RESEARCH CALL TO DOE NATIONAL LABORATORIES

RESEARCH AND DEVELOPMENT ACTIVITIES TO SUPPORT SOLID-STATE LIGHTING CORE TECHNOLOGIES

CONTACT: Ryan Egidi, Project Manager
TELEPHONE NO.: (304) 285-0945
FAX NO.: (304) 285-4403
E-MAIL: Ryan.Egidi@netl.doe.gov

ISSUING OFFICE: U.S. DEPARTMENT OF ENERGY
National Energy Technology Laboratory
3610 Collins Ferry Road, P. O. Box 880
Morgantown, WV 26507-0880

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SECTION I – GENERAL INFORMATION

1.0 SUMMARY

The Department of Energy (DOE), National Energy Technology Laboratory (NETL), on behalf of the Office of Energy Efficiency and Renewable Energy's (EERE) Building Technologies Program (BT), is seeking proposals for applied research in the Solid-State Lighting (SSL) Core Technologies Program. DOE has set aggressive and ambitious goals for SSL Research and Development: By 2025, to develop advanced solid-state lighting technologies that, compared to conventional lighting technologies, are much more energy efficient, longer lasting, and cost-competitive. The objective of the present Laboratory Call is to support applied research in certain key technical areas by fostering a collaborative atmosphere favorable to overcoming the significant, although not impossible, technical challenges that restrict the application of SSL today to only relatively low luminous output products.

Lighting Research and Development Program

Mission:
To increase end-use efficiency in buildings by aggressively researching new and evolving lighting technologies, in close collaboration with partners, to develop viable methodologies that have the technical potential to conserve 50% of electric lighting consumption by 2025.

To address these issues and to advance energy conservation in lighting in US Buildings, the DOE's Building Technologies Program maintains a Lighting Research and Development (LR&D) activity. Key to the objectives of this activity is its mission statement.

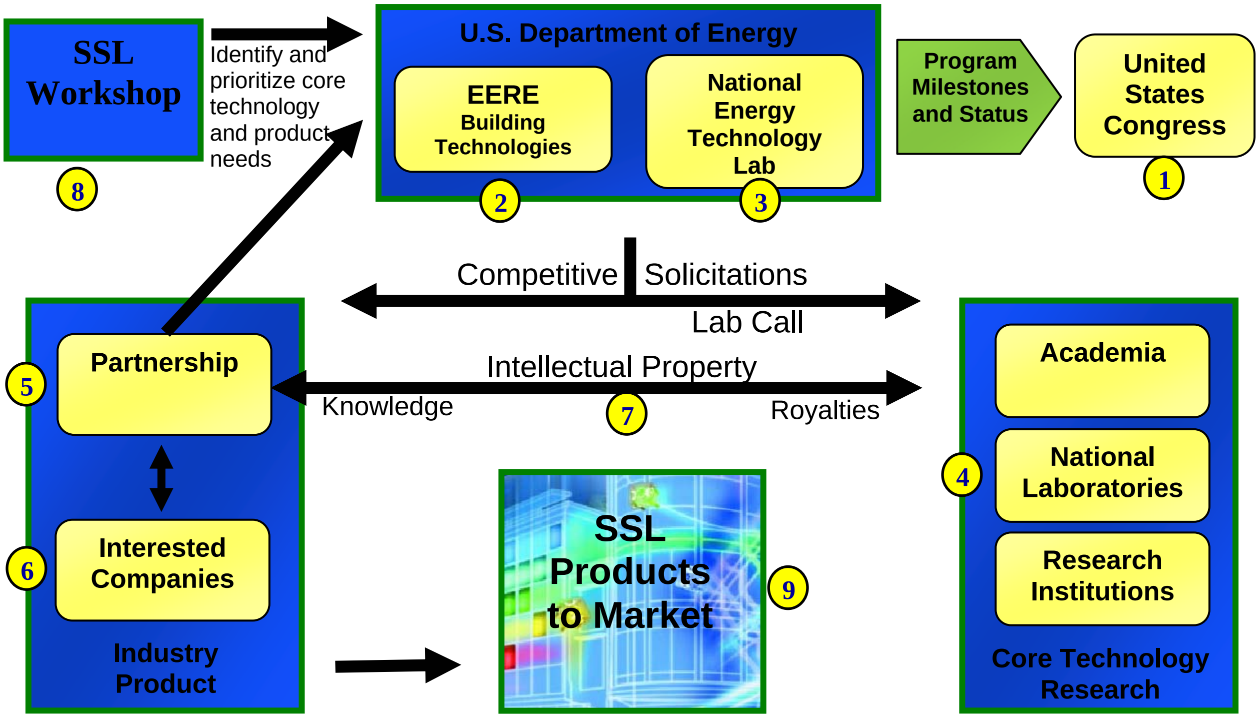
The SSL portfolio has developed a specific statement of objectives tailored to the aggressive needs suitable for general illumination applications. It targets aggressive performance goals that, if met and successfully deployed into the marketplace, will achieve the energy conservation goals of the LR&D program while meeting or exceeding the performance attributes of electric light that allows for direct comparison to natural sunlight spectra.

The present Laboratory Call is the second in a series that may span the next decade. As the relevant SSL technology base matures, it is anticipated that the level of technology maturation will advance from the present level, applied research, eventually to market conditioning once the targets for efficiency, cost, longevity, stability and control are demonstrated in a product environment.

The DOE envisions a LR&D Program that works together with the SSL industry to meet the program's goal by the year 2025. Critical to this LR&D Program are seven important aspects:

- Emphasize Competition
- Cost (and Risk) Sharing
- Partners Involved in Planning and Funding
- Targeted Research for Focused Need
- Innovative IP Provisions
- Open Information and Process
- Success Determined by Milestones Met and Ultimately Energy Efficient, Long-life and Cost-competitive Products Developed

The SSL LR&D program has developed an Operational Plan to accomplish its goal while incorporating these aspects. Its structure is demonstrated graphically below:



The graphic demonstrates the pathway to ultimately move general illumination SSL products to the marketplace. A brief description of each aspect is described, in numeric order, below:

1. The US Congress issues appropriations and language that "authorizes" the DOE to perform research and development in programs. Congress requires reporting on program success – milestones and project status.

2. The US Department of Energy (DOE) consists of many offices including the EERE BT program. The EERE BT office serves as the Program Lead for the SSL activities. The BT office performs the strategic planning as well as program definition. The BT office is also responsible for interfacing with Congress. Information about advanced building technologies, systems and partnership opportunities that promote energy efficiency, renewable energy and pollution prevention can be found at http://www.eere.energy.gov/buildings/

3. NETL is a unique entity within the DOE located in Morgantown, WV and Pittsburgh, PA. NETL is responsible for developing and issuing Funding Opportunity Announcements (FOAs). NETL will perform management of resulting projects and is responsible for reporting project status to DOE HQ. NETL is not permitted to participate as an applicant.

4. The Core Technology Program offers open FOAs to academia and research institutions and National Laboratories via a separate "lab call." The Core Technology Program focuses on earlier "technology gap" stages of development. Applicants will focus on barrier issues that may benefit multiple technical areas or platforms. The present Laboratory Call covers only applied research, the foundation that the rest of the SSL portfolio is built upon.

5. The SSL Partnership was recently awarded via Memorandum of Understanding (MOU) to the Next Generation Lighting Industry Alliance (NGLIA). The purpose of the NGLIA is to provide input and prioritization of the core technology needs, provide administrative expertise and staffing to organize and conduct technical meetings and workshops, and support demonstrations of SSL technologies, among others.

