The Influence of Solid State Lighting Patents Funded by the U.S. Department of Energy's Building Technologies Office and Other DOE Offices

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Executive Summary

This report describes the results of an analysis tracing the technological influence of solid state lighting (SSL) research funded by the U.S. Department of Energy (DOE)'s Building Technologies Office (BTO) and its precursor programs, as well as SSL research funded by other offices in DOE. The tracing is carried out both backwards and forwards in time, and focuses on patents filed in three systems: the U.S. Patent & Trademark Office (U.S. patents); the European Patent Office (EPO patents); and the World Intellectual Property Organization (WIPO patents). The primary period covered in this analysis is 1976 to 2018.

The main purpose of the backward tracing is to determine the extent to which BTO-funded SSL research has formed a foundation for innovations patented by leading SSL organizations. Meanwhile, the primary purpose of the forward tracing is to examine the broader influence of BTO-funded SSL research upon subsequent technological developments, both within and outside SSL technology. In addition to these BTO-based analyses, we also extend many elements of the analysis to other DOE-funded SSL patents, in order to gain insights into their influence.

The main finding of this report is:

- SSL research funded by BTO, and by DOE in general, has had a significant influence on subsequent developments, both within and beyond SSL technology. This influence can be seen on innovations associated with the leading SSL companies. It can also be traced on innovations across a range of other technologies, including semiconductors, electronics and advanced materials.

More detailed findings from this report include:

- In SSL technology, in the period 1976-2018, we identified a total of 100,726 patents (47,666 U.S. patents, 22,836 EPO patents and 30,224 WIPO patents). We grouped these patents into 72,054 patent families, where each family contains all patents resulting from the same initial application (named the 'priority application').

- 439 SSL patents are confirmed to be associated with BTO funding (242 U.S. patents, 91 EPO patents, and 106 WIPO patents). We grouped these BTO-funded SSL patents into 181 patent families.

- In addition, we identified a further 149 SSL patents (105 U.S. patents, 10 EPO patents and 34 WIPO patents) that are associated with DOE funding. These "Other DOE-funded" patents are grouped into 72 patent families.

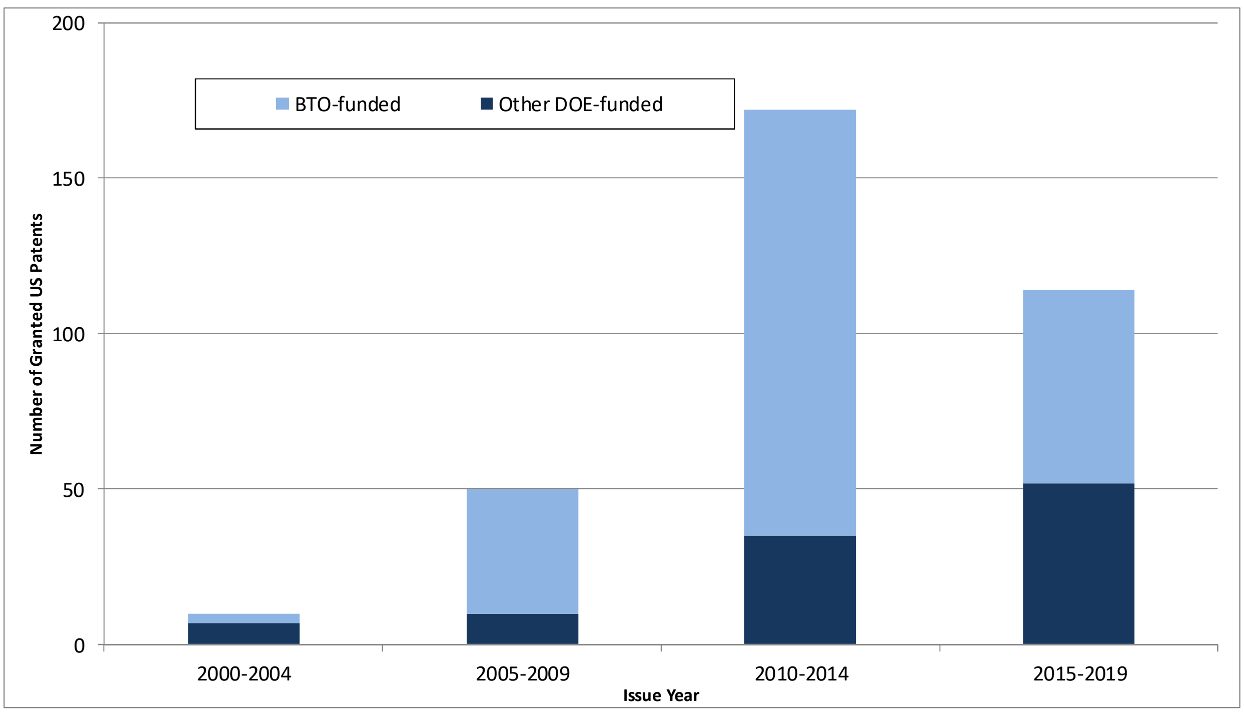
- Out of these 72 Other DOE-funded patent families, 60 are definitely not BTO-funded. These patent families were either funded by a different DOE office, or were marked as being not BTO-funded by inventors or BTO technology managers, but without specifying funding from another DOE source.

- The remaining 12 Other DOE-funded SSL patent families could not be linked definitively to a specific DOE funding source, and may in fact have been BTO-funded. Hence, up to 16.7% (12 out of 72) of the Other DOE-funded SSL patent families in this analysis may in fact be BTO-funded. As such, the results presented in this report may understate the influence of BTO-funded SSL research, relative to the influence of SSL research funded by DOE in general.

- The total number of DOE-funded SSL patents (BTO-funded plus Other DOE-funded) is 588, corresponding to 253 patent families. This represents 0.35% of the total number of SSL patent families in the period 1976-2018.

- The first DOE-funded SSL patent families were filed in the late 1990s, with the first U.S. patents granted in 2000-2004 (see Figure E-1). This corresponds with the start of DOE's funding of SSL research. There was then a rapid increase in DOE-funded SSL patenting, with BTO-funded patents representing a high percentage of the total. The peak came in 2010-2014, with 172 granted U.S. patents, 137 of which were funded by BTO. There was then a decline to 114 U.S. patents granted in 2015-2019, 62 of which were BTO-funded. This recent decline is partially explained by the incomplete data for this time period (see note below Figure E-1).

Figure E-1 - Number of BTO/Other DOE-funded SSL Granted U.S. Patents by Issue Year (5-Year Totals)



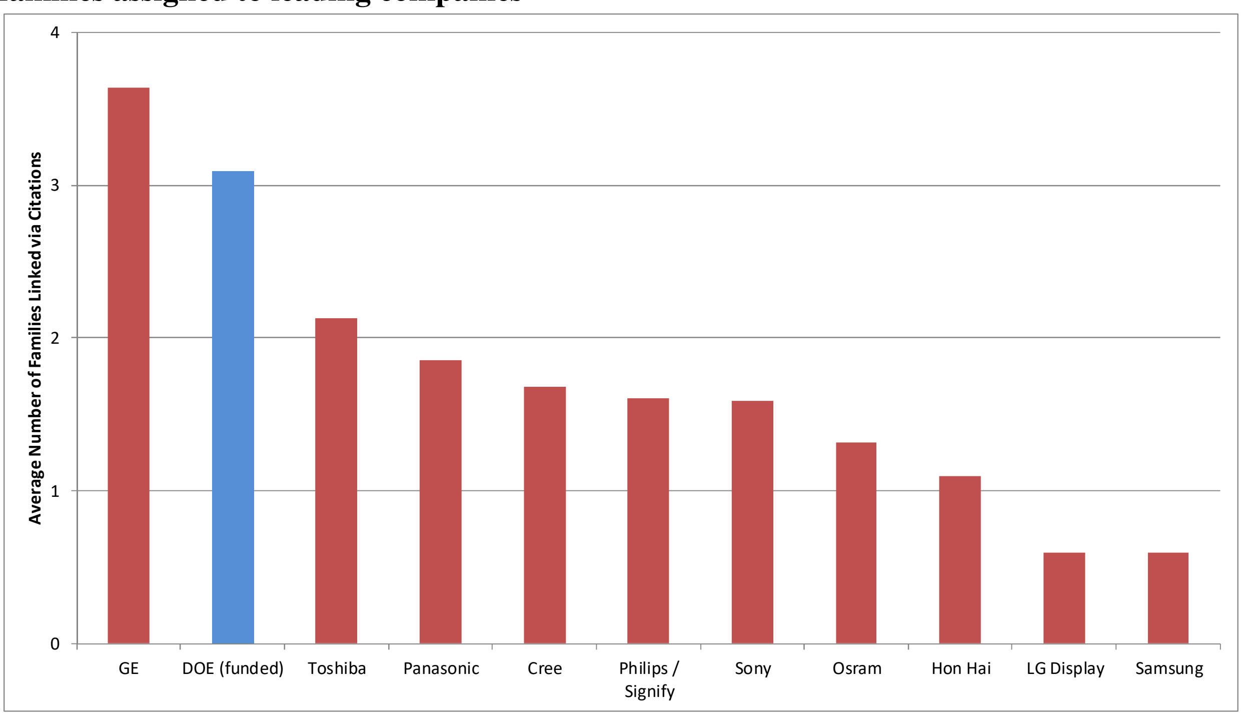
Note: The data collection period for this analysis ended with 2018. Any 2019 patents in the 2015-2019 column are additional patents that have been included because they are members of the same patent families as pre-2019 patents. No new patent search for 2019 was carried out.

