs)	Federal Funding Opportunities
<p>Start</p> <p>UNPROVEN IDEA, PROPOSAL, PAPER CONCEPT</p> <p>No analysis or testing has been performed.</p>	<p>Preparation of application for TRL-1 funding:</p> <ul style="list-style-type: none">• Describe idea, concept, approach• Explain significance of your idea, concept, approach• Identify societal, environmental, or economic need that will be addressed• Lay out proposed research plan, objectives, methods, tasks, controls, and feasibility, risk, and solution measures• Assemble research team• Identify milestones and go/no-go criteria• Describe alternatives if primary approach does not work out <p>This will be your core proposal, which should be adjusted, amplified, and updated at the conclusion of each TRL.</p>

THE FIRST STEP: Basic Research

TRL-1

SCIENTIFIC RESEARCH IS INITIATED

beginning the translation to applied research and development (R&D). [Basic principles are observed and reported](#). The concept and its basic functionality are demonstrated through analysis, testing, and reference to features shared with existing systems / technologies. First-principles modeling and simulation may complement physical experiments.

SUCCESSFUL COMPLETION: when it is shown that the proposed technology, concept, process, or approach is likely to meet objectives with additional testing.

Federal funding opportunities:

- **NATIONAL SCIENCE FOUNDATION (NSF)**
The NSF provides financial support in a wide range of scientific areas, from astronomy to zoology. In addition to funding research in the traditional academic areas, the agency also supports “high risk, high pay off” ideas, novel collaborations, and projects that may seem like science fiction today but may be commonplace tomorrow. With an annual budget of \$11.5 billion, NSF makes about 12,000 new grant awards each year, providing support for all fields of fundamental science and engineering, including energy innovation and energy efficiency.
- **U.S. DEPARTMENT OF AGRICULTURE (USDA)**
 - **National Institute of Food and Agriculture (NIFA)**
NIFA supports research, educational, and extension efforts in a wide range of scientific fields related to agricultural and behavioral sciences. This includes:
 - **Advanced Technologies:** bioenergy, biotechnology, nanotechnology
 - **Animals:** animal breeding, animal health, animal production, aquaculture
 - **Business and Economics:** markets and trade, natural resource economics, small business, StrikeForce
 - **Education:** learning and engagement, minority serving institutions, workforce development
 - **Environment:** climate change, ecosystems, invasive pests and diseases



Technology Readiness Levels (TRLs)

TRL-1

continued

Must Do:

- Expand section in core proposal on societal, environmental, or economic need that will be addressed: identify relevant market, target customers, customer needs, direct and indirect competitors, competitive advantages.
- Outline commercialization plan.
- Develop “elevator speech” and “pitch deck” to summarize key concepts / TRL-1 results for potential investors / funders.
- Prepare peer-reviewed paper, if appropriate.
- Begin preparing business plan.



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Federal Funding Opportunities (continued)

- **Farming and Ranching:** agricultural safety, agricultural technology, farmer education, organic agriculture, small and family farms, sustainable agriculture
 - **Food Science:** food quality, food safety **International:** global food security
 - **Natural Resources:** air, forests, grasslands and rangelands, soil, water
 - **Plants:** crop production, pest management, plant breeding, plant health
- **U.S. DEPARTMENT OF DEFENSE (DOD)**

More than 1,000 grant opportunities are offered each year by the DOD through its various branches of service, medical units, laboratories, research projects, engineering divisions, environmental cleanup and restoration programs, business and inventory management divisions, and energy security initiatives. These include:

 - **Defense Advanced Research Projects (DARPA)**

DARPA’s mission is “to make pivotal investments in breakthrough technologies and capabilities for national security.” DARPA has repeatedly delivered on that mission, transforming revolutionary concepts and even seeming impossibilities into practical capabilities. The results have included not only game-changing military capabilities such as precision weapons and stealth technology, but also such icons of modern civilian society such as the Internet, automated voice recognition and language translation, and Global Positioning System receivers small enough to embed in myriad consumer devices.

DARPA explicitly reaches for transformational change instead of incremental advances. It is looking for promising technologies within science and engineering research communities. These new designs and technologies have to radically improve military capabilities, offering “strategies to surprise our adversaries,” with payoffs for non-military uses afterwards (such as the computer, ceramic bearings, and insulators). The DARPA investment has to fundamentally reshape existing fields or create entirely new disciplines and transform these initiatives into profoundly new, game-changing technologies for U.S. national security and the commercial and private sectors



Technology Readiness Levels (TRLs)

TRL-1 continued



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Federal Funding Opportunities (continued)

- **Other DOD grant opportunities**

While DARPA focuses exclusively on transformational and disruptive innovations, there are many other opportunities to propose new ideas, concepts, and approaches to the DOD. The primary criterion the DOD uses in assessing a proposal is: will its development result in a procurement contract from DOD? In other words, once it reaches TRL-9 and is ready for commercialization, will it improve the DOD's ability to carry out its mission through better technologies, systems, or operational readiness? If so, will DOD buy it? If not, you need to look elsewhere for grants.