6. Interested companies may apply to the competitive funding opportunity for Product Development subject to the qualification criteria set forth in this document. Applicants will be required to provide a plan that

demonstrates a feasible pathway through development of a marketable SSL product.

7. The SSL LR&D program has implemented innovative Intellectual Property provisions. This program has been granted an exceptional circumstances determination under the Bayh-Dole Act. The exceptional circumstances determination applies to awards under the Core Technologies Program and is expected to stimulate commercial utilization of new technology developed by Core awardees. This potentially benefits product participants by pushing the availability of the core technology to them. The Core Technology Program participants will also benefit by having a ready set of potential licensees to which to license their invention(s), and, if the SSL Partnership members are successful in commercializing their lighting systems, may reap income in the form of royalties. The determination also requires substantial manufacturing in the US of products embodying new inventions. More detailed information about the Exceptional Circumstances Determination can be found at: http://www.netl.doe.gov/ssl/PDFs/SSL%20Determination%20-%20Signed%20June%202005_1.pdf.

8. In an effort to accelerate efficiency improvements and other advances in SSL technology, the 2nd DOE SSL Workshop was held in San Diego, CA on February 3-4, 2005. The overall purpose of the workshop is to help identify and prioritize core technology and product needs for the next 1 to 2 years. The resulting needs for the core Laboratory Call are incorporated into this document as Section I Part 3.0 Program Areas of Interest. Workshop materials and highlights can be found at http://www.netl.doe.gov/ssl/.

9. The SSL goal …. "By 2025, develop advanced solid-state lighting technologies that compared to conventional lighting technologies, are much more energy efficient, longer lasting, and cost competitive by targeting a product system efficiency of 50 percent with lighting that accurately reproduces sunlight spectrum."

This Laboratory Call seeks proposals in an attempt to address the crosscutting or technology gap needs, benefiting multiple technology platforms and manufacturers. A Funding Opportunity Announcement will run concurrently with this Laboratory Call to also address the Core Technologies.

2.0 OBJECTIVES

The specific focus of this Laboratory Call is to ensure that the LR&D portfolio of SSL technology sufficiently addresses the Core Technologies that can be readily and widely applied to existing and future lighting products, which in turn will be energy efficient and cost competitive. It is in this collaborative atmosphere that proposals are sought; proposals that are truly innovative and groundbreaking, fill technology gaps, provide enabling knowledge or data, and will represent a significant advancement in the SSL technology base.

Core Technology Research will provide the focused applied research needed to advance SSL technology – research that is typically longer-term in nature and not the focus of sustained industry investment. Through this Laboratory Call, the DOE will fund research efforts at national laboratories. The product funding opportunity announcement will solicit proposals from interested companies (or teams of companies) for product development, demonstrations, and market conditioning. Product applications will systematically use the knowledge gained from basic or applied research to develop or improve commercially viable materials, devices, or systems.

Many of the needs identified in Section I Part 3.0, "Program Areas of Interest" are described in terms of applied research objectives. Ordinarily, these descriptions are associated with products or a specific product vision. Due to the perceived early stage of SSL portfolio, such advanced descriptions are not possible. Progress towards meeting many of the specific needs in Part 3.0 can be made by advancements in enabling technology or basic knowledge and information.

For the purposes of this Laboratory Call, research to produce generic technology, knowledge and information is considered not to be applied research as defined below. Such "basic research" is specifically excluded in this Laboratory Call.

Therefore, the technology maturation stage eligible for this Laboratory Call is limited to maturation Stage 2 only. However, each stage is defined below in order to provide the overall picture of which stage a particular R&D activity on a technology may fit.

Technology Maturation Stage 1 – Basic Science Research (excluded from this Laboratory Call)

Fundamental science exploration is performed to expand the knowledge-base in a given field. Scientific principles (with data-empirical and/or theoretical derivation) are formulated and proven. The output from these projects would generally be peer-reviewed papers published in recognized scientific journals. Specific applications are not necessarily identified in Stage 1.

Technology Maturation Stage 2 - Applied Research

Scientific principles are demonstrated, an application is identified, and the technology shows potential advantages in performance over commercially available technologies. Lab testing and/or math modeling is performed to identify the application(s), or provide the options (technical pathways) to an application. Testing and modeling add to the knowledge base that supports an application and point to performance improvements.

Technology Maturation Stage 3 – Exploratory Development (excluded from this Laboratory Call)

A product concept addresses an energy efficiency priority. From lab performance testing, down select from alternative technology approaches for best potential performance, via selection of materials, components, processes, cycles, and so on. With lab performance testing data, down select from a number of market applications to the initial market entry ideas. This product concept must exhibit cost and/or performance advantages over commercially available technologies. Technical feasibility should be demonstrated through component bench-scale testing with at least a laboratory bread board of the concept.

Technology Maturation Stage 4 – Advanced Development (excluded from this Laboratory Call)

Product concept testing is performed on a fully functional lab prototype – "proof of design concept" testing. Testing is performed on prototypes for a number of performance parameters to address issues of market, legal, health, safety, etc. Through iterative improvements of concept, specific applications and technology approaches are refocused and "down selected." Product specification (for manufacturing or marketing) is defined. Technology should identify clear advantages over commercially available technologies, and alternative technologies, from detailed assessment.

Technology Maturation Stage 5 – Engineering Development (excluded from this Laboratory Call)

"Field ready prototype" system is developed to refine product design features and performance limits. Performance mapping is evaluated. Performer conducts testing of a field-ready prototype/system in a representative or actual application with a small number of units in the field. The number of units is a function of unit cost, market influences (such as climate), monitoring costs, owner/operator criteria, etc. Feedback from the owner/operator and technical data gathered from field trials are used to improve prototype design. Further design modifications and re-testing are performed as needed.

Technology Maturation Stage 6 – Product Demonstration (excluded from this Laboratory Call)

Operational evaluation of the demonstration units in the field is conducted to validate performance as installed. Third party monitoring of the performance data is required, although less data is recorded relative to the "field ready prototype" test in Stage 5. Pre-production units may be used. Size of demo is a function of unit cost, monitoring cost, etc., and involves relatively more visibility. Energy savings are measured, with careful analysis of economic viability and field durability for specific applications.

3.0 PROGRAM AREAS OF INTEREST

There are four specific Areas of Interest for this Laboratory Call that were identified in the SSL Workshop of February, 2005 as high priority applied research areas. Applicants must select and target only one (1) Area of Interest per application. A separate application must be submitted for each technology or technical approach targeted under a single Area of Interest. Any single application that offers two or more technologies or technical approaches will be rejected without discussion and will not be evaluated for funding.

If the same applicant submits multiple applications that appear nearly identical (e.g. different only to the extent of operational or experimental variations), only one application will be retained as representative of the group. This applies whether the applications are in one Area of Interest or multiple Areas of Interest. The single application retained for evaluation will be evaluated in the Area of Interest that DOE determines is most appropriate.

The Areas of Interest target innovations in both Light Emitting Diodes (LED) and Organic Light Emitting Diodes (OLED). Descriptive information on each of these four Areas of Interest is provided in the following paragraphs:

LED

Currently manufactured LEDs grown from known III-V materials systems have demonstrated impressive gains in performance and efficiency since their inception and continue to make important improvements. These improvements suggest that the realization of the DOE's aggressive performance goals for this technology shown in Figure 1[1] with the corresponding Tables D.1 and D.2 are achievable. However, despite the potential of achieving these impressive performance goals, device price may limit penetration into general illumination markets thereby limiting the DOE's ability to facilitate technology transitions that represent energy conserving alternatives to conventional lighting solutions.