- SSL has been a very active area of patenting for many large companies. The ten companies with the largest SSL patent portfolios are: Samsung (3,171 patent families); Philips/Signify (2,815); Hon Hai Precision (2,076); Osram (1,996); Panasonic (1,642); Cree (1,273); Sony (902); Toshiba (824); LG Display (784) and General Electric (745). In comparison, the portfolios of 181 BTO-funded and 72 Other DOE-funded SSL patent families are relatively small. These size differences are taken into account in assessing the influence of the various patent portfolios.

- A large number of BTO-funded and Other DOE-funded SSL patents are related to organic solid state devices, and materials associated with these devices. Meanwhile, the leading companies have a greater concentration on the mechanical and structural characteristics of lighting devices.

- On average, DOE-funded SSL patent families are each linked via citations to over three subsequent patent families assigned to the leading SSL companies (see Figure E-2). This puts DOE in second place in Figure E-2, behind only General Electric. It means that, on average, more SSL patent families owned by leading companies are linked via citations to earlier DOE-funded SSL patents than are linked to the SSL patents assigned to any other leading company (with the exception of General Electric). This is an impressive result and suggests that, while the portfolio of DOE-funded SSL patents is much smaller than those of the leading companies, this portfolio has formed an important part of the foundation for technologies developed by these companies.

Figure E-2 - Average Number of Leading Company SSL Patent Families Linked via Citations to SSL Families from Each Leading Company
e.g. on average, each DOE-funded patent family is linked to over three subsequent patent families assigned to leading companies



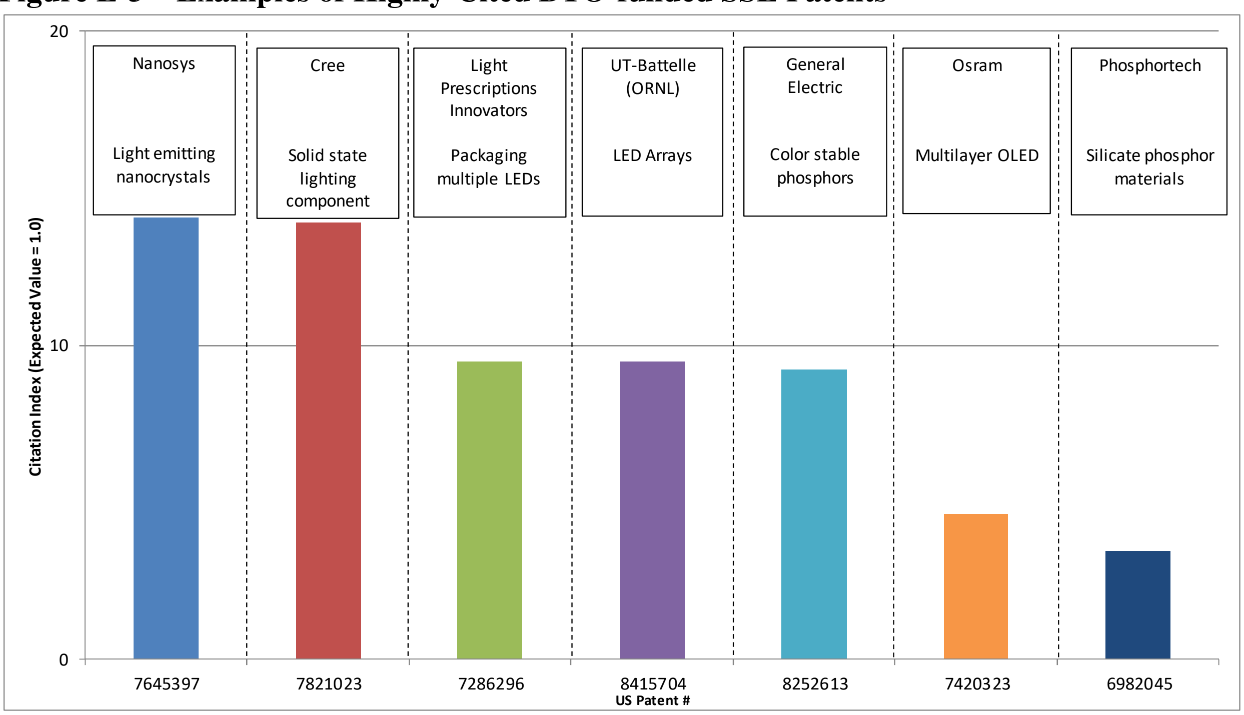
- Among the leading companies, SSL patent families owned by Cree have the largest number of citation links to earlier BTO-funded SSL patents. Other leading companies with extensive citation links to BTO include General Electric, Osram, Samsung and Toshiba. This suggests that BTO-funded SSL research has had an especially strong influence on innovations developed by these companies.

- BTO-funded SSL patents have an average Citation Index value of 2.10 (the Citation Index is a normalized citation metric with an expected value of 1.0; a value of 2.10 shows that, based on their age and technology, BTO-funded SSL patents have been cited as prior art over twice as frequently as expected by subsequent patents). Meanwhile, Other DOE-funded SSL patents have an even higher average Citation Index of 4.7, showing that they have been cited almost five times more frequently than expected (although some of the most highly cited Other DOE-funded patents are marked as "unknown" for funding source, and may in fact be BTO-funded).

- The influence of BTO-funded and Other DOE-funded SSL patents can be seen both within SSL technology, and in adjacent technologies such as semiconductors, electronics and advanced materials.

- There are a number of individual high-impact BTO-funded SSL patents, examples of which are shown in Figure E-3. They include a Nanosys patent describing nanomaterials that can be used in lighting applications, a Cree patent for compact solid state lamps incorporating multiple lighting elements, and a Light Prescriptions Innovators patent outlining LED packaging.

Figure E-3 – Examples of Highly-Cited BTO-funded SSL Patents



1.0 Introduction

This report focuses on solid state lighting (SSL) technology. Its objective is to trace the influence of SSL research funded by the Department of Energy (DOE) Building Technologies Office (BTO) – as well as SSL research funded by DOE as a whole – upon subsequent developments both within and outside SSL technology. The purpose of the report is to:

(i) Locate patents awarded for key BTO-funded (and other DOE-funded) innovations in SSL technology; and

(ii) Determine the extent to which BTO-funded (and other DOE-funded) SSL research has influenced subsequent technological developments both within and beyond SSL.

The primary focus of the report is on the influence of BTO-funded SSL patents. That said, we also extend many elements of the analysis to DOE-funded SSL patents that could not be definitively linked to BTO funding. There are both evaluative and practical reasons for extending the analysis in this way. From an evaluation perspective, it is interesting to examine the influence of BTO itself upon the development of SSL technology, while also tracing the influence of DOE more generally. Meanwhile, in practical terms, determining which patents were funded by BTO, versus other offices within DOE, is often very difficult.

In the U.S. patent system, applicants are required to acknowledge any government funding they have received related to the invention described in their patent application. Typically, this government support is reported at the level of the agency (e.g. Department of Energy, Department of Defense, etc.). Hence, the only way to determine which office within DOE funded a given patent is via other data resources (e.g. iEdison), or through direct input from offices, program managers and individual inventors. For older patents, such information is often unavailable, because records may be less comprehensive, and there is less access to the inventors and program managers involved.

Rather than discard patents confirmed as DOE-funded, but that could not be definitively categorized as BTO-funded, we instead included these patents in the analysis under a separate "Other DOE-funded" category. Some of these patents are confirmed as being linked to funding from other DOE offices, while for others the source of funding within DOE is unknown. Many of these "unknown" patents may in fact have been funded by BTO, although a definitive link could not be established. Hence, the results reported here may underestimate the influence of BTO-funded SSL research, relative to the influence of SSL research funded by the rest of DOE.