*DOD has set a goal to reduce petroleum use throughout all branches of the military and increase its use of alternative energy sources for all power and fuel consumed by 50 percent within the next five years. **Any innovation – at any TRL – that will help DOD meet this goal will be of interest to DOD.***

- **U.S. DEPARTMENT OF ENERGY (DOE)**

- **Advanced Research Program Agency – Energy (ARPA-E)**

Since 2009, ARPA-E has provided approximately \$1.8 billion in R&D funding for more than 660 potentially transformational energy technology projects. ARPA-E funds technology-focused, applied research and development aimed at creating real-world solutions to important problems in energy creation, distribution, and use. ARPA-E issues periodic Funding Opportunity Announcements (FOAs), which are focused on overcoming specific technical barriers around a specific energy area. ARPA-E also issues periodic OPEN FOAs to identify high-potential projects that address the full range of energy-related technologies, as well as funding solicitations aimed at supporting America's small business innovators.

- **Office of Science (OS)**

The Office of Science is the basic scientific research arm of the Department of Energy. It issues a cross-cutting, open solicitation annually that is open year-round. It also issues several FOAs each year focusing on specific research needs that are open to one or more institutions, as well as DOE National Laboratory Announcements that are open only to DOE laboratories.



Technology Readiness Levels (TRLs)

Federal Funding Opportunities (continued)

NEXT: Basic Research (continued) / Research to Prove Viability

TRL-2

Invention begins

The application, utilization, and operation of the technology, concept, process, or approach is formulated. Design and novel features are validated through model or small-scale testing in a laboratory environment. Technical and business potential are confirmed.

Successful Completion:

when it is shown that the proposed technology, concept, process, or approach can meet specified acceptance criteria with additional testing.

Must-Do:

- Update core proposal, along with feasibility, risk and solution measures, based on TRL-2 results.
- Prepare value proposition.
- Expand economic and market analysis: conduct market study to flesh out details on target customers, customer needs, competitors, and competitive advantages.
- Complete descriptions of company, management, proposed products and services, and market analysis sections of business plan.
- Refine “elevator speech” and “pitch deck.”
- Assess intellectual property value of R&D in case the idea, concept, process, or approach is ultimately not ready for commercialization.

Federal funding opportunities:

- **NATIONAL SCIENCE FOUNDATION (NSF)**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF AGRICULTURE (USDA)**
 - **National Institute of Food and Agriculture (NIFA)**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF DEFENSE (DOD)**
See description of financial support under TRL-1 above
 - **Defense Advanced Research Projects (DARPA)**
See description of financial support under TRL-1 above
 - **Defense Innovation Unit Experimental (DIUx)**
DIUx is a Silicon-Valley based and inspired, fast-moving government entity that provides non-dilutive capital to companies to solve national defense problems. It can move from initial presentation to approval of a funding award in as little as 90 days. It seeks to contract with companies offering disruptive, game-changing solutions in a range of areas – from autonomy and artificial intelligence to human systems, information technology, and space – to solve a host of defense problems. View the PBS NewsHour special on DIUx that aired on August 15, 2018, at: <https://www.pbs.org/newshour/show/how-the-pentagon-joins-forces-with-silicon-valley-startups>.
 - **Other DOD grant opportunities**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF ENERGY (DOE)**
DOE funding for ideas, concepts, and approaches in the TRL-2, -3, and -4 stages of development typically come through the DOE’s SBIR/STTR program, which issue SBIR/STTR funding solicitations twice per year tied to specific areas of focus from its various offices, except for ARPA-E. (See the Phase I SBIR/STTR description below.) Each DOE office also issue periodic Funding Opportunity Announcements (FOAs) targeted to a wide range of TRLs for research, development, and demonstration in the fields of interest related to their missions. These include:
 - **Advanced Research Program Agency – Energy (ARPA-E)**
See description of financial support under TRL-1 above



Technology Readiness Levels (TRLs)

Federal Funding Opportunities (continued)

TRL-2 continued



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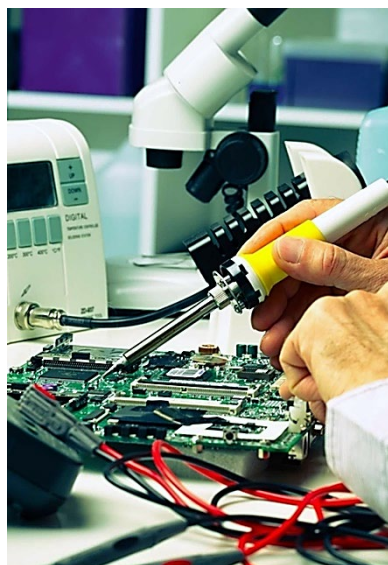
- **Office of Science (OS)**
See description of financial support under TRL-1 above
- **Office of Fossil Energy (FE)**
The Office of Fossil Energy is responsible for federal research, development, and demonstration efforts for advanced power generation, power plant efficiency, and carbon capture, utilization, and storage (CCUS) technologies. Its interests include transformational approaches, preliminary design and techno-economic analyses, and new methods for making products from fossil fuel byproducts, wastes, and emissions; reducing the environmental impacts of fossil fuel use; and improving the efficiency, reliability, and flexibility of existing fossil fuel systems and operations.
- **Office of Energy Delivery and Reliability (OE) and Office of Cybersecurity, Energy Security, and Emergency Response (CESER)**
The Office of Electricity (OE) leads the Department of Energy's efforts to ensure a resilient, reliable, and flexible electricity system. OE works to develop new technologies to improve the infrastructure that brings electricity into the nation's homes, offices, and factories. It also oversees the federal and state electricity policies and programs that shape electricity system planning and market operations. OE accomplishes its mission through research, partnerships, facilitation, modeling, and analytics. Funding interests include research, development, and demonstration of next generation transformers, distributed energy systems, flexible and adaptable designs for power generation and transmission systems, and grid security and resilience.
- **Office of Energy Efficiency and Renewable Energy (EERE)**
EERE's mission is to create and sustain American leadership in the transition to a global clean energy economy. It does this through several offices and programs, including:
 - **Bioenergy Technologies**
The Bioenergy Technologies Office (BETO) works to develop industrially relevant technologies to enable domestically produced biofuels and bioproducts.
 - **Efficiency**