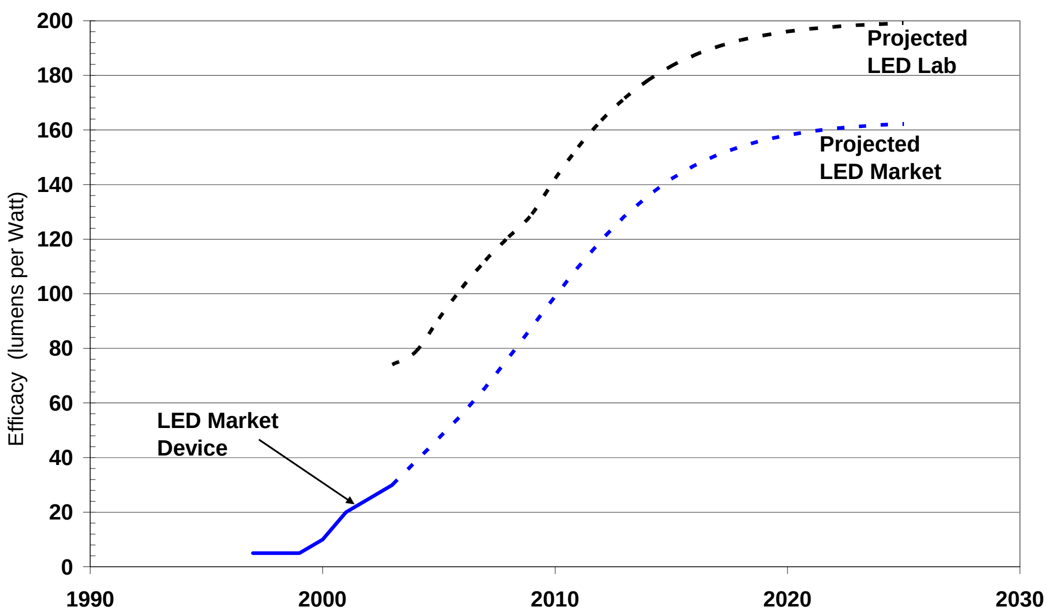


Figure 1 White-Light LED Efficacy Targets

* Note: This projection is for white-light LED chips operating at a CCT of 3000K and a CRI of 80 or higher. These performance characteristics have not been demonstrated yet.

	2005	2006	2007	2008	2009	2010	2015	2020	2025
Efficacy (lumens/watt)	47	56	66	76	88	99	142	158	162

[1] The DOE and industry often characterize SSL with simple, easy to understand metrics such as luminous efficacy expressed in lumens per watt (lm/W). Please see ATTACHMENT A for a more complete discussion of how individual contributions such as those sought under the core area may contribute to overall device efficiency.

Lamp Life (1000 hours)	16	19	23	28	36	45	87	98	100
Lamp Cost ($/klm)	146	127	107	86	67	51	11	4.3	3.3

Table D.1 Commercially Available White-Light LED System Efficacy Estimates

Table D.1 presents the projected performance of commercially available white-light LEDs. This data represents the "high CRI" SSL sources projected under the accelerated investment scenario of a recent DOE study.[2] The cost and performance estimates were developed in consultation with industry, and represent the average performance of white-light LED systems sold to consumers.

* Note: This projection is for white-light LED chips operating at a CCT of 3000K and a CRI of 80 or higher. These performance characteristics have not been demonstrated yet.

	2005	2006	2007	2008	2009	2010	2015	2020	2025	2030
Efficacy (lumens/watt)	90	103	115	125	132	154	183	196	199	200
Life (1000 hours)	28	36	45	55	65	74	96	100	100+	100+

Table D.2 Laboratory Efficacy Estimates for White-Light LED Technology

Table D.2 provides a projection of the performance levels the Department anticipates for laboratory LEDs. This data represents the anticipated performance estimates of future prototype LEDs to be developed in leading research laboratories in the United States.

The DOE's Building Technologies (BT) Program has hosted two technical workshops aimed at identification and prioritization of the research opportunities. While considerable effort has been expended to produce a comprehensive plan directed squarely at overcoming the numerous technical barriers impeding the advancement of SSL, the cost associated with underwriting a comprehensive plan is prohibitive. As a result, these workshops have been used to help focus the resources available to this activity on technical topics that will produce the most impact early. Complete reports are available at the DOE's web site for SSL that may be found at http://www.netl.doe.gov/ssl/. For more information on the Portfolio or the SSL Workshop Report please refer to http://www.netl.doe.gov/ssl/project.html and http://www.netl.doe.gov/ssl/PDFs/DOE_SSL_Workshop_Report_Feb2005.pdf respectively.

Area of Interest 1: LED High-efficiency semiconductor materials – Area of Interest Number: (DE-PS26-05NT42478-01)

It is widely believed by researchers that the key to unlocking both price and performance objectives simultaneously rest within the purview of "core" semiconductor materials research. Research sought under this area is principally aimed at "breakthrough" technologies or solutions as opposed to incremental improvements on existing solutions.

For the purposes of this solicitation only, the relevant semiconductor materials research sought under this solicitation will be in fundamental photonic materials. Performance expectations associated with each are included as guidelines to be used to formulate proposal themes. While the exact metrics described here need not be strictly adhered to, alternative or comparable metrics may be substituted by offerors. In any case, all

[2] *Energy Savings Potential of Solid-State Lighting in General Illumination Applications*, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, US DOE, prepared by Navigant Consulting, Washington DC, November 2003. Available on-line at: www.netl.doe.gov/ssl

successful proposals must include relevant, quantitative, non-arbitrary performance metrics as project milestones. Achievement of these stated milestones will be used during the selection process and following award as indicators of project progress.

(a) Fundamental photonic materials[1.1.2]

Many novel fundamental photonic materials systems and processes have been investigated by the DOE and others in the past and have included the popular III-nitrides systems as well as II-VI systems such as ZnO. Research proposed into this area should be novel and clearly not duplicative of prior activities in this area. Example candidate topics include:

- novel, high efficiency materials systems including orange, yellow, green, and UV (360nm to 410nm) radiant emission. Viable candidate materials systems must demonstrate Internal Quantum Efficiencies (IQE) consistent with the performance objectives stated in ATTACHMENT A. Succinctly, any proposed research in this area must clearly state the IQE baseline for existing or known systems compared to the proposed system at comparable emission wavelengths and brightness;

- defect reduction and lateral epitaxy overgrowth techniques in existing materials systems. Prior DOE research has already achieved certain types of defect densities of 10^{-7} or below. Any new research proposed here must exceed these previously achieved defect densities and identify specific defect reduction goals for the project's duration. Successful proposals will include predictions of the impact this will have on IQE;

- p-type dopant research including p-doping and charge mobility studies and electron-hole mobility. Existing studies have focused on known p-type dopant research that has successfully demonstrated 600 to 700 $cm^2/(V\text{-}s)$ electron mobility (in Silicon) at concentrations of 10^{17} cm^{-3} illustrating the well-known effects of impurity or phonon scattering with temperature. Research sought under this area must transcend these performance goals and clearly demonstrate the impact advancements in this area will have on device performance and cost;

- other unique and novel multiple quantum well physics that might simultaneously increase efficiency and reduce manufacturing costs.