This report contains three main sections. The first of these sections describes the project design. This section includes a brief overview of patent citation analysis, and outlines its use in the multi-generation tracing employed in this project. The second section outlines the methodology, and includes a description of the various data sets used in the analysis, and the processes through which these data sets were constructed and linked.

The third section presents the results of our analysis. Results are presented at the organizational level for both BTO-funded and Other DOE-funded patents. These results show the distribution of

BTO-funded (and Other DOE-funded) patents across SSL technologies (as defined by Cooperative Patent Classifications). They also evaluate the extent of BTO's influence (and DOE's influence in general) on subsequent developments in SSL and other technologies. Patent level results are then presented to highlight individual BTO-funded SSL patents that have been particularly influential, as well as to reveal key patents from other organizations that build extensively on BTO-funded SSL research.[1]

2.0 Project Design

This section of the report outlines the project design. It begins with a brief overview of patent citation analysis, which forms the basis for much of the evaluation presented in this report. This overview is followed by a description of the techniques used to link the various patent sets in the analysis, along with a listing and description of the metrics employed in the study.

The analysis described in this report is based largely upon tracing citation links between successive generations of patents. This tracing is carried out both backwards and forwards in time. The primary purpose of the backward tracing is to determine the extent to which technologies developed by leading companies in the SSL industry have used BTO-funded research as a foundation. Meanwhile, the primary purpose of the forward tracing is to examine how BTO-funded SSL patents influenced subsequent technological developments more broadly, both within and outside SSL technology. Many elements of both the backward and forward tracing are also extended to the Other DOE-funded patents, in order to trace their influence, both overall and upon the leading SSL companies.[2]

Our analysis covers patents filed in three systems: the U.S. Patent & Trademark Office (U.S. patents); the European Patent Office (EPO patents); and the World Intellectual Property Organization (WIPO patents). By covering multiple generations of citations across patent systems, our analysis allows for a wide variety of possible linkages between DOE-funded SSL research and subsequent technological developments. Examining all of these linkage types at the level of an entire technology involves a significant data processing effort, and requires access to specialist citation databases, such as those maintained at 1790 Analytics. As a result, this project is more ambitious than many previous attempts to trace through multiple generations of research, which have often been based on studying very specific technologies or individual products.

Patent Citation Analysis

In many patent systems, patent documents contain a list of references to prior art. The purpose of these prior art references is to detail the state of the art at the time of the patent application, and to demonstrate how the new invention is original over and above this prior art. Prior art

[1] This is one of a series of similar reports examining research portfolios across a range of DOE offices. Note that the results are not designed to be compared across portfolios, for example in terms of numbers of patents granted, number of citations received etc. The portfolios have very different profiles with respect to research risks, funding levels and time periods covered, plus there are wide variations in the propensity to patent across technologies. Hence, the results reported in the various reports should not be used for comparative analyses across portfolios.

[2] The analyses described in this report were carried out separately for BTO-funded SSL patents and Other DOE-funded SSL patents. However, referring repeatedly to "BTO-funded/Other DOE-funded patents" or "BTO-funded/Other DOE-funded research" in describing the analyses is lengthy, so we instead use the collective terms "DOE-funded patents" and "DOE-funded research" in the Project Design and Methodology sections of the report.

references may include many different types of public documents. A large number of the references are to earlier patents, and these references form the basis for this study. Other references (not covered in this study) may be to scientific papers and other types of documents, such as technical reports, magazines and newspapers.

The responsibility for adding prior art references differs across patent systems. In the U.S. patent system, it is the duty of patent applicants to reference (or "cite") all prior art of which they are aware that may affect the patentability of their invention. Patent examiners may then reference additional prior art that limits the claims of the patent for which an application is being filed. In contrast to this, in patents filed at the European Patent Office (EPO) and World Intellectual Property Organization (WIPO), prior art references are added solely by the examiner, rather than by both the applicant and examiner. The number of prior art references on EPO and WIPO patents thus tends to be much lower than the number on U.S. patents.[3]

Patent citation analysis focuses on the links between generations of patents that are made by these prior art references. In simple terms, this type of analysis is based upon the idea that the prior art referenced by patents has had some influence, however slight, upon the development of these patents. The prior art is thus regarded as part of the foundation for the later inventions.

In assessing the influence of individual patents, citation analysis centers on the idea that highly cited patents (i.e. those cited by many later patents) tend to contain technological information of particular interest or importance. As such, they form the basis for many new innovations and research efforts, and so are cited frequently by later patents. While it is not true to say that every highly cited patent is important, or that every infrequently cited patent is necessarily trivial, many research studies have shown a correlation between patent citations and measures of technological and economic importance. For background on the use of patent citation analysis, including a summary of validation studies supporting its use, see: Breitzman A. & Mogee M. "The many applications of patent analysis", *Journal of Information Science*, 28(3), 2002, 187-205; and Jaffe A. & de Rassenfosse G. "Patent Citation Data in Social Science Research: Overview and Best Practices", NBER Working Paper No. 21868, January 2016.

Patent citation analysis has also been used extensively to trace technological developments over time. For example, in the analysis presented in this report, we use citations from patents to earlier patents to trace the influence of DOE-funded SSL research. Specifically, we identify cases where patents cite DOE-funded SSL patents as prior art. These represent first-generation links between DOE-funded patents and subsequent technological developments. We also identify cases where patents cite patents that in turn cite DOE-funded SSL patents. These represent second-generation links between technological developments and DOE-funded research.

The idea behind this analysis is that the later patents have built in some way on the earlier DOE-funded SSL research. By determining how frequently DOE-funded SSL patents have been cited

[3] Note that this analysis does not cover patents from other systems, notably patents from the Chinese, Japanese and Korean patent offices. This is because patents from these systems do not typically list any prior art. Hence, it is not possible to use citation links to trace the influence of DOE research on patents from these systems. Having said this, Chinese, Japanese and Korean organizations are among the most prolific applicants in the WIPO system. Our analysis thus picks up the role of organizations from these countries via their WIPO filings.

by subsequent patents, it is thus possible to evaluate the extent to which DOE-funded research forms a foundation for various technologies both within and beyond SSL.

Forward and Backward Tracing

As noted above, the purpose of this analysis is to trace the influence of DOE-funded SSL research upon subsequent developments both within and beyond SSL technology. There are two approaches to such a tracing study – backward tracing and forward tracing – each of which has a slightly different objective.

Backward tracing, as the name suggests, looks backwards over time. The idea of backward tracing is to take a particular technology, product, or industry, and to trace back to identify the earlier technologies upon which it has built. In the context of this project, we first identify the leading SSL organizations in terms of patent portfolio size. We then trace backwards from the patents owned by these organizations. This makes it possible to determine the extent to which innovations associated with these leading SSL organizations build on earlier BTO-funded and Other DOE-funded research.

The idea of forward tracing is to take a given body of research, and to trace the influence of this research upon subsequent technological developments. In the context of the current analysis, forward tracing involves identifying all SSL patents resulting from research funded by DOE (i.e. BTO plus Other DOE). The influence of these patents on later generations of technology is then evaluated. This tracing is not restricted to subsequent SSL patents, since the influence of a body of research may extend beyond its immediate technology. Hence, the purpose of the forward tracing element of this project is to determine the influence of DOE-funded SSL patents upon developments both inside and outside this technology.

Tracing Multiple Generations of Citation Links

The simplest form of tracing study is one based on a single generation of citation links between patents. Such a study identifies patents that cite, or are cited by, a given set of patents as prior art. The analysis described in this report extends the tracing by adding a second generation of citation links.[4] The backward tracing starts with patents assigned to the leading patenting organizations in SSL technology. The first generation contains the patents that are cited as prior art by these starting patents. The second generation contains patents that are in turn cited as prior art by these first generation patents. In other words, the backward tracing starts with SSL patents owned by leading organizations in this technology, and traces back through two generations of patents to identify the technologies upon which they were built, including those funded by DOE.

The forward tracing starts with DOE-funded patents in SSL technology. The first generation contains the patents that cite these DOE-funded patents as prior art. The second generation contains the patents that in turn cite these first-generation patents. Hence, the analysis starts with DOE-funded SSL patents and traces forward for two generations of subsequent patents.

[4] As noted above, the forward and backward tracing were carried out separately for BTO-funded and Other DOE-funded SSL patents. The references in this section to "DOE patents" are shorthand, and do not mean that the tracing was carried out for all DOE-funded SSL patents as a single portfolio.