Technology Readiness Levels (TRLs)

TRL-2

continued



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Federal Funding Opportunities (continued)

The goal of EERE's Energy Efficiency program is to work with researchers and industry partners to develop innovative, cost-effective, energy-saving solutions through better power production methods, advanced materials and manufacturing processes, commercial and consumer products, new homes, ways to improve older homes, and green building designs and materials which meet the internationally-used Leadership in Energy and Environmental Design (LEED) green building rating system.

- **Renewables**

EERE cooperates with a large network of researchers, universities, DOE national laboratories, and industry partners to develop, manufacture, and install cutting-edge,

high-tech renewable energy systems, with the goal of "catalyzing the transformation of the nation's energy system" to promote "U.S. leadership in science and engineering as a cornerstone of our economic prosperity."

- **Transportation**

Through its Vehicle, Bioenergy, and Fuel Cell Technologies Offices, EERE advances the development of next-generation technologies to make transportation cleaner and more efficient through advanced combustion engine and vehicle efficiency, innovative new transportation technologies, and solutions that put electric drive and fuel cell vehicles on the road and replace oil with clean domestic fuels.

- **PHASE I SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND SMALL BUSINESS TECHNOLOGY TRANSFER (STTR)**

The Small Business Innovation Research Program (SBIR) provides more than \$2 billion per year in non-recourse contracts and grants to small U.S.-owned companies to develop new products and services that are based on innovative, unproven concepts and technologies.

The objective of the SBIR program is to support innovation that leads to the commercialization of new technologies and final products and services to benefit U.S. communities, companies, and residents. The program is broken down into three phases.



Technology Readiness Levels (TRLs)

Federal Funding Opportunities *(continued)*

TRL-2

continued



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The objective of Phase I is to establish the technical merit, feasibility, and commercial potential of an applicant’s proposed research and research and development (R/R&D) efforts and to determine the quality of performance of the small business organization prior to providing further federal support in Phase II. SBIR Phase I awards normally do not exceed \$150,000 (although, in a few cases, awards may go up to \$225,000) and are for projects lasting 6 to 12 months. The agencies that offer SBIR grants are as follows.

- U.S. Department of Agriculture (USDA)
- U.S. Department of Commerce (DOC):
 - National Institute of Standards (NIS)
 - National Oceanic and Atmospheric Administration (NOAA)
- U.S. Department of Defense (DOD) – also offers Phase I STTR grants
- U.S. Department of Energy (DOE) – also offers Phase I STTR grants
- U.S. Department of Health and Human Services (HHS), including the National Institutes of Health (NIH) – also offers Phase I STTR grants
- U.S. Department of Homeland Security (DHS)
- U.S. Department of Transportation (DOT)
- U.S. Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA) – also offers Phase I STTR grants
- National Science Foundation (NSF) – also offers STTR grants

NEXT: Research to Prove Feasibility *(continued)* / Technology Development

TRL-3

INITIATION OF ACTIVE R&D

Proof-of-concept studies and laboratory analyses are conducted to test and validate analytical and experimental critical functions and characteristics.
Bench-scale, prototype, and model

Federal funding opportunities:

- **NATIONAL SCIENCE FOUNDATION (NSF)**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF AGRICULTURE (USDA)**
 - **National Institute of Food and Agriculture (NIFA)**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF DEFENSE (DOD)**
 - **Defense Advanced Research Projects (DARPA)**
See description of financial support under TRL-1 above
 - **Defense Innovation Unit Experimental (DIUx)**



Technology Readiness Levels (TRLs)

TRL-3

continued

components, units, process reactors, and simulators are built and functionally demonstrated, individually or in series, through testing over a limited range of simulated or actual operating conditions.

SUCCESSFUL COMPLETION:

when it is shown that critical functions and characteristics operate or respond as projected.

MUST-DO:

- Update core proposal, value proposition, and business plan based on TRL-3 results
- Identify areas that need further development: concepts that have been thoroughly researched in the lab with no consideration given to scale-up challenges should be viewed as insufficiently de-risked. Conversely, a highly detailed design with an unproven core element should be dismissed.
- Begin development of financial model: identify and quantify input and production costs.
- If minimum cost is unacceptable, additional work will be required to identify different inputs, sources of inputs, and production methods to lower costs.
- This step is necessary to validate the value proposition and commercial viability of the proposed technology, concept, process, or approach to give confidence to investors and other funders that it is ready for scale up.