Research proposed under this area should be restricted to more fundamental materials issues that represent novel solutions or breakthrough opportunities that will have a profound and positive impact on eventual device efficiency (see ATTACHMENT A). Research that applies novel materials or device physics to the manufacture of practical SSL devices should not be submitted.

[For more information, refer to SSL research topic 1.1.2 of *DOE SSL Workshop: Workshop Report* at http://www.netl.doe.gov/ssl/

Area of Interest 2: LED Device approaches, structures and systems - Area of Interest Number: (DE-PS26-05NT42478-02)

A key element in achieving the DOE's aggressive price and performance value relationship rests with the effective use of the light produced once it is efficiently produced from a semiconductor quantum well structure or chip. For the purposes of this solicitation, Internal Quantum Efficiency (IQE) refers to chip-level photonic process often referred to as conversion efficiency or simply, quantum efficiency. External Quantum Efficiency (EQE) refers to out-coupling efficiency or external photonic process that occur outside the quantum well structure but still within the physical confines of the device. While some novel geometry may include multiple chips, EQE may be calculated for each individual quantum well structure and summed over the array or calculated for the entire assembly. Either approach is acceptable.

The effective use of efficiently produced light must begin by carefully managing the photons as close to the chip or light emissive surface as possible. Currently manufactured devices fail to efficiently out couple light

[1.1.2] Subtask 1.1.2: High-efficiency semiconductor materials from SSL Workshop produced from a chip with EQE typically much less than 30%. Thus, even with materials systems that produce very good IQE, device efficiency is often far less than desired.

Research in this area is sought that will make a significant and lasting change to the external quantum efficiency characteristic of energy efficient SSL products of the future (see ATTACHMENT A). Appropriate research proposed in this core area should be novel and represent realistic opportunities that will produce the desired increase in performance yet maintain a cost competitive manufacturing methodology.

(a) Device design[1.2.1]

Research leading to completely different and novel device geometries is included under this topic that could include numerical modeling efforts to examine novel optical solutions or complex device configurations. In addition, research towards development of novel device geometries including resonant cavities and photonic lattices or integration of advanced optics to the chip design is also included. However, the development of new tools to perform such modeling or analytical studies are not included. Also included under this topic would be novel methods to reduce optical device losses particularly those that produce chip heating.

[For more information, refer to SSL research topic 1.2.1 of *DOE SSL Workshop: Workshop Report* at http://www.netl.doe.gov/ssl/

[1.2.1] Subtask 1.2.1: Device approaches, structures and systems from SSL Workshop

OLED

Current OLED materials simply do not have the efficiency or lifetime performance necessary to qualify them as viable candidates for the demanding general illumination market. Estimates of lifetime and efficiencies necessary for OLED based general illumination are roughly 50,000 hours and 100 lumens/Watt respectively. Lifetime and efficiency of state-of-the-art white OLEDs (at 850 cd/m^2) are about 500 hours and 20 lumens/Watt respectively.

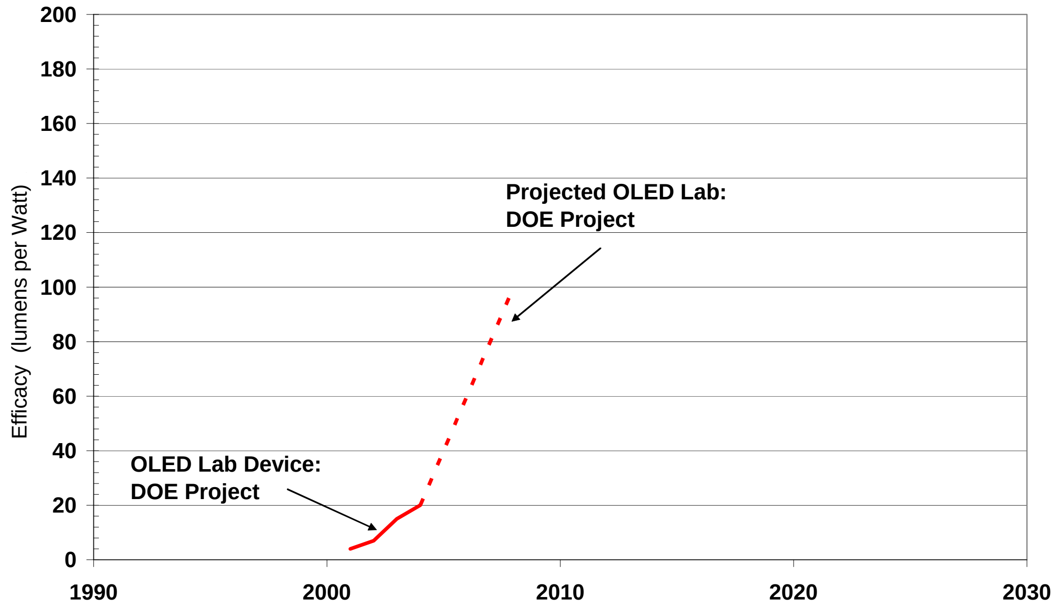


Figure 2 White-Light OLED Efficacy Targets

	Today	2008
Efficacy	20 lpw	100 lpw
Brightness	850 cd/m^2	850 cd/m^2
Lifetime	> 400 hrs	> 10,000 hrs
CRI	88	> 90

Table D.3 Laboratory Efficacy Estimates for White-Light OLED Technology

To realize the full potential of OLED technology, new materials and systems are needed that offer the promise of vastly improved efficiency and stability illustrated in Figure 2[3] with the corresponding Table D.3.

[3] The DOE and industry often characterize SSL with simple, easy to understand metrics such as luminous efficacy expressed in lumens per watt (lm/W). Please see ATTACHMENT A for a more complete discussion of how individual contributions such as those sought under the core area may contribute to overall device efficacy.

Area of Interest 3: OLED Materials Issues - Area of Interest Number: (DE-PS26-05NT42478-03)

Materials used during the fabrication of today's OLEDs span a very wide range of materials science, chemistry and physics.

A detailed, technical discussion of individual contributions of core technologies for OLEDs and how they impact overall device efficiency may be found in ATTACHMENT A. The importance of materials advancements in attaining the DOE's objectives are summarized in the following list of the top five research objectives confronting the advancement of OLEDs for practical SSL applications:

1) Develop a highly efficient, long-lived blue OLED emitter
2) Develop low-cost manufacturing – maximizing lumens while minimizing cost
3) Establish industry standards for general illumination devices
4) Research the OLED white-light system overall, including materials stability and device stability over its service life
5) Address research at the fundamental science level, including understanding and controlling singlet to triplet ratios to achieve 100% IQE and understanding degradation mechanisms to maximize lifetime.

In this list, which was developed by participants of the Second DOE SSL Workshop available at www.netl.doe.gov/ssl, three objectives are clearly materials oriented with one associated with manufacturing and the last addressing standards.

(a) High-efficiency OLED materials[3.1.2]

The development of an efficient, long-lived blue emitter was the top rated research objective of the group assembled to participate in the OLED breakout session of the SSL Workshop. However, this research objective is also the beneficiary of considerable industry and DOE investment already and is specifically excluded from this solicitation for this reason. Instead, advancements in the fundamental science that is associated with high efficiency materials that seek to increase internal quantum efficiency through enabling physics and chemistry is sought. For example, maintenance of charge balances between multiple layers; electron-hole injection, transport and blocking layers; exciton formation; and triplet harvesting are all viable candidates for core research proposed under this materials topic. Research proposed in this area may include single and multiple layered OLED systems and may also include hybrid materials systems (inorganic and organic components). Of special importance under this topic is research that will increase stability while simultaneously increasing IQE. Research proposed under this topic should be novel and not duplicative or an embellishment of previous research directions or work presently supported unless a significant new or enabling development has occurred. For a list of previous and ongoing work, please refer to the SSL Portfolio http://www.netl.doe.gov/ssl/project.html.