This means that we trace forward through two generations of citations starting from DOE-funded SSL patents; and backward through two generations starting from the patents owned by leading SSL organizations. Hence there are two types of links between DOE-funded patents and subsequent generations of patents:

1. **Direct Links**: where a patent cites a DOE-funded SSL patent as prior art.
2. **Indirect Links**: where a patent cites an earlier patent, which in turn cites a DOE-funded SSL patent. The DOE patent is thus linked indirectly to the subsequent patent.

The idea behind adding the second generation of citations is that agencies such as DOE often support basic scientific research. It may take time, and numerous generations of research, for this basic research to be used in an applied technology, for example that described in a patent owned by a leading company. Introducing a second generation of citations provides greater access to these indirect links between basic research and applied technology.

One potential problem with adding generations of citations must be acknowledged. Specifically, if one uses enough generations of links, eventually almost every node in the network will be linked. This is a problem common to many networks, whether these networks consist of people, institutions, or scientific documents. The most famous example of this is the idea that every person is within six links of any other person in the world. By the same logic, if one takes a starting set of patents, and extends the network of prior art references far enough, almost all patents will be linked to this starting set. Hence, while including a second generation of citations provides insights into indirect links between basic research and applied technologies, adding further generations may bring in too many patents with little connection to the starting patent set.

Constructing Patent Families

The coverage of a patent is limited to the jurisdiction of its issuing authority. For example, a patent granted by the U.S. Patent & Trademark Office (a "U.S. patent") provides protection only within the United States. If an organization wishes to protect an invention in multiple countries, it must file patents in each of those countries' systems. For example, a company may file to protect a given invention in the U.S., China, Germany, Japan and many other countries. This results in multiple patent documents for the same invention.[5] In addition, in some systems – notably the U.S. – inventors may apply for a series of patents based on one underlying invention.

In the case of this study, one or more U.S., EPO and WIPO patents may result from a single invention. To avoid counting the same inventions multiple times, it is necessary to construct "patent families". A patent family contains all of the patents and patent applications that result from the same original patent application (named the "priority application"). A family may include patents from multiple countries, and also multiple patents from the same country. In this project, we constructed patent families for DOE-funded SSL patents, and also for the patents owned by leading SSL organizations. We also assembled families for all patents linked via citations to DOE-funded SSL patents.

To construct these patent families, we matched the priority documents of the U.S., EPO and WIPO patents, in order to group them into the appropriate families. It should be noted that the

[5] It also means that patents from a given country's system are not synonymous with inventions made in that country. Indeed, roughly half of all U.S. patent applications are from overseas inventors.

priority document need not necessarily be a U.S., EPO or WIPO application. For example, a Japanese patent application may result in U.S., EPO and WIPO patents, which are grouped in the same patent family because they share the same Japanese priority document.

Metrics Used in the Analysis

Table 1 contains a list of the metrics used in the analysis. These metrics are divided into three main groups – technology landscape metrics (trends, assignees, and technology distributions), backward tracing metrics, and forward tracing metrics. Findings for each of these three groups of metrics can be found in the Results section of the report.

Table 1 – List of Metrics Used in the Analysis

Metric
Trends
• Number of BTO/Other DOE-funded SSL patent families by year of priority application
• Number of BTO/Other DOE-funded granted U.S. SSL patents by issue year
• Overall number of SSL patent families by priority year
• Percentage of SSL patents families funded by BTO/Other DOE by priority year
Assignee Metrics
• Number of SSL patent families for leading patenting organizations
• Assignees with largest number of SSL patent families funded by BTO/Other DOE
Technology Metrics
• Patent classification (CPC) distribution for BTO-funded SSL patent families (vs Other DOE-funded, leading SSL companies, all SSL)
Backward Tracing Metrics
• Total/Average number of leading company SSL patent families linked via citations to earlier patent families from BTO/Other DOE-funding and other leading companies
• Number of SSL patent families for each leading company linked via citations to earlier BTO/Other DOE-funded patent families
• Total citation links from each leading company to BTO/Other DOE-funded patent families
• Percentage of leading company SSL patent families linked via citations to earlier BTO/Other DOE-funded patent families
• BTO/Other DOE-funded SSL patent families linked via citations to largest number of leading company SSL patent families
• Leading company SSL patent families linked via citations to largest number of BTO-funded SSL patent families
• Highly cited leading company SSL patent families linked via citations to earlier BTO-funded SSL patent families
Forward Tracing Metrics
• Citation Index for SSL patent portfolios owned by leading companies, plus portfolios of BTO/Other DOE-funded SSL patents
• Number of patent families linked via citations to BTO/Other DOE-funded SSL patents by patent classification
• Organizations (beyond leading SSL companies) linked via citations to largest number of BTO/Other DOE-funded SSL patent families
• Highly cited BTO-funded SSL U.S. patents
• BTO/Other DOE-funded SSL patent families linked via citations to largest number of subsequent SSL/non-SSL patent families
• Highly cited patents (not leading company-owned) linked via citations to BTO-funded SSL patents

3.0 Methodology

The previous section of the report outlines the objective of our analysis – that is, to determine the influence of BTO-funded (and Other DOE-funded) SSL research on subsequent developments both within and outside SSL technology. This section of the report describes the methodology used to implement the analysis. Particular emphasis is placed on the processes employed to construct the various data sets required for the analysis. Specifically, the backward tracing starts from the set of all SSL patents owned by leading patenting organizations in this technology. Meanwhile, the forward tracing starts from the sets of SSL patents funded by BTO and Other DOE. We therefore had to define various data sets – BTO-funded SSL patents; Other DOE-funded SSL patents; and SSL patents assigned to the leading organizations in this technology.

Identifying BTO-funded and Other DOE-funded SSL Patents

The objective of this analysis is to trace the influence of SSL research funded by BTO (plus SSL research funded by the remainder of DOE) upon subsequent developments both within and outside SSL technology. Outlined below are the three steps used to identify BTO-funded and Other DOE-funded SSL patents. These three steps are:

(i) Defining the universe of DOE-funded patents;

(ii) Determining which of these DOE-funded patents are relevant to SSL; and

(iii) Categorizing these DOE-funded SSL patents according to whether or not they can be linked definitively to BTO funding.

Defining the Universe of DOE-Funded Patents

Identifying patents funded by government agencies is often more difficult than locating patents funded by companies. When a company funds internal research, any patented inventions emerging from this research are likely to be assigned to the company itself. In order to construct a patent set for a company, one simply has to identify all patents assigned to the company, along with all of its subsidiaries, acquisitions, etc.

Constructing a patent list for a government agency is more complicated, because the agency may fund research carried out at many different organizations. For example, DOE operates seventeen national laboratories. Patents emerging from these laboratories may be assigned to DOE. However, they may also be assigned to the organization that manages a given laboratory. For example, many patents from Sandia National Laboratory are assigned to Lockheed Martin (Sandia's former lab manager), while many Lawrence Livermore National Laboratory patents are assigned to the University of California. Lockheed Martin and the University of California are large organizations with many interests beyond managing DOE labs, so one cannot simply take all of their patents and define them as DOE-funded. A further complication is that DOE does not only fund research in its own labs and research centers, it also funds extramural research carried out by other organizations. If this research results in patented inventions, these patents may be assigned to the organizations carrying out the research, rather than to DOE.

We therefore constructed a database containing all DOE-funded patents. These include patents assigned to DOE itself, and also patents assigned to individual labs, lab managers, and other organizations and companies funded by DOE. This "All DOE" patent database was constructed using a number of sources:

1. ***DOEPatents Database*** – The first source is a database of DOE-funded patents put together by DOE's Office of Scientific & Technical Information (OSTI), and available on the web at www.osti.gov/doepatents/. This database contains information on research grants provided by DOE. It also links these grants to the organizations or DOE labs that carried out the research, the sponsor organization within DOE, and the patents that resulted from these DOE grants.

2. ***iEdison Database*** – EERE staff provided us with an output from the iEdison database, which is used by government grantees and contractors to report government-funded subject inventions, patents, and utilization data to the government agency that issued the funding award.

3. ***Visual Patent Finder Database*** – EERE also provided us with an output from its Visual Patent Finder tool. This tool takes DOE-funded patents and clusters them based on word occurrence patterns. In our case, the output was a flat file containing DOE-funded patents.

4. ***Patents assigned to DOE*** – in the USPTO database, we identified a small number of U.S. patents assigned to DOE itself that were not in the any of the sources above. These patents were added to the list of DOE patents.