Federal Funding Opportunities (continued)

See description of financial support under TRL-2 above

- **Other DOD grant opportunities**

See description of financial support under TRL-1 above

- **U.S. DEPARTMENT OF ENERGY (DOE)**

- **Advanced Research Program Agency – Energy (ARPA-E)**

See description of financial support under TRL-1 above

- **Office of Science (OS)**

See description of financial support under TRL-1 above

- **Office of Fossil Energy (FE)**

See description of financial support under TRL-2 above

- **Office of Energy Delivery and Reliability (OE) and Office of Cybersecurity, Energy Security, and Emergency Response (CESER)**

See description of financial support under TRL-2 above

- **Office of Energy Efficiency and Renewable Energy (EERE)**

See description of financial support under TRL-2 above

- **PHASE I SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND SMALL BUSINESS TECHNOLOGY TRANSFER (STTR)**

See description of Phase I financial support under TRL-2 above

- U.S. Department of Agriculture (USDA)

- U.S. Department of Commerce (DOC):

- National Institute of Standards (NIS)

- National Oceanic and Atmospheric Administration (NOAA)

- U.S. Department of Defense (DOD)

- U.S. Department of Energy (DOE)

- U.S. Department of Health and Human Services (HHS), including the National Institutes of Health (NIH)

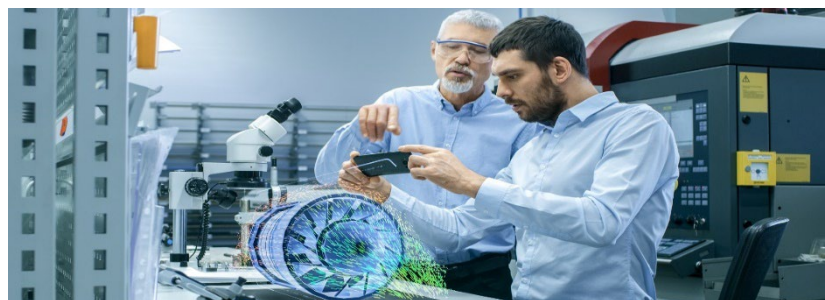
- U.S. Department of Homeland Security (DHS)

- U.S. Department of Transportation (DOT)

- U.S. Environmental Protection Agency (EPA)

- National Aeronautics and Space Administration (NASA)

- National Science Foundation (NSF)



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Technology Readiness Levels (TRLs)

TRL-4 INTEGRATION OF BASIC COMPONENTS

The basic elements, components, and processes central to the technology, concept, process, or approach are integrated. Component, process, and/or bench-scale validation is conducted in a laboratory environment to establish that the pieces will work together.

SUCCESSFUL COMPLETION:

when it is shown that the pieces work together, and the new technology, concept, process, or approach is ready for first use.

MUST-DO:

- Develop / refine initial flow sheets, schematics, heat, material, energy balances, etc.
- Refine financial models and costs
- Update core proposal, value proposition, and business plan based on TRL-4 results
- Ensure update presents a compelling story to investors and funders; moving to TRL-5 requires a significant investment to support additional technical labor and capital equipment.



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Federal Funding Opportunities (continued)

Federal funding opportunities:

- **NATIONAL SCIENCE FOUNDATION (NSF)**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF AGRICULTURE (USDA)**
 - **National Institute of Food and Agriculture (NIFA)**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF DEFENSE (DOD)**
 - **Defense Advanced Research Projects (DARPA)**
See description of financial support under TRL-1 above
 - **Defense Innovation Unit Experimental (DIUx)**
See description of financial support under TRL-2 above
 - **Other DOD grant opportunities**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF ENERGY (DOE)**
 - **Advanced Research Program Agency – Energy (ARPA-E)**
See description of financial support under TRL-1 above
 - **Office of Science (OS)**
See description of financial support under TRL-1 above
 - **Office of Fossil Energy (FE)**
See description of financial support under TRL-2 above
 - **Office of Energy Delivery and Reliability (OE) and Office of Cybersecurity, Energy Security, and Emergency Response (CESER)**
See description of financial support under TRL-2 above
 - **Office of Energy Efficiency and Renewable Energy (EERE)**
See description of financial support under TRL-2 above
- **PHASE II SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND SMALL BUSINESS TECHNOLOGY TRANSFER (STTR)**
The objective of Phase II is to continue the R/R&D efforts initiated in Phase I. Funding is based on the results achieved in Phase I and the scientific and technical merit and commercial potential of the project proposed in Phase II. Only Phase I awardees are eligible for a Phase II award. SBIR Phase II awards normally do not exceed \$1.5 million in total costs for 2 years.
 - U.S. Department of Agriculture (USDA)
 - U.S. Department of Commerce (DOC):
 - National Institute of Standards (NIS)
 - National Oceanic and Atmospheric Administration (NOAA)



Technology Readiness Levels (TRLs)