[For more information, refer to SSL research topic 3.1.2 of *DOE SSL Workshop: Workshop Report* at http://www.netl.doe.gov/ssl/

Area of Interest 4: OLED Packaging, encapsulation and fabrication - Area of Interest Number: (DE-PS26-05NT42478-04)

Most present day thinking about packaging, encapsulation technology, fabrication processes and even materials selection is driven by the Flat Pannel Display (FPD) industry. Accordingly, most SSL Workshop participants agreed that OLEDs successfully used for general illumination applications will have different requirements especially in terms of reduced manufacturing costs and time required for processing. Because of this perceived deviation from what has become almost commonplace in the FPD industry, participants identified the following area as a high priority "Core" research topic:

[3.1.2] Subtask 3.1.2: High-efficiency, low-voltage, stable materials from SSL Workshop

(a) Encapsulation and Packaging[3.3.2]

Novel methods to seal environmental contaminants such as oxygen and water from the active regions of an OLED stack especially around the edges are viewed as critical by the workshop participants if OLEDs are to advance into general illumination applications. Presently, encapsulation techniques are one of the most expensive elements of white OLED manufacturing in terms of material and process time. For example, present encapsulation rates are approximately 30 minutes per square foot, but this will have to be reduced to seconds per square foot for large scale, low cost manufacturing of OLED's for lighting. Today, realistic lifetimes of OLEDs are limited to just a few thousand hours. The SSL objective is to extend this to at least 20,000 hours and eventually to 50,000 hours to be competitive with fluorescent lamps. Proposals that address this opportunity and that represent fundamental shifts in process, materials or design are therefore sought. Successful proposals submitted to this topic will be consistent with the definitions of "Core" research and will be directed at making fundamental changes in the methods used today to seal environmental contaminants form the OLED stack. Proposals that seek to exploit these advancements in packages designed for SSL applications should not be submitted.

[For more information, refer to SSL research topic 3.3.2 of *DOE SSL Workshop: Workshop Report* at http://www.netl.doe.gov/ssl/

[3.3.2] Subtask 3.3.2: Low-cost Encapsulation and packaging technology from SSL Workshop

SECTION II: REQUIREMENTS AND ELIGIBILITY

1.0 ELIGIBLE APPLICANTS

All DOE National Laboratories are encouraged to submit proposals in response to this Laboratory Call. For-profit, non-profit, state and local governments, Indian Tribes, and institutions of higher education are not eligible for this Laboratory Call, but are encouraged to submit proposals to the companion Funding Opportunity Announcement (DE-PS26-05NT42478) at http://e-center.doe.gov/iips/faopor.nsf/3b3cff0a4a1f243485256ec100490e1a/5814332d284184308525705b0051e948?OpenDocument. All proposed team members must accept the Exceptional Circumstances language found in Section II Part 7.0. Teaming with other DOE National Laboratories is acceptable if this teaming leads to a greater likelihood of achieving the goals of the SSL program in a timely fashion. Industry and Universities are excluded from participating as subcontractors unless they are providing some sort of general service as opposed to research.

2.0 TYPE OF AWARD INSTRUMENT

Any project awarded as a result of the Laboratory Call will be processed through the NETL Financial Management Office as a Field Work Proposal, an Interoffice Work Order or any other allowable method deemed appropriate by the Government.

3.0 ESTIMATED FUNDING

Approximately $3.75 million dollars is expected to be available for new awards under this laboratory call, funded over multiple government fiscal years.

4.0 EXPECTED NUMBER OF AWARDS

DOE anticipates making approximately 2-5 awards this fiscal year under this announcement. However, the Government reserves the right to fund, in whole or in part, any, all, or none of the proposals submitted in response to this laboratory call and will award that number of instruments which serves the public purpose and is in the best interest of the Government. In addition, the Government reserves the right to make "conditional selections" in the event that future funding should become available.

5.0 ESTIMATED AWARD SIZE

DOE anticipates that awards will not exceed the amount set forth below. However, applicants are not encouraged to try to equal these estimates but should offer logical work plans and appropriate costs:

Project Period Length	Maximum Federal Share
12 months	$ 600,000
12 - 24 months	$1,200,000
24 – 36 months	$1,800,000

This information is for estimating purposes only and in no way commits the Government.

6.0 PERIOD OF PERFORMANCE

DOE anticipates making awards that will range from twelve (12) months to thirty-six (36) months. Awards will have project and budget periods that are specific to the project and funding.

7.0 EXCEPTIONAL CIRCUMSTANCES

Regarding any award made to a National Laboratory under this Laboratory Call, the Department of Energy has approved a determination titled "Exceptional Circumstances Determination for Inventions Arising Under the Solid-State Lighting Core Technologies Program." This Determination is based on the Department's belief that circumstances surrounding the Solid-State Lighting Core Technologies Program are exceptional and justify modified intellectual property arrangements as allowed by the Bayh-Dole Act (35 U.S.C. 202(a)(ii)). More detailed information about the Exceptional Circumstances Determination can be found at http://www.netl.doe.gov/ssl/PDFs/SSL%20Determination%20-%20Signed%20June%202005_1.pdf

The Department of Energy intends that disposition of rights to subject inventions made by a National Laboratory under awards resulting from this announcement will be subject to the terms of this Determination. The restriction of patent rights under the Determination will be basically as described in the following paragraph. The Department is requiring minimum licensing rights that the Core Technology Program recipients will have to agree to. Under 35 U.S.C. § 203(2), an awardee adversely affected by this exceptional circumstance determination has a right to appeal the determination to the Department of Energy or to the United States Court of Federal Claims.

All recipients under this lab call shall be required to offer to each member of the Solid State Lighting Partnership (i.e., the Next Generation Lighting Industry Alliance (NGLIA)) the option to enter into a non-exclusive license in the field of solid state lighting applications for subject inventions developed under the Core Technologies Program. Such licenses shall be granted upon terms that are reasonable under the circumstances, including royalties. This option shall only be available to NGLIA members and must be kept available for one year after the U.S. patent issues. After this one-year period, the Core recipient will be free from the licensing restrictions. The Core recipient must agree to negotiate in good faith with any and all NGLIA members that indicate a desire to obtain at least a non-exclusive license. Exclusive licensing may be considered if only one NGLIA member expresses an interest in licensing the invention. Partially exclusive licenses in a defined field of use may be granted to a NGLIA member, provided such license would not preclude any other NGLIA member that indicates a desire to license the invention from being granted at least a non-exclusive license. In the event the Core Recipient and a NGLIA member cannot reach agreement after nine months from the start of diligent and responsible negotiations between them, the NGLIA member shall have the right of a third party beneficiary to maintain an action in a court of competent jurisdiction to force licensing of the subject invention on reasonable terms and conditions. The licensing of any background patents owned by the Core recipient is not required.

SECTION III: SUBMISSION INSTRUCTIONS

1.0 SUBMISSION INSTRUCTIONS

Proposals shall be submitted electronically to the following email address **no later than October 18, 2005 at 4:00 pm EST**:

Ryan Egidi, Project Manager
US Department of Energy
National Energy Technology Laboratory
Ryan.Egidi@netl.doe.gov

The applicant is encouraged to request a return notification to verify receipt of proposal.