5. ***Patents with DOE Government Interest*** – A U.S. patent has on its front page a section entitled 'Government Interest', which details the rights that the government has in a particular invention. For example, if a government agency funds research at a private company, the government may have certain rights to patents granted based on this research. We identified all patents that refer to 'Department of Energy' or 'DOE' in their Government Interest field, including different variants of these strings. We also identified patents that refer to government contracts beginning with 'DE-' or containing the string '-ENG-'. The former string typically denotes DOE contracts and financial assistance projects, while the latter is a legacy code listed on a number of older DOE-funded patents.

   We manually checked all of the patents containing these strings that were not already in any of the sources above, to make sure that they are indeed DOE-funded (e.g. '-ENG-' is also used in a small number of NSF contracts). We then included any additional DOE funded patents in the database.

The "All DOE" patent database constructed from these five sources contains more than 31,000 U.S. patents issued between January 1976 and December 2018 (the end-point of the primary data collection for this analysis).

Identifying DOE-Funded SSL Patents

Having defined the universe of DOE-funded patents, the next step was to determine which of these patents are relevant to SSL technology. We designed a custom patent filter to identify SSL patents, consisting of a combination of Cooperative Patent Classifications (CPCs) and keywords. Details of the patent filter are shown in Table 2. The form of the filter is (Filter A OR Filter B), so patents that qualify under either of the filters in Table 2 were included in the initial patent set.

Table 2 – Filter used to identify DOE-funded SSL Patents

Cooperative Patent Classification	Description
F21V 19/001-0055	Solid state light fixtures
G09G 3/32-3291	Solid state displays
H01L 25/167	Multiple optoelectronic devices
H01L 27/32-3297	Solid state components for light emission
H01L 33/08	Devices with plural light emitting regions
H01L 51/50-56	Organic light emitting devices (OLED, PLED)
H01L 51/5287	OLED with fiber structure
H01L 2227/32-326	Devices incorporating OLED
H01L 2251/50-568	OLED devices
H01L 2924/12044	OLED devices
Y02B 20/30-386	Energy efficient solid state lighting

We then manually checked the initial list of patents to determine which of them appear relevant to SSL. Having constructed this draft patent list, we then sent it to BTO for review. Following this review, and based on feedback from BTO, the initial list of SSL patents funded by DOE contained a total of 311 granted U.S. patents.[6]

Defining BTO-funded vs. Other DOE-funded SSL Patents

As noted above, linking DOE-funded patents to individual offices is often a difficult task. For this analysis, EERE staff undertook an exhaustive process to determine which of the 311 DOE-funded SSL patents in the initial list could be linked definitively to BTO funding. This process involved a number of steps, which are listed below:

(i) Linking contract numbers listed in patents to EERE project contract numbers, for financial assistance projects,
(ii) Linking contract numbers listed in patents to EERE SBIR project agreement numbers,
(iii) Asking BTO technology managers to verify individual patents,
(iv) Asking BTO technology managers to send lab patents to lab POCs to get direct verification of these patents,

[6] One issue that emerged during this review process was how broadly to define SSL technology. Many technologies (such as OLED) and materials (such as luminescent phosphors) have potential applications in lighting, but also in other applications, including displays. Given that patents often do not specify a single application, in order to avoid narrowing their coverage, the guidance from BTO technology managers was to include all patents with potential SSL applications. This approach was employed to construct all the patent portfolios in the analysis, including DOE-funded patents and patents assigned to the leading SSL organizations.

(v) Contacting individual inventors listed on patents to ask them to confirm whether individual patents were funded by BTO, and
(vi) Locating references to patents in available office annual project progress reports or patent disclosure documents with accomplishments reported by PIs.

Final List of BTO-funded and Other DOE-funded SSL Patents

Based on the process described above, we divided the initial list of 311 DOE-funded SSL U.S. patents into two categories – BTO-funded and Other DOE-funded. We then searched for equivalents of each of these patents in the EPO and WIPO systems. An equivalent is a patent filed in a different patent system covering essentially the same invention. We also searched for U.S. patents that are continuations, continuations-in-part, or divisional applications of each of the patents in the final set. We then grouped the patents into families by matching priority documents (see earlier discussion of patent families). Table 3 contains a summary of the final number of BTO-funded and Other DOE-funded SSL patents and patent families.

Table 3 – Number of BTO-funded and Other DOE-funded SSL Patents and Patent Families

	# Patent Families	# U.S. Patents	# EPO Patents	# WIPO Patents
BTO-funded	181	242	91	106
Other DOE-funded	72	105	10	34
Total DOE-funded	253	347	101	140

Table 3 shows that we identified a total of 181 BTO-funded SSL patent families, containing 242 U.S. patents, 91 EPO patents, and 106 WIPO patents (see Appendix A for patent list). We also identified 72 Other DOE-funded SSL patent families, containing 105 U.S. patents, 10 EPO patents, and 34 WIPO patents (see Appendix B for patent list). These patents date as far back as the turn of the century, corresponding to the start of DOE's funding of SSL research.

As noted throughout this report, the approach used to define patents as BTO-funded was very stringent. Hence, a number of the 72 Other DOE-funded patent families may in fact have been funded by BTO, but are not categorized as such because a definite link could not be established. To get a better sense of how many of these Other DOE-funded patents (and patent families) may in fact be BTO-funded, we divided them into two groups.

The first group contains DOE-funded patent families that were definitely not funded by BTO. These include families linked specifically to funding from an office other than BTO, or that the inventor or BTO technology manager said were not funded by BTO (but without specifying funding from a different office). There are 60 such patent families.

The second group contains DOE-funded patent families where the funding source within DOE could not be established, and inventors and BTO technology managers could not state categorically whether or not they were funded by BTO. There are twelve such patent families. Hence, up to 16.7% (12 out of 72) of the Other DOE-funded patent families included in this analysis may in fact be BTO-funded. As a result, the findings in this analysis may understate the influence of BTO-funded SSL patents, relative to the influence of the remainder of DOE patents.

Identifying SSL Patents Assigned to Leading Organizations

The backward tracing element of our analysis is designed to evaluate the influence of BTO-funded (and Other DOE-funded) research on SSL innovations produced by leading organizations in this technology. To identify such organizations, we first defined the universe of SSL patents in the period 1976-2018 using the patent filter detailed earlier in Table 2. Based on this filter, we identified a total of 47,666 SSL U.S. patents, 22,836 SSL EPO patents, and 30,224 SSL WIPO patents. We grouped these patents into 72,054 patent families by matching priority documents.

We then located the most prolific patenting organizations in this overall SSL patent universe, based on number of patent families. The ten organizations with the largest number of SSL patent families are shown in Table 4.[7] The number of patent families listed in this table includes all variant names under which these companies have patents, taking into account including all subsidiaries and acquisitions. The SSL patent families of these ten companies in Table 4 form the starting point for the backward tracing element of the analysis.

Table 4 – Top 10 Patenting SSL Companies

Company	# SSL Patent Families
Samsung	3171
Philips/Signify[8]	2815
Hon Hai Precision (Foxconn)	2076
Osram	1996
Panasonic	1642
Cree	1273
Sony	902
Toshiba	824
LG Display	784
General Electric	745

Constructing Citation Links

Through the processes described above, we constructed starting patent sets for both the backward forward tracing elements of the analysis. The patent set for the backward tracing consisted of patent families assigned to the leading patenting organizations in SSL technology. The patent sets for the forward tracing consisted of BTO-funded (and, separately, Other DOE-funded) SSL patent families. We then traced backward through two generations of citations from the leading organizations' SSL patents, and forward through two generations of citations from the BTO/Other DOE-funded SSL patents. These included citations listed on U.S., EPO and WIPO patents, and required extensive data cleaning to account for differences in referencing formats

[7] All ten of these organizations are companies. For clarity, they are referred to in the results section of the report as the leading SSL companies, rather than organizations. Note that they are selected based on patent portfolio size, which does not necessarily reflect units sold or revenues, profits etc. A fuller description would be the leading patenting SSL companies, but this is a cumbersome description to use throughout the results section of the report.
[8] Signify is the new name for Philips Lighting NV.

across these systems. The citation linkages identified, along with characteristics of the starting patent sets, form the basis for the results described in the next section of this report.