Federal Funding Opportunities *(continued)*

TRL-4

continued



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- U.S. Department of Defense (DOD) - also offers Phase II STTR grants
- U.S. Department of Energy (DOE) - also offers Phase II STTR grants
- U.S. Department of Health and Human Services (HHS), including the National Institutes of Health (NIH) - also offers Phase II STTR grants
- U.S. Department of Homeland Security (DHS)
- U.S. Department of Transportation (DOT)
- U.S. Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA) - also offers Phase II STTR grants
- National Science Foundation (NSF) - also offers Phase II STTR grants

NEXT: Technology Development *(continued)* / Technology Demonstration

TRL-5

VALIDATION OF OPERATIONAL INTEGRITY

Component, process, and/or bench-scale validation is conducted in an actual or simulated relevant environment. The completion of TRL-5 marks the end of bench-scale work and the final reduction of scientific risk. For technologies, concepts, processes, or approaches that will produce an end product, continuous, integrated tests during TRL-5 should be designed to produce small lots of the end product with its intended formulations and specifications, which should then be validated through third-party testing and analysis. These test lots can be provided to investors, offtake partners, and regulatory agencies. Some developers in the

Federal funding opportunities:

- **NATIONAL SCIENCE FOUNDATION (NSF)**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF AGRICULTURE (USDA)**
 - **National Institute of Food and Agriculture (NIFA)**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF DEFENSE (DOD)**
 - **Defense Advanced Research Projects (DARPA)**
See description of financial support under TRL-1 above
 - **Defense Innovation Unit Experimental (DIUx)**
See description of financial support under TRL-2 above
 - **Other DOD grant opportunities**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF ENERGY (DOE)**
 - **Advanced Research Program Agency – Energy (ARPA-E)**
See description of financial support under TRL-1 above
 - **Office of Science (OS)**
See description of financial support under TRL-1 above
 - **Office of Fossil Energy (FE)**
See description of financial support under TRL-2 above
 - **Office of Energy Delivery and Reliability (OE) and Office of Cybersecurity, Energy Security, and Emergency Response (CESER)**
See description of financial support under TRL-2 above
 - **Office of Energy Efficiency and Renewable Energy (EERE)**



Technology Readiness Levels (TRLs)

Federal Funding Opportunities *(continued)*

TRL-5

continued

food, biomaterials and personal-care spaces may have the opportunity in TRL-5 to provide free samples to the public and market test their acceptance.

Successful Completion:

when it is shown that the new technology, concept, process, or approach and its related processes, systems, hardware, and components operate as predicted in the intended environment and are ready to be integrated into a fully operational prototype.

Must-Do:

- Refine and expand technical and engineering capabilities (via new hires or by engaging outside firms).
- Update and expand core proposal; value proposition; cost breakdowns; financial model; business plan; flowsheets; heat, material, and energy balances; and feasibility, risk, and solution analyses based on TRL-5 results.

See description of financial support under TRL-2 above

- **PHASE II SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND SMALL BUSINESS TECHNOLOGY TRANSFER (STTR)**

See description of Phase II financial support under TRL-4 above

- U.S. Department of Agriculture (USDA)
- U.S. Department of Commerce (DOC):
 - National Institute of Standards (NIS)
 - National Oceanic and Atmospheric Administration (NOAA)
- U.S. Department of Defense (DOD)
- U.S. Department of Energy (DOE)
- U.S. Department of Health and Human Services (HHS), including the National Institutes of Health (NIH)
- U.S. Department of Homeland Security (DHS)
- U.S. Department of Transportation (DOT)
- U.S. Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA)
- National Science Foundation (NSF)



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NEXT: Technology Development *(continued)* / Technology Demonstration *(continued)* / System / Subsystem Development

TRL-6

MODEL, PROTOTYPE, OR PILOT TESTING

[A fully integrated, fully operational system /](#)

Federal funding opportunities:

As new technologies, concepts, processes, and approaches move into TRL-6, the pool of grants and grant sources falls off – significantly, by more than \$10 billion – just as the costs for each TRL escalate. For example:

- **The 10,000+ grants and \$7.5 billion of funding offered each year by NSF** *focus solely on basic and applied research. The bulk*



Technology Readiness Levels (TRLs)

TRL-6

continued

subsystem model, technology, prototype, process, or pilot is demonstrated in a relevant environment, with interface and functionality tests are conducted.

There is no sharp transition between TRL-5 and TRL-6, which focuses on the design and operation of a prototype or pilot-scale (nominally 1/100th of commercial scale) testing unit. Prototype and pilot development may still take place in a laboratory, but experiments are carried out at engineering scale, rather than bench scale. Prototype and pilot-scale unit operations may be designed and procured while bench-scale work continues, with the larger units replacing smaller units as they are brought online and validated. Engineering-scale equivalents of all the unit operations that will be required at scale, including prototypes of any novel operations such as product separation.

SUCCESSFUL COMPLETION:

when it is shown that the technology, concept, process, or approach has demonstrated a sustained, consistent functionality and is ready for scale up. To the extent that there is a “valley of death” for proposed ventures moving up the TRL scale, it is most likely to occur in TRL-5/ -6. Careful selection and specification of pilot, prototype, and process equipment in TRL-5, and a deep understanding of their operational nuances in TRL-6 is critical to a successful continuous run in TRL-7.