2.0 LATE APPLICATIONS, AMENDMENTS AND WITHDRAWALS OF PROPOSALS

A proposal or amendment of a proposal shall be considered timely if it is received on or before the closing date indicated above. Proposals or amendments of proposals may be withdrawn by written notice from an authorized representative to the above address via e-mail or in writing.

A second proposal or amendment may then be submitted. The second or subsequent proposal must be submitted before the closing date to be considered. In the event that two or more proposals are received for the same project with the same title, the proposal with the latest postmark will be considered for review. Therefore, it is important that you not merely make page changes and re-submit portions of the proposal that are amended. A complete amended proposal must be sent.

Proposals or amendments received after the closing date will not be considered.

SECTION IV: APPLICATION PREPARATION

1.0 PREPARATION

It is requested that the entire proposal not exceed thirty-five (35) pages, single spaced, 1" margins (top, bottom, left, right), and when printed will fit on size 8 1/2" by 11" paper. The type must be legible and not smaller than 11 point. The Technical Content (see Section IV Part 2.4) shall not exceed twenty (20) pages of the total page limit. Evaluators will review only the number of pages specified. Any proposals exceeding these limitations may result in a weakness to their overall scored based on technical evaluation Criterion 3 – Applicant and Team Member Roles & Capabilities. In order to produce a comprehensive application for this Lab Call, the offeror shall address, at a minimum, the areas listed in the Table of Contents, below. The offeror shall use the following Table of Contents:

Section	**Page**
Field Work Proposal Cover Sheet	i
Public Abstract	Ii
Table of Contents	iii
List of Tables	Iv
List of Figures	v
List of Acronyms	vi
Detailed Cost Analysis	vii
Technical Content	#
Technical Approach	#
Technology Value	#
Applicant and Team Members Roles and Capabilities	#
Previous or On-going Related Work	#
Appendices	#
Statement of Project Objectives (Statement of Work; SOW)	A
Resumes of Key/Critical Personnel	B
Qualifications and Experience of Participating Organization(s)	C

2.1 FIELD WORK PROPOSAL COVER SHEET

The form must be completed and signed by an official who is authorized to act for the proposer and project team members (other National Laboratories) and who can commit the proposer to comply with the terms and conditions of award, if one is issued.

2.2 PUBLIC ABSTRACT

This section shall contain a public abstract of not more than one (1) typewritten page. The offeror shall provide a point of contact for coordination, preparation and distribution of press releases. The public abstract shall not contain confidential, proprietary, or otherwise sensitive information as it may be released by the DOE to the general public at any time.

2.3 DETAILED COST ANALYSIS

The applicant shall provide detailed cost information pertaining to their proposal. At a minimum, the cost analysis shall provide information regarding personnel costs, overheads, travel, equipment, and supplies. Include a supplemental schedule that identifies the labor hours, labor rates, and cost by labor classification for each budget year. Also indicate the basis of the labor classification, number of hours, and labor rates.

2.4 TECHNICAL CONTENT

The proposer shall address with detail each of the criterion described below:

2.4.1. Technical Approach

- Provide a clear and concise statement of the scientific merits and validity of the proposed approach. Explain any areas of technical uncertainty and the basis for the approach selected.
- Include a table of milestones for each interval of the proposed effort. Be quantitative and descriptive. Typically, projects contain one to four milestones which may be accomplished in no longer than 18 months. These milestones should relate to the determination of technical "value" as described in Criterion 2.4.2.
- Provide a succinct Statement of Project Objectives (SOPO) as described below (Part 2.5) followed by an expanded discussion of technical approach. Provide a discussion of anticipated outcomes and results.
- Provide an innovative and novel technical approach to achieving the stated objectives. Do not duplicate or elaborate on previous or ongoing research unless a significant new or enabling development has occurred. For a list of previous and ongoing work, please refer to the SSL Portfolio at http://www.netl.doe.gov/ssl/project.html.

2.4.2. Technology "Value"

- Provide a discussion of how the proposed subject and approach will impact the eventual achievement of the DOE SSL mission/goal as contained in Section I of this Announcement.
- Explain how the proposed approach is applicable to multiple SSL technologies or may impact other DOE energy efficiency objectives (crosscutting). Examples might include SSL lighting and windows, SSL lighting and commercial buildings, etc.
- Explain the importance of the proposed work and its potential impact on eventual SSL products. If possible, estimates of lighting energy conservation should be made to help relate the importance of the proposed work to DOE energy efficiency goals.
- Explain the importance of the proposed work in terms of meeting the published statement of needs.
- Explain how the proposed research will allow the DOE to achieve their SSL goals earlier than planned. Be quantitative and estimate the impact this achievement might have on cumulative lighting energy conservation.
- Describe how the technology will be made available to a cross-section of the end-user industry or other cross-cutting industries at the earliest practicable time. Include current and potential licensing strategies and a discussion of potential barriers and how they will be overcome.

2.4.3. Applicant and Team Members Roles and Capabilities

- Discuss the ability of the team to perform and achieve the goals stated in the SOPO. This should include current corporate experience and success in similar projects resulting in successful technology development and commercialization or technology transfer to commercial product(s). Outline the roles and responsibilities of each participant in the expanded discussion of technical approach.
- Discuss the abilities of the applicant to successfully perform project management functions on previous programs, Federal or non-Federal. The Proposer, or "Prime," is expected to perform a major portion of the effort for this work.
- Provide a breakdown of key personnel to SOPO tasks (manpower matrix). The matrix should illustrate estimated labor hours and labor categories (e.g., project manager, principal investigator, etc.) required for each task and shall provide rolled-up total for each period. The same should also be included for any proposed subcontracting or consulting efforts. Discuss the rationale used to develop estimates for labor hours and categories, and subcontracting/consulting efforts. Cost information is not to be included in the technical proposal volume.
- Discuss the availability of facilities and equipment. Identify any major equipment needed for the proposed project which will need to be acquired during the course of the project.

2.4.4. Previous or On-going Related Work

- Describe any linkages to current Federal programs (i.e. DOE, DARPA, DOD, NIST, etc.) and any leverage that may be relevant. Show that the early SSL conceptions have already been pursued.
- Explain any overall corporate commitments that demonstrate a buy-in to the potential of SSL or linkages to its strategic plans.

STATEMENT OF WORK (APPENDIX A) INSTRUCTIONS

A Statement of Work shall be developed that addresses how the project objectives will be met. The Statement of Work must contain a clear, concise description of all activities to be completed during project performance and follow the structure discussed below. This section shall be restricted to 1-3 pages in length. The Statement of Work may be released to the public by DOE in whole or in part at any time. It is therefore required that it shall not contain proprietary or confidential business information.

TITLE OF WORK TO BE PERFORMED
(Insert the title of work to be performed. Be concise and descriptive.)

A. OBJECTIVES

Include one paragraph on the overall objective(s) of the work. Also, include objective(s) for each phase of the work.

B. SCOPE OF WORK

This section should not exceed one-half page and should summarize the effort and approach to achieve the objective(s) of the work for each Phase.

C. TASKS TO BE PERFORMED

Tasks, concisely written, should be provided in a logical sequence and should be divided into the phases of the project. This section provides a brief summary of the planned approach to this project.

PHASE I

Task 1.0 - (Title)

(Description)

Subtask 1.1 (Optional)

(Description)

Task 2.0 - (Title)

PHASE II (Optional)

Task 3.0 - (Title)

D. DELIVERABLES

The periodic, topical, and final reports shall be submitted in accordance with the attached "Federal Assistance Reporting Checklist" and the instructions accompanying the checklist.