4.0 Results

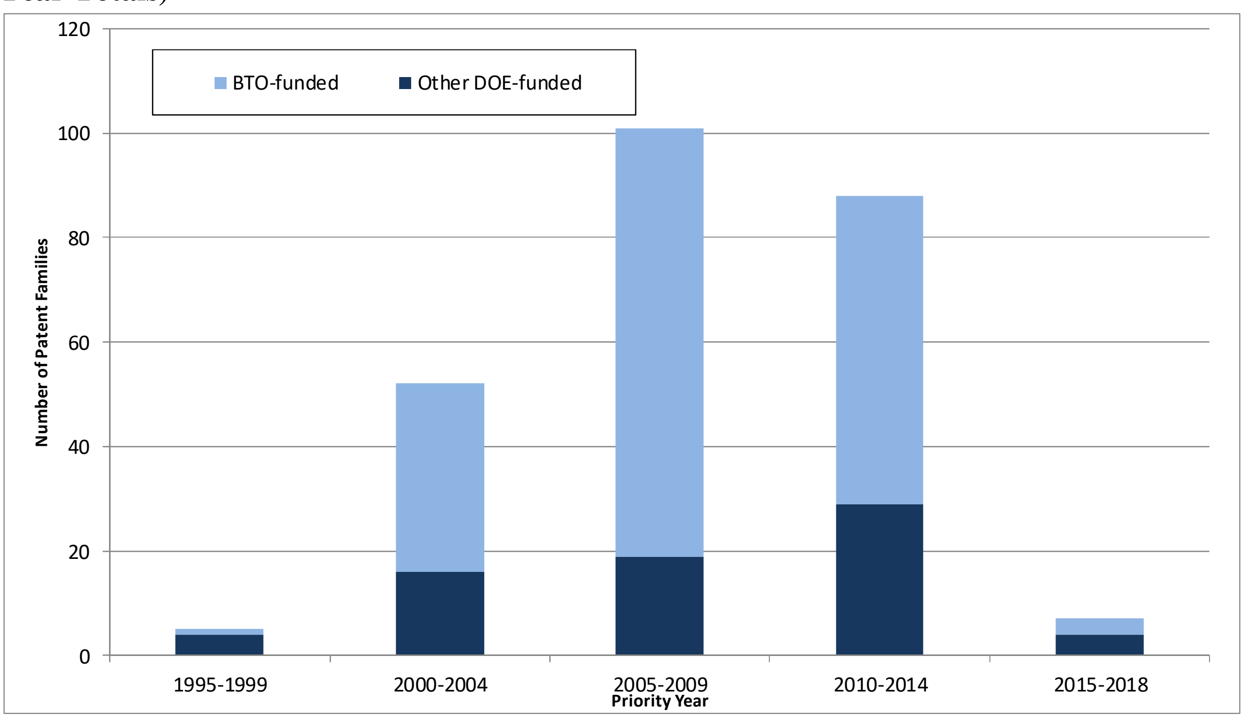
This section of the report outlines the results of our analysis tracing the influence of BTO-funded and Other DOE-funded SSL research on subsequent developments both within and beyond SSL technology. The results are divided into three main sections. In the first section, we examine trends in SSL patenting over time, and assess the distribution of BTO-funded and Other DOE-funded patents across SSL technologies. The second section then reports the results of an analysis tracing backwards from SSL patents owned by the leading companies in this technology. The purpose of this analysis is to determine the extent to which SSL innovations developed by leading companies build upon earlier SSL research funded by BTO (plus SSL research funded by the remainder of DOE). In the third section, we report the results of an analysis tracing forwards from BTO-funded (and Other DOE-funded) SSL patents. The purpose of this analysis is to assess the broader influence of DOE-funded research upon subsequent developments within and beyond SSL technology.

Overall Trends in SSL Patenting

Trends in SSL Patenting over Time

Figure 1 shows the number of BTO-funded and Other DOE-funded SSL patent families by priority year – i.e. the year of the first application in each patent family.

Figure 1 – Number of BTO/Other DOE-funded SSL Patent Families by Priority Year (5-Year Totals)

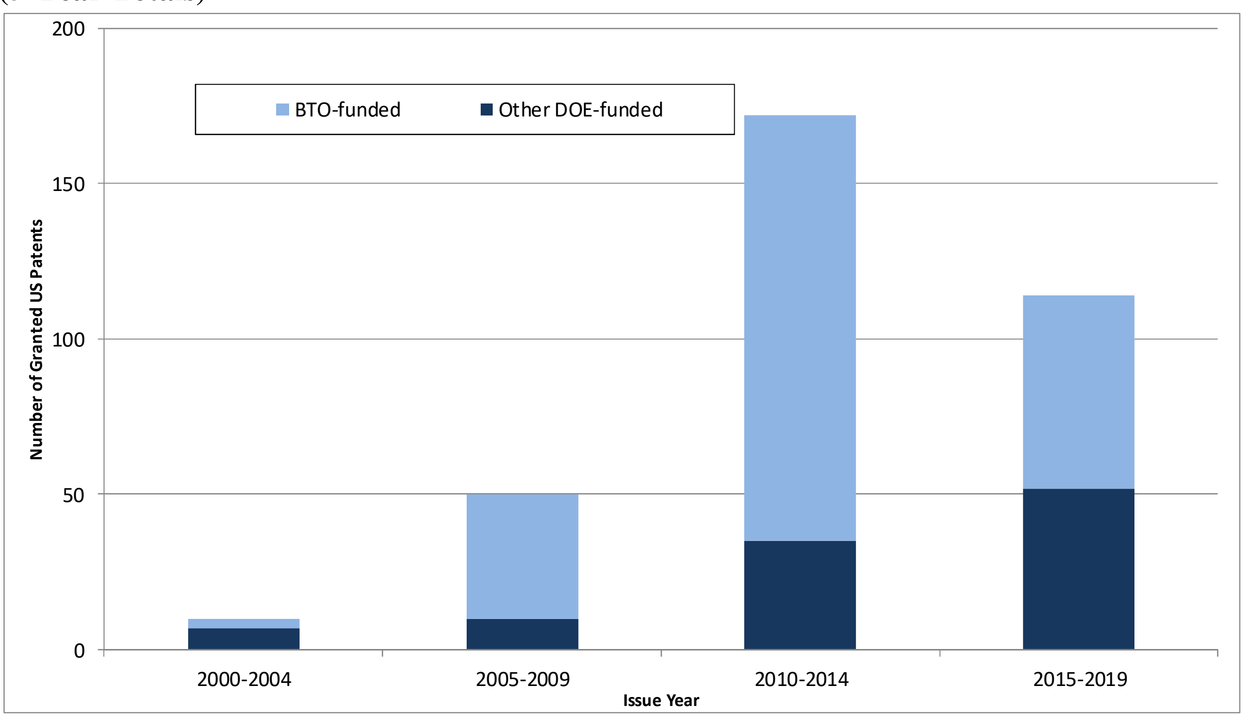


Note: The final time period in this figure is 2015-2018, and is shown for completeness, although data for this time period are incomplete. Our primary data collection covered only patents issued through 2018. Due to time lags associated with the patenting process, only a fraction of the patent families from 2015-2018 will be included.

While this analysis covers the period from 1975 onwards, Figure 1 reveals that the first DOE-funded SSL patent families were not filed until the latter part of the 1990s (corresponding to the start of DOE's funding of SSL research), with five such families filed in 1995-1999. That said, once it started, DOE-funded patenting related to SSL technology grew very rapidly, with 52 patent families filed in 2000-2004 and 101 filed in 2005-2009. The majority of these patent families were funded by BTO (36 out of 52 in 2000-2004; 82 out of 101 in 2005-2009). The number of DOE-funded SSL patent families then fell slightly to 88 (59 BTO-funded) in 2010-2014. This decline continued in 2015-2018, although data for this time period are incomplete (see note below Figure 1).

Figure 1 suggests that DOE-funded SSL patenting increased throughout the period from 1995-2009, with BTO-funding associated a high percentage of these patents. After that time, there was then a decline in DOE-funded (and BTO-funded) SSL patenting. This pattern is also reflected in Figure 2, which shows the number of SSL granted U.S. patents funded by DOE since 2000 (the first time period in which there were any such patents). As in Figure 1, there is a rapid increase in DOE-funded patenting over time, peaking at 172 U.S. patents granted in 2010-14, 137 of which were funded by BTO. There is then a decline in the most recent time period, with 114 U.S. patents granted in 2015-19, 62 of which were BTO-funded. This decline is partially explained by the incomplete data for this time period (see note below Figure 2).