Federal Funding Opportunities (continued)

of NFS’s solicitations are targeted to TRLs 1-3, with a smaller number of grants for TRLs-4 and -5.

- **The \$300 million or so in annual grants available from DOE’s Office of Science and ARPA-E, with few exceptions, also focus on basic and applied research and technology development.**
- **Finally, the \$2.5 billion offered each year through the SBIR/STTR program focus solely on stimulating innovation and moving promising ideas and concepts up through TRL-5. While the SBIR/STTR program is targeted to ideas and concepts that are initiated with a view toward eventual commercialization, its Phase III stage does not include any additional grant funding:**
- **PHASE III SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND SMALL BUSINESS TECHNOLOGY TRANSFER (STTR)**

The objective of the SBIR/STTR Phase III, where appropriate, is for the small business to pursue commercialization objectives resulting from the Phase I/II R/R&D activities. The SBIR program does not fund Phase III; instead, the agencies that participate in the SBIR/STTR program offer multiple grant and incentive funding opportunities through their standing programs and other solicitations to fund further development of the technologies, concepts and approaches that show commercial promise in Phase I/II R/R&D. For some federal agencies, Phase III may involve follow-on non-SBIR funded R&D or production contracts for products, processes, or services intended for use by the U.S. government.

Most of the agencies that participate in the SBIR/STTR program, therefore, are potential source of grants for TRL-6, -7, and -8:

- U.S. Department of Agriculture (USDA)
- U.S. Department of Commerce (DOC):
 - National Institute of Standards (NIS)
 - National Oceanic and Atmospheric Administration (NOAA)
- U.S. Department of Defense (DOD)
- U.S. Department of Energy (DOE)
- U.S. Department of Health and Human Services (HHS), including the National Institutes of Health (NIH)
- U.S. Department of Homeland Security (DHS)
- U.S. Department of Transportation (DOT)
- U.S. Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA)



Technology Readiness Levels (TRLs)

Federal Funding Opportunities *(continued)*

TRL-6

continued



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Must-Do:

- Update and expand all project specifications, proposals, analyses, economics, etc. based on TRL-6 results.
- The TRL-6 prototype, process, pilot, model, or approach will be used by an engineering, procurement, and construction (EPC) or another appropriate firm to develop estimates for

Continued below:

construction (or fabrication, development, or manufacturing) for the TRL-7 demonstration-scale prototype, process, model, approach, or plant (at 1/10th commercial scale) and develop relatively accurate (\pm 30-40 percent) capital / production cost estimates for the full-size, commercial-scale technology, plant, process, product, or approach.

Follow-on grants for projects funded at earlier TRL stages, as well as grants for projects applying for grants at TRL-6 also are available from:

- **U.S. DEPARTMENT OF AGRICULTURE (USDA)**
 - **National Institute of Food and Agriculture (NIFA)**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF DEFENSE (DOD)**
 - **Defense Advanced Research Projects (DARPA)**
See description of financial support under TRL-1 above
 - **Defense Innovation Unit Experimental (DIUx)**
See description of financial support under TRL-2 above
 - **Other DOD grant opportunities**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF ENERGY (DOE)**
 - **Office of Fossil Energy (FE)**
See description of financial support under TRL-2 above
 - **Office of Energy Delivery and Reliability (OE) and Office of Cybersecurity, Energy Security, and Emergency Response (CESER)**
See description of financial support under TRL-2 above
 - **Office of Energy Efficiency and Renewable Energy (EERE)**
See description of financial support under TRL-2 above
- **OTHER FEDERAL GOVERNMENT AGENCIES** beyond those listed above and those that participate in the SBIR/STTR program have grant programs and offer funding that may assist in, or supplement other grants, in carrying out TRL-6. For a list of these agencies, see TRL-7 below.

**NEXT: Technology Demonstration *(continued)* /
System / Subsystem Development *(continued)* /
System / Subsystem Demonstration**



Technology Readiness Levels (TRLs)

TRL-7

DEMONSTRATION-SCALE TESTING

A fully integrated, fully operational system / subsystem model, technology, prototype, process, or pilot is demonstrated in an operational environment.

Tests are conducted under sustained day-in and day-out operating conditions over a prolonged period (a continuous, steady-state run of 1,000 hours is the industry standard for new technologies, equipment, processes, and plants to instill confidence in investors and funders). Investors and funders will most likely employ independent engineers to scrutinize and validate the prototype and pilot runs.

SUCCESSFUL COMPLETION:

when it is shown that the fully integrated technology, prototype, process, pilot, or approach and all of its components, systems, and subsystems operate as intended.