[Note: The Recipient shall provide a list of deliverables other than those identified on the "Federal Assistance Reporting Checklist" that will be delivered. These reports shall also be identified within the text of the Statement of Project Objectives. See the following examples:

1. Task 1.1 - (Report Description)
2. Task 2.2 - (Report Description)]

E. BRIEFINGS/TECHNICAL PRESENTATIONS (If applicable)

The Recipient shall prepare detailed briefings for presentation to the DOE Project Officer at the NETL facility located in Pittsburgh, PA or Morgantown, WV. Briefings shall be given by the Recipient to explain the plans, progress, and results of the technical effort.

The Recipient shall provide and present a technical paper(s) at the DOE/NETL Annual Contractor's Review Meeting to be held at the NETL facility located in Pittsburgh, PA or Morgantown, WV; or other location specified by the DOE Project Officer.

The Recipient shall provide and present a technical paper(s) at the DOE/NETL Peer Review Meeting to be held at DOE Headquarters in Washington D.C.; or other location specified by the DOE Project Officer.

SECTION V: EVALUATION AND SELECTION

1.0 INITIAL REVIEW CRITERIA

Prior to a comprehensive merit evaluation, DOE will perform an initial review to determine that (1) the applicant is eligible for an award; (2) the information required by the announcement has been submitted; (3) all mandatory requirements are satisfied; and (4) the proposed project is responsive to the objectives of the Laboratory Call.

2.0 MERIT REVIEW CRITERIA

Proposals submitted in response to this funding opportunity will be evaluated and scored in accordance with the criteria and weights listed below:

2.1 TECHNICAL APPROACH (CRITERION 1) – 40%

- Validity of the proposed approach, the likelihood of success, and the scientific merit of the key technology issues addressed.
- Comprehensiveness of the proposed technical milestones for each interval of the proposed effort with special emphasis on the descriptive, qualitative and especially quantitative, where applicable, milestone aspects. Technical realism and likelihood of success of the proposed technical milestones for each interval of the effort.
- Thoroughness and feasibility of the proposed Statement of Project Objectives (SOPO) and the anticipated outcomes and results; validity of the proposed roles and responsibilities of each participant.
- The proposed technical innovation and its relevance to the stated objectives.

2.2 TECHNOLOGY "VALUE" (CRITERION 2) – 30%

- The extent to which the proposed project will contribute to the eventual achievement of DOE's SSL mission and/or goal.
- The extent to which the proposed approach will contribute to multiple SSL technologies or how it may positively impact other DOE energy efficiency objectives (crosscutting).
- The importance of the proposed work and its potential impact on eventual SSL products.

- The degree to which the proposed work meets the published statement of needs.
- Feasibility of the proposed work allowing DOE to achieve the SSL goals earlier than planned.
- The feasibility of the proposed technology dissemination to a cross-section of end users and the proposed licensing strategies and plans to overcome any licensing barriers.

2.3 APPLICANT AND TEAM MEMBERS ROLES AND CAPABILITIES (CRITERION 3) – 20%

- Adequacy of the proposed team's abilities to achieve the goals stated in the SOPO; The level of professional and academic credentials.
- Demonstrated abilities to successfully perform project management functions on previous programs, Federal or non-Federal.
- Reasonableness of time allocations outlined in the manpower matrix; effectiveness of the proposed roles and responsibilities of outlined personnel.
- The adequacy (quality, availability, and appropriateness) of facilities and equipment to accommodate the proposed project.

2.4 PREVIOUS OR ON-GOING RELATED WORK (CRITERION 4) – 10%

- Linkages to current Federal Programs (i.e., DOE, DARPA, DOD, NIST, etc.) and any leverage that may be relevant.
- Potential benefits of the applicant's corporate commitments or linkages to its strategic plans.

3.0 OTHER SELECTION FACTORS

These factors, while not indicators of the Proposal's merit, e.g., technical excellence, cost, Applicant's ability, etc., may be essential to the process of selecting the proposal(s) that, individually or collectively, will best achieve the program objectives. Such factors are often beyond the control of the Applicant. Applicants should recognize that some very good proposals may not receive an award because they do not fit within a mix of projects which maximizes the probability of achieving the DOE's overall research and development objectives. Therefore, the following factors may be used by the DOE to assist in determining which of the ranked proposal(s) shall receive DOE funding.

1. It may be desirable to select for award a group of projects which represents a diversity of technical approaches and methods;
2. It may be desirable to support complementary and/or duplicative efforts or projects, which, when taken together, will best achieve the research goals and objectives;
3. It may be desirable, because of the nature of the energy source, the type of projects envisioned, or limitations of past efforts, to select a group of projects with a broad or specific geographic distribution;
4. It may be desirable to select project(s) of less technical merit than other project(s) if such a selection will optimize use of available funds by allowing more projects to be supported and not be detrimental to the overall objectives of the program.

The above factors will be independently considered by the DOE in determining the optimum mix of proposals that will be selected for support.

ATTACHMENT A EFFICIENCY

The DOE believes that SSL device price and performance can be improved sufficiently to eventually enable SSL to be a viable alternative to conventional sources for general illumination applications. While many different organizations share this viewpoint and support R&D in many different areas, it is often difficult to compare one technical activity with another. This attachment will establish certain performance metrics and define relevant terms with the expectation that eventually, all participants of the DOE's SSL activity will use the same terms and performance metrics helping to make comparison of one technical project to another possible and meaningful. Also, the separate contributions of individual elements of a SSL device will be defined in such a way as to permit non-arbitrary comparison of different approaches to the same performance objective as well as a measure of the relative importance of one contribution to another. Figures 1 and 2 in Section I Part 3.0 represent estimates prepared by the DOE and SSL participants that itemize SSL product performance goals by fiscal year. Since these goals indicate only SSL product efficacy, no direct measure of individual component performance or contributing efficiencies are provided except by inference. There are many different pathways to achieve the final product efficiencies included in Table D.1 and Table D.2.

Thus, the following contributing elements and definitions are provided to establish a uniform method to compare these different approaches.

For the purposes of this attachment, only the three principle elements that comprise SSL product efficacy (Λ) are considered: internal quantum efficiency (ε), external quantum efficiency (Ψ), and device efficiency (ς). Thus, for the purposes of this solicitation only,

$$\Lambda = \varepsilon \bullet \Psi \bullet \varsigma \qquad (1)$$

The following paragraphs will elaborate definitions of each of these three elements. Careful consideration has been made to define these terms to be technology unspecific (e.g., they are applicable to III-Nitride LEDs, novel materials systems inorganic LEDs, small and large molecule OLEDs). As a result, some terms may have slightly irregular definitions or may require additional interpretation to be applied to the specific geometry and/or material system under consideration.

Internal Quantum Efficiency:

For the purposes of this attachment, internal quantum efficiency (IQE) refers to the electrical-chemical conversion of electrical charge into useful photonic emissions. It is a term limited in scope to the materials systems that comprise a device or chip. Usually discussed in the literature as a dimensionless ratio of input charge to output energy, for the purposes of this attachment, it has units of measure normally associated with efficacy, e.g., lumens per watt or LPW.

For solid-state lambertian sources of interest to the DOE's SSL activity, the luminous efficacy associated (Λ) is defined by the internal power or quantum efficiency (ε) and the operating voltage (V) as:

$$\Lambda = \varepsilon / V \qquad (2)$$

where (Λ) is in lumens per watt (LPW), (ε) is in lumens (or candela) as a function of current, and (V) is operating voltage (usually DC). For the simplest devices, luminous efficacy (Λ) is the product of two power efficiency terms, the internal quantum efficiency and the out coupling efficiency (ε and Ψ respectively):

$$\Lambda = K \bullet \varepsilon \bullet \Psi \qquad (3)$$

where (ε) is the ration of the number of electron-hole pairs or excitons to the number of photons produced per unit current produced only within the active region and (Ψ) represents a similar ratio of the number of photons released from the structure verses the number created within. The constant K is associated with photopic response of the human eye, which is not linear for all wavelengths, e.g.:

$$K = f(\lambda) \quad (4)$$

Hence, rearrangement of (2) and substitution of (3) and (4) into (2) yields:

$$\Lambda = K_{(\lambda)} \bullet \varepsilon \bullet \Psi \ / \ V \quad (5)$$

Thus, for simple devices, luminous efficacy (Λ) is a function of internal quantum efficiency and light extraction efficiency but inversely proportional to operating voltage.

Typically for modern III-Nitride chips, IQE (ε) can exceed 100 LPW for some monochrome designs. But for these devices, the EQE (Ψ) or out coupling efficiency can be as low as 30%. Thus, if the luminous power of such a chip were measured in an integrating sphere as 30 LPW, the IQE (ε) could be calculated from (3),

$$\varepsilon = \Lambda/K \bullet \Psi = 30 \text{ LPW} /(1 \bullet 0.30) = 100 \text{ LPW} \quad (6)$$

Notice that the device efficiency (ς) is not included in this chip-level example. Also note that the photopic response function is assumed to be unity, which would be a reasonable approximation for white light producing devices that approximate the black body radiation spectrum of sunlight.

External Quantum Efficiency:

External quantum efficiency (EQE) includes a number of terms occasionally treated as separate terms in the literature. As a illustrative example, consider a broad spectrum, white light producing LEDs using near UV or blue light as a pump for a yellow phosphor that is coated to the inside of an encapsulating sphere incorporating the chip. The efficacy of this type of device commonly referred to as a pcLED is governed by the following relationship:

$$\Lambda_{white} = WPE(\Lambda,\varepsilon) \bullet \varepsilon_{ph} \bullet \eta_{QD} \bullet \eta_{ph}(T) \bullet \eta_{pkg} \quad (7)$$

where, Λ_{white} is the luminous efficacy in LPW and WPE(Λ) is the wall plug efficiency as a function of temperature and is related to IQE (ε). The luminous efficacy of the phosphor is included as ε_{ph} expressed as dimensionless ratio. The stokes loss or quantum deficit between the energy associated with the emitting LED and the phosphor's emission energy is another dimensionless ratio, η_{QD}. The phosphor quantum efficiency, i.e., conversion of pump light into emitted light is included as η_{ph} (T) that is also a function of temperature. A term corresponded to the package efficiency our out coupling efficiency is included as η_{pkg}. To illustrate, imagine that a measurement of an example of this type of pcLED design in an integrating sphere produced a value of 30 LPW. It is known by separate experiment (typically accomplished using photo luminescent measurements with a pump laser at the center frequency of the LED) that the phosphor efficacy is 85%. By calculation, the sum of the stokes loss and phosphor quantum efficiency is 65%. The efficiency of the phosphor package (η_{pkg}) been measured to be 54%. Thus, using (7), the IQE (ε) can be calculated:

$$\varepsilon = \Lambda_{white} /(\varepsilon_{ph} \bullet \eta_{QD} \bullet \eta_{ph}(T) \bullet \eta_{pkg})$$
$$= 30 \text{ LPW} / (0.85 \bullet 0.65 \bullet 0.54) = 100 \text{ LPW} \quad (8)$$

Another way to interpret EQE (ε) is all device level terms that impact device performance that are not specifically included as IQE. Thus, for the purposes of this attachment, EQE (Ψ) is defined as:

$$\Psi = \varepsilon_{ph} \bullet \eta_{QD} \bullet \eta_{ph}(T) \bullet \eta_{pkg} \quad (9)$$

Device Efficiency:

Device efficiency includes the product of IQE (ε) and EQE (Ψ) as in equations (7), (8) and (9) above. Thus, a proposal to increase the EQE by increasing the efficiency of the phosphor package (η_{pkg}) for example might have 70% as a goal. In the example shown above in equation (8) the proposed device efficiency sought as a consequence of this specific improvement would be:

$$\Lambda = \varepsilon \bullet \Psi = \varepsilon \bullet \varepsilon_{ph} \bullet \eta_{QD} \bullet \eta_{ph}(T) \bullet \eta_{pkg}$$
$$= 100 \text{ LPW} \bullet 0.85 \bullet 0.65 \bullet 0.70 = 38.7 \text{ LPW} \qquad (10)$$

Interpretation between devices and products is often clouded by variations in what manufacturers consider a "product". Many manufacturers supply materials that are subsequently used in the manufacture of devices or final consumer type products such as lamps with integral power supplies and reflectors. A manufacturer might produce epi materials that are not packaged or encapsulated to another manufacturer who provides this additional value. In this example, the first manufacture might be most concerned with IQE. Since they may have little to do with how their "product" is subsequently incorporated into a device, they may elect to submit a proposal that addresses a specific element under their control that impacts IQE. In such a case, the proposal should include an estimate of how the subject innovation will impact eventual device efficiency by using realistic values in the above calculations.

For the purposes of this attachment, a device is defined as a stand-alone structure that when some type of power is supplied, produces useful illumination. A device may be monochrome in which case, the subsequent conversion of pump luminance to the desired white light is part of the product package design as described below. Similarly, device efficiency calculations do not include power conversion efficiencies that are ordinarily considered part of the product package unless the device is an active element in the power supply.

SSL Product Efficacy:

Solid-state products are the final goal of the work of interest to the DOE. Ultimately, it is the SSL product price and performance that will dictate penetration into the general illumination market and at the end of the day, energy conservation within this important end use building energy sector. The SSL product efficacy tables (Tables D.1 and D.2) are projections of the performance desired but price is not included. Price is not a component of this attachment although it is clearly a limiting factor in market penetration and has been discussed elsewhere.

Solid-state product efficacy includes a device efficiency term (ς), that may include a number of individual contributions, i.e.,

$$\varsigma = \eta_{Optic} \bullet \eta_{Reflector} \bullet \eta_{Color} \bullet \eta_{Power} \cdots \qquad (11)$$

Where (η_{Optic}) is defined as the efficiency of the optical system, ($\eta_{Reflector}$) refers to the efficiency of the reflector. (η_{Color}) refers tot he color conversion or mixing efficiency, and (η_{Power}) refers to the efficiency of the power supply. Naturally, not all SSL products will have each f these terms and some may have many more. The objective here is to include a single term that describes the product package efficiency and form factor in a meaningful way.

There are many possible solutions to the achievement of the SSL product efficacies shown in Tables D.1 and D.2. Some solutions will be more difficult to achieve and others may be more expensive. The objective of this attachment is to provide a simple framework to encourage comparisons in a non-arbitrary way. Using the data of the above examples, Table D.3 provides an illustration of such an example:

Solution #	IQE (LPW) ε	EQE Ψ	Device ς	Efficacy Λ
1	200	0.5	0.5	50
2	150	0.6	0.6	50
3	100	0.7	0.7	50
4	80	0.8	0.8	50

Table D.3 – Sample solutions resulting in 50 LPW Final SSL Product Efficacy