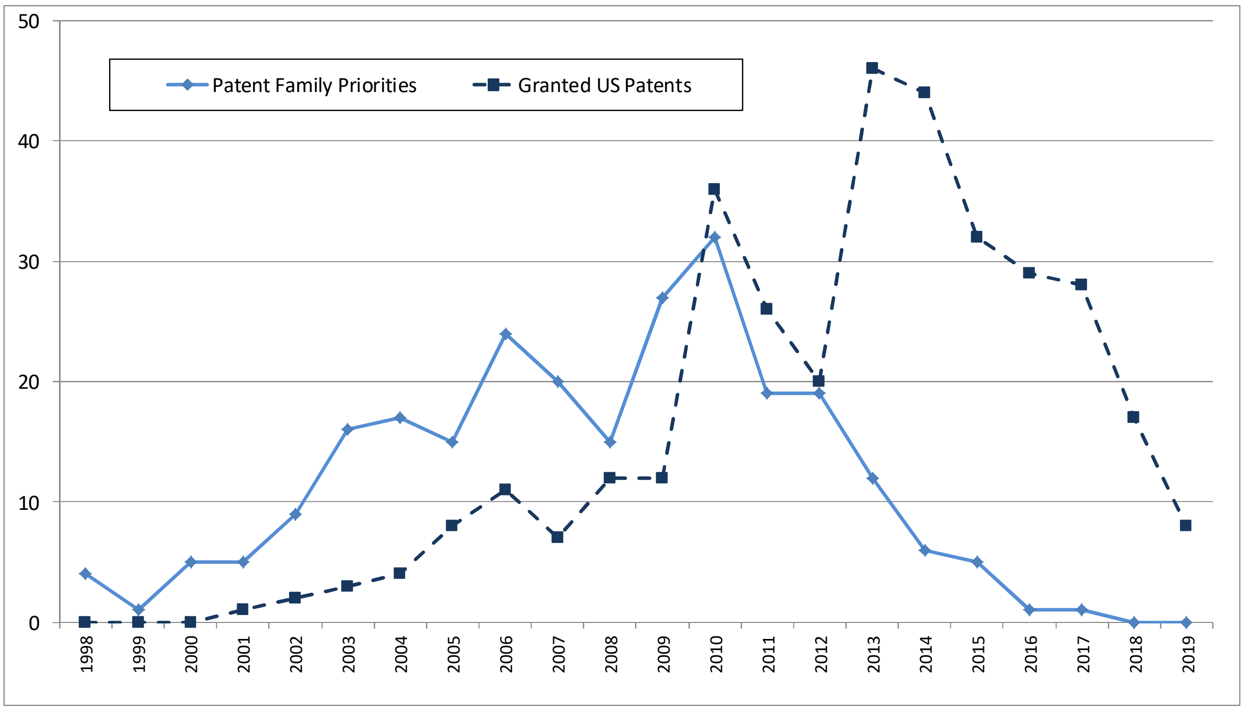
Figure 2 - Number of BTO/Other DOE-Funded SSL Granted U.S. Patents by Issue Year (5-Year Totals)



Note: The data collection period for this analysis ended with 2018. Any 2019 patents in the 2015-2019 column are additional patents that have been included because they are members of the same patent families as pre-2019 patents. No new patent search for 2019 was carried out.

Comparing Figures 1 and 2 shows the effect of time lags in the patenting process, with many of the patent families with priority dates in 2005-2009 and 2010-2014 (Figure 1) resulting in granted U.S. patents in 2010-2014 and 2015-2019 (Figure 2). These time lags can also be seen in Figure 3, which shows SSL patent family priority years alongside issue years for granted U.S. SSL patents (in this figure, BTO and Other DOE are combined, in order to simplify the presentation). In this figure, there are peaks in patent family priorities in 2006 and 2010, with corresponding peaks in granted U.S. patents occurring in 2010 and 2013-2014. More recently, patent family priorities dropped away after 2012, resulting in a decline in U.S. patents from 2015 onwards (note that, due to the primary data collection for this analysis ending in 2018, the number of granted U.S. patents declines sharply in 2019, and the number of families is zero).

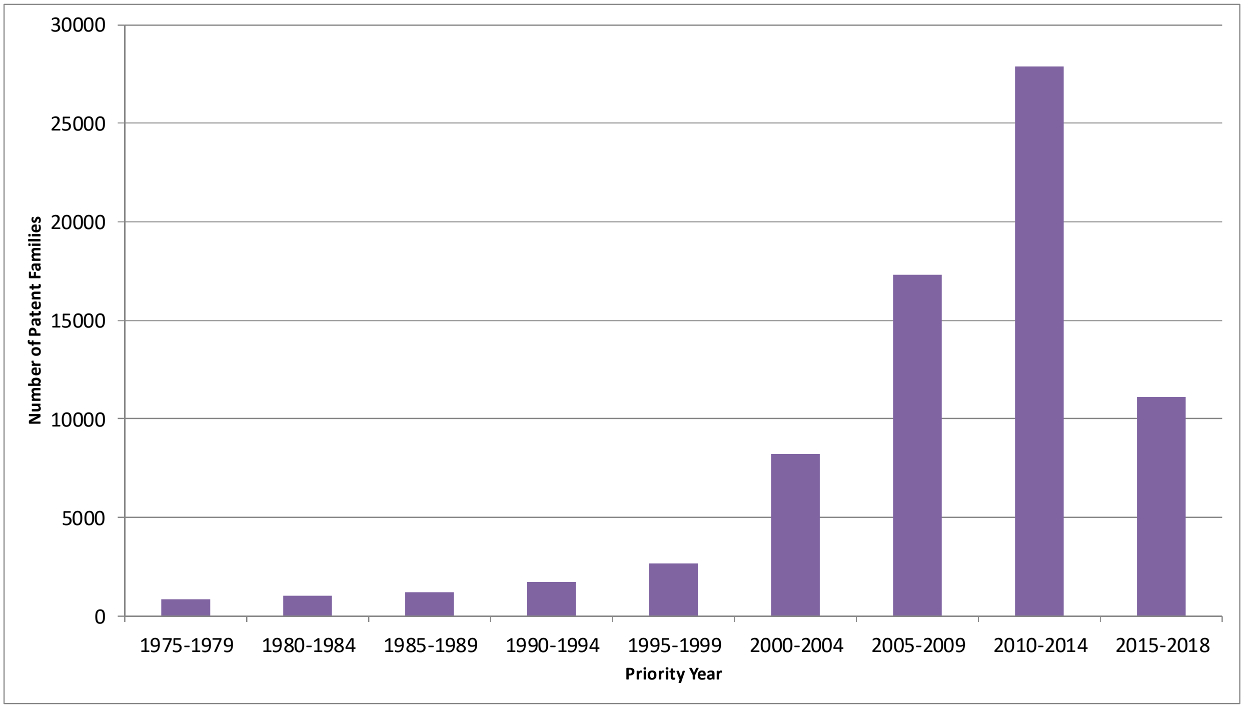
Figure 3 - Number of DOE-funded SSL Patent Families (by Priority Year) and Granted U.S. Patents (by Issue Year)



Note: The data collection period for this analysis ended with 2018. Any 2019 patents are additional patents that have been included because they are members of the same patent families as pre-2019 patents. No new patent search for 2019 was carried out.

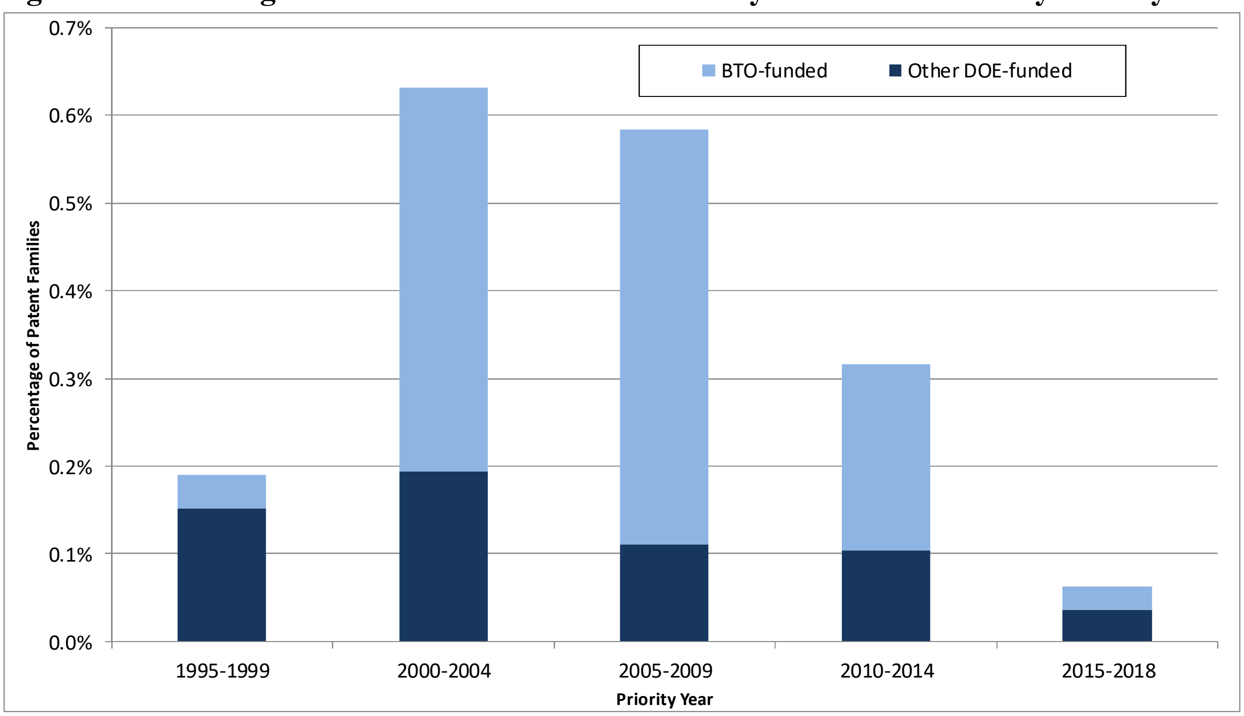
Figures 1-3 focus on DOE-funded SSL patent families. Figure 4 broadens the scope, and shows the overall number of SSL patent families by priority year (based on USPTO, EPO, and WIPO filings). This chart covers the period back to 1975. It reveals that overall SSL patenting was relatively steady throughout the period from 1975 to 1994, averaging around 200-300 patent families per year (i.e. 1000-1500 families per 5-year period). The number of SSL patent families then started to grow, with the increase being particularly substantial from 2000 onwards, peaking at 27,853 families filed in 2010-2014. There were more than ten times as many SSL patent families filed in 2010-2014 as there were in 1995-1999. In 2015-2018, the number of patent families declined to 11,101, although data for this period are incomplete. Comparing Figure 4 with Figure 1 suggests that the trend in DOE-funded (and BTO-funded) SSL patenting is in line with the broader trend in this technology, with a rapid growth in the early part of this century, followed by a decline in the most recent years. That said, the peak in DOE-funded patenting occurred earlier than the peak for overall patenting (2005-2009 versus 2010-2014).