MUST-DO:

- Documentation is critical in TRL-7, requiring that data be carefully recorded and compiled, including which operations were running when, for how long, and how they performed.
- Flowsheets; heat, material, and energy balances; detailed engineering and design; cost analyses; etc. should be refined to near final form, with a very high level of detail. Investors and funders.
- This, along with information and lessons gained from the

Federal Funding Opportunities (continued)

Federal funding opportunities:

See description of funding opportunities for TRL-6, above. Other funding opportunities may be available, if there is a fit with your technology, concept, process, or approach, from:

- **U.S. DEPARTMENT OF COMMERCE (DOC)**

*DOC has one overarching goal: **Helping the American Economy Grow**. The DOC promotes job creation and economic growth, provides the data necessary to support commerce, oversees ocean and coastal navigation, and fosters innovation by setting standards and conducting foundational research and development. Of its nine bureaus, five provide occasional grant and funding opportunities that can assist with moving commerce-related and oceanic- and atmospheric-related technologies, concepts, and approaches through advanced TRLs. These include:*

- **Economic Development Administration (EDA)**
- **National Institute of Standards & Technology (NIST)**
- **National Oceanic and Atmospheric Administration (NOAA)**
- **Institute of Standards & Technology (NIST)**
- **National Telecommunications & Information Administration (NTIA)**

- **U.S. DEPARTMENT OF THE INTERIOR (DOI)**

DOI manages the nation's lands. Its current priorities are to maintain and expand conservation stewardship on public lands, sustainably develop the nation's energy and natural resources, modernize the infrastructure overseen by DOI, and promote economic development for Tribal Nations and ensure their sovereignty. Several of DOI's nine bureaus offer grants to support energy innovation, adoption, and deployment, including:

- **Bureau of Indian Affairs (BIA)**
- **Bureau of Land Management (BLM)**
- **Bureau of Ocean Energy Management (BOEM)**
- **Bureau of Reclamation (BOR)**
- **National Park Service (NPS)**
- **Office of Surface Mining Reclamation and Enforcement**
- **U.S. Fish and Wildlife Service (FWS)**
- **U.S. Geological Survey (USGS)**

- **U.S. DEPARTMENT OF TRANSPORTATION (DOT)**

DOT has embarked on an aggressive program to promote sustainability in its policies, operations, investments and research, and ensure that by 2020 not less than 20 percent of electric energy consumed by DOT comes from renewable energy



Technology Readiness Levels (TRLs)

Federal Funding Opportunities (continued)

TRL-7

continued

operation, design, construction, start up, and operation of the demonstration system, technology, prototype, process, plant, or approach will be used through external EPC resources to develop detailed construction, fabrication, manufacturing, or development estimates for the commercial plant, product, technology, or approach.

sources. DOT also has made a commitment to pursue opportunities for the national transportation system that will promote energy and natural resource conservation, decrease emissions of greenhouse gases (GHGs), reduce dependence on fossil fuels, and increase energy efficiency.

One innovative program, the [Smart Cities Challenge](#), selected Columbus, Ohio, in June 2016, to receive \$40 million from DOT to become the first U.S. city to fully integrate innovative technologies – self-driving cars, connected vehicles, and smart sensors – into its transportation network. Another DOT initiative is exploring [Renewable Energy Uses in Highway Rights of Way](#).

NEXT: System / Subsystem Development (continued) / System / Subsystem Demonstration (continued) / System Preparation for Launch & Operations

TRL-8

PRECOMMERCIAL DEMONSTRATION: PROOF OF OPERATIONAL TECHNOLOGY, CONCEPT, OR APPROACH

A full- or near-full-size operational system is completed, troubleshot, operated continuously, and qualified through test and demonstration.

Operating conditions are explored to prove the technology, process, or approach within and outside of normal parameters. Deviations from the predictions made during the pilot stage are identified and mitigation plans are developed. Simulations are finalized and scaled up to commercial scale.

Federal funding opportunities:

See TRL-7 above.



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Continuation of TRL-8 description:

SUCCESSFUL COMPLETION: when it is shown that the technology, process, or approach is proven to work at full or near-full-size commercial scale.

MUST-DO: Using analyses of demonstration-scale operability, final costs will be determined for operations and production, and for construction, fabrication, or manufacturing. Commercial-scale detailed engineering and design will be completed.



Technology Readiness Levels (TRLs)

Federal Funding Opportunities (continued)

THE FINAL STEP: System Launch & Operations

TRL-9

FIRST COMMERCIAL DEPLOYMENT

Application of the technology, process, or approach in its final form. The fully developed technology, process, or approach is completed, built, operated, and deployed for the first time at full commercial / final scale to provide [proof of successful operation of the actual system in an operational environment.](#)

SUCCESSFUL COMPLETION:

when deployment in its final form demonstrates that it is operationally, economically, and functionally superior to other existing or similar technologies, processes, or approaches and is replicable, marketable, and financeable.

MUST-DO:

- A full-time engineering staff will continuously monitor operations to verify that they are meeting cost, yield, efficiency, and productivity targets.