Figure 4 - Total Number of SSL Patent Families by Priority Year (5-Year Totals)



Note: The final time period in this figure is 2015-2018, and is shown for completeness, although data for this time period are incomplete. Our primary data collection covered only patents issued through 2018. Due to time lags associated with the patenting process, only a fraction of the patent families from 2015-2018 will be included.

Figure 5 - Percentage of SSL Patent Families Funded by BTO/Other DOE by Priority Year



The overall number of SSL patent families is very high, showing that this has been an important technology for many large companies over a significant period of time. Within this highly active patent landscape, DOE-funded patent families represent only a small percentage of the overall total, as reflected in Figure 5. This figure shows the percentage of SSL patent families that were funded by DOE (BTO plus Other DOE). The percentage has never been above 1% of the total, peaking at 0.63% in 2000-2004. Overall, 0.35% of SSL patent families in the period 1976-2018 were funded by DOE. The small DOE-funded SSL patent portfolio, relative to the overall SSL patent landscape, should be kept in mind in assessing the results of this analysis.

Leading SSL Assignees

The ten leading patenting companies in SSL technology are listed above in Table 4, along with their number of SSL patent families. Figure 6 shows the same information in graphical form, while also including DOE-funded patent families. The SSL patents of these top ten companies form the basis for the backward tracing element of the analysis, as outlined below.

Figure 6 – Top 10 SSL Companies (based on number of patent families)

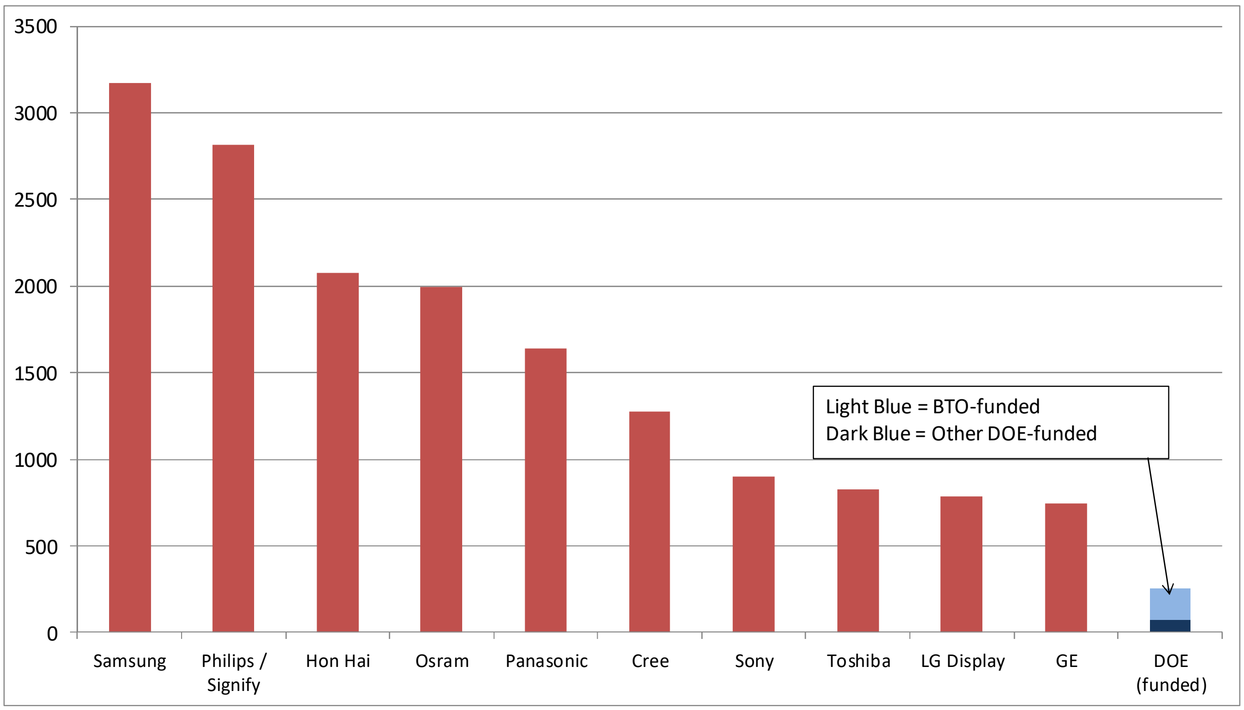


Figure 6 is headed by Samsung with 3,171 SSL patent families, followed by Philips/Signify (2,815 families), Hon Hai Precision (2,076 families) and Osram (1,996 families). It is interesting to note the geographical distribution of the leading SSL companies in Figure 6. Out of these ten companies, six are based in Asia, two in Europe and two in North America. This reinforces the earlier point that, while the analysis does not include patents from Asian systems, this does not mean that patents associated with Asian companies are excluded.

Figure 6 also shows that the DOE-funded SSL patent portfolio is much smaller than those assigned to the leading companies. For example, while Samsung has over 3,000 SSL patent families, there are a total of 253 DOE-funded SSL patent families, 181 of which are associated with BTO funding. In assessing the impact of BTO-funded and Other DOE-funded SSL patents,

versus the impact of the patent portfolios associated with the leading companies, we therefore take into account this difference in portfolio size.
It should be noted that there is some double-counting of patent families in Figure 6, specifically where innovations developed by a leading company were funded in whole or in part by BTO (or another office within DOE). For example, Cree, General Electric, Philips/Signify, Osram and Samsung all have SSL patent families that were partially or fully funded by BTO. In Figure 6, these patent families are counted in both the BTO segment of the DOE column, and in the respective company columns. This double-counting is appropriate, since these patent families are both funded by BTO and assigned to a leading company.

Assignees of BTO/Other DOE-funded SSL Patents

The DOE-funded SSL patent portfolios are constructed somewhat differently from the portfolios of the top ten companies listed in Figure 6. Specifically, DOE's 253 patent families are those funded by DOE, but they are not necessarily assigned to the agency. For example, BTO (or another DOE office) may have partially or fully funded research projects at DOE labs or companies. In such cases, the assignees of any resulting patents will be the respective DOE lab managers or companies (as in the case of the leading company patent families discussed above).

Figure 7 shows the leading assignees on BTO-funded patent families. This chart is headed by three of the ten leading SSL companies included in this analysis: General Electric (40 patent families), Osram (15 families) and Cree (13 families). The remaining assignees in Figure 7 include other lighting and display companies, including Universal Display, Philips/Signify and Eastman Kodak. They also include a number of universities, including the University of Southern California, University of California (Santa Barbara), University of Michigan and Lehigh University. Figure 7 thus reflects the range of organizations that have carried out BTO-funded SSL research.

Figure 7 - Assignees with Largest Number of BTO-Funded SSL Patent Families