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Federal funding opportunities:

- **U.S. DEPARTMENT OF AGRICULTURE (USDA)**
 - **Rural Development**
 - *Section 9003 Biorefinery, Renewable Chemical, and Bioproduct Manufacturing Assistance Loan Guarantee*
- **U.S. DEPARTMENT OF DEFENSE (DOD)**
 - **Defense Advanced Research Projects (DARPA)**
See description of financial support under TRL-1 above
 - **Defense Innovation Unit Experimental (DIUx)**
See description of financial support under TRL-2 above
 - **Other DOD grant opportunities**
See description of financial support under TRL-1 above
- **U.S. DEPARTMENT OF ENERGY (DOE)**
 - **Loan Program Office (LPO)**
 - *Title 17 Loan Guarantee Program*
 - Renewable Energy and Energy Efficiency Projects
 - Advanced Fossil Energy Projects
 - Advanced Nuclear Energy Projects
 - Tribal Energy Projects
 - *Advanced Technology Vehicle Manufacturing (ATVM) Direct Loan Program*
- **U.S. TREASURY**
 - **Investment Tax Credit (ITC)**
The ITC reduces federal income taxes based on capital investment in innovative and renewable energy projects (measured in dollars). The ITC is earned when the equipment is placed into service.
 - **Production Tax Credit (PTC)**
The PTC reduces federal the income taxes of innovative and renewable energy projects based on the electrical output (measured in kilowatt-hours, or kWh) of grid-connected renewable energy facilities.
 - **Modified Accelerated Cost-Recovery System (MACRS)**
*Or **Bonus Depreciation** allows businesses and project developers to reduce their federal taxes through a deduction for depreciation when renewable energy equipment or facilities producing renewable energy are placed into service. With passage of the 2017 **Tax Cuts and Jobs Act**, the first-year depreciation allowance was increased from 50 percent to 100 percent. Several other types of technologies and properties that incorporate innovative concepts also are now eligible for MARCS program bonus depreciation.*



Technology Readiness Levels (TRLs)

**The End
DEVELOPMENT IS
COMPLETE, COMMERCIAL
ROLL-OUT BEGINS
ADDITIONAL DEPLOYMENT /
REPLICATION**



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**ADDITIONAL DEPLOYMENT /
REPLICATION**

Federal Funding Opportunities *(continued)*

Federal funding opportunities:

- **U.S. DEPARTMENT OF AGRICULTURE (USDA)**
 - **Rural Development Business Programs**
 - Business & Industry (B&I) Loan Guarantees
 - Value Added Producer Grants
 - **Rural Development Energy Programs**
 - Advanced Biofuel Payment Program
 - Repowering Assistance Program
 - Renewable Energy for America Program (REAP) Loan Guarantees
 - **Rural Utility Service (RUS) Electric Programs**
 - Distributed Generation Energy Project Financing Loan Guarantees
 - Electric Infrastructure Loans & Loan Guarantees
 - **Rural Utility Service (RUS) Telecommunications Programs**
 - Rural Broadband Loans & Loan Guarantees
 - Telecommunications Infrastructure Loans & Loan Guarantees
 - **Rural Utility Service (RUS) Water & Environmental Programs**
 - Water & Waste Disposal Loans and Grants
 - Water & Waste Disposal Loan Guarantees
- **U.S. DEPARTMENT OF DEFENSE (DOD)**
 - **Contracting / Procurement**
- **U.S. DEPARTMENT OF ENERGY (DOE)**
 - **Contracting / Procurement**
- **U.S. DEPARTMENT OF COMMERCE (DOC)**
 - **Contracting / Procurement**
 - **As well as grant programs** to promote job creation and economic development
- **U.S. DEPARTMENT OF TRANSPORTATION (DOI)**
 - **Contracting / Procurement**
 - **As well as grant programs** for investments in and rebuilding of surface transportation infrastructure and infrastructure enhancements
- **U.S. DEPARTMENT OF THE TREASURY**

See descriptions above under TRL-9 of the Investment Tax Credit (ITC), Production Tax Credit (PTC), and Modified Accelerated Cost-Recovery System (MACRS) or Bonus Depreciation Allowance.



Technology Readiness Levels (TRLs)

Federal Funding Opportunities (continued)

continued



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- **Clean Renewable Energy Bonds (CREBs)**
Clean Renewable Energy Bonds (CREBs) can be used to finance renewable energy projects using technologies that also qualify for the federal renewable energy production tax credit (PTC). CREBs may be issued by electric cooperatives, government entities (states, cities, counties, territories, Indian tribal governments or any political subdivision thereof), and certain lenders. The bondholder receives federal tax credits in lieu of a portion of the traditional bond interest, resulting in a lower effective interest rate for the borrower.
- **Qualified Energy Conservation Bonds (QECBs)**
Qualified Energy Conservation Bonds (QECBs) may be used by state, local and tribal governments to finance certain types of energy projects. QECBs are qualified tax credit bonds, and in this respect are similar to Clean Renewable Energy Bonds or CREBs. The difference is that borrower who issues the bond pays back only the principal of the bond, and the bondholder receives federal tax credits in lieu of the traditional bond interest.
- **NATIONAL AERONAUTICAL AND SPACE ADMINISTRATION (NASA)**
 - **Contracting / Procurement**

Where to Find Grants for Each TRL ... and Beyond

**Project
Development
\$\$
GRANTS / LOANS / LOAN
GUARANTEES**

American Diversified Energy has experts in the research, science, engineering, and project management disciplines required to move through each TRL, as well as expert grant writers with government grant-making and loan guarantee expertise.

The [Federal Grants page on the American Diversified Energy website](#) serves as a portal to the grants, funding, and support provided by each of the 10 federal agencies listed above, with links to each agency's grant-making programs and lists of current solicitations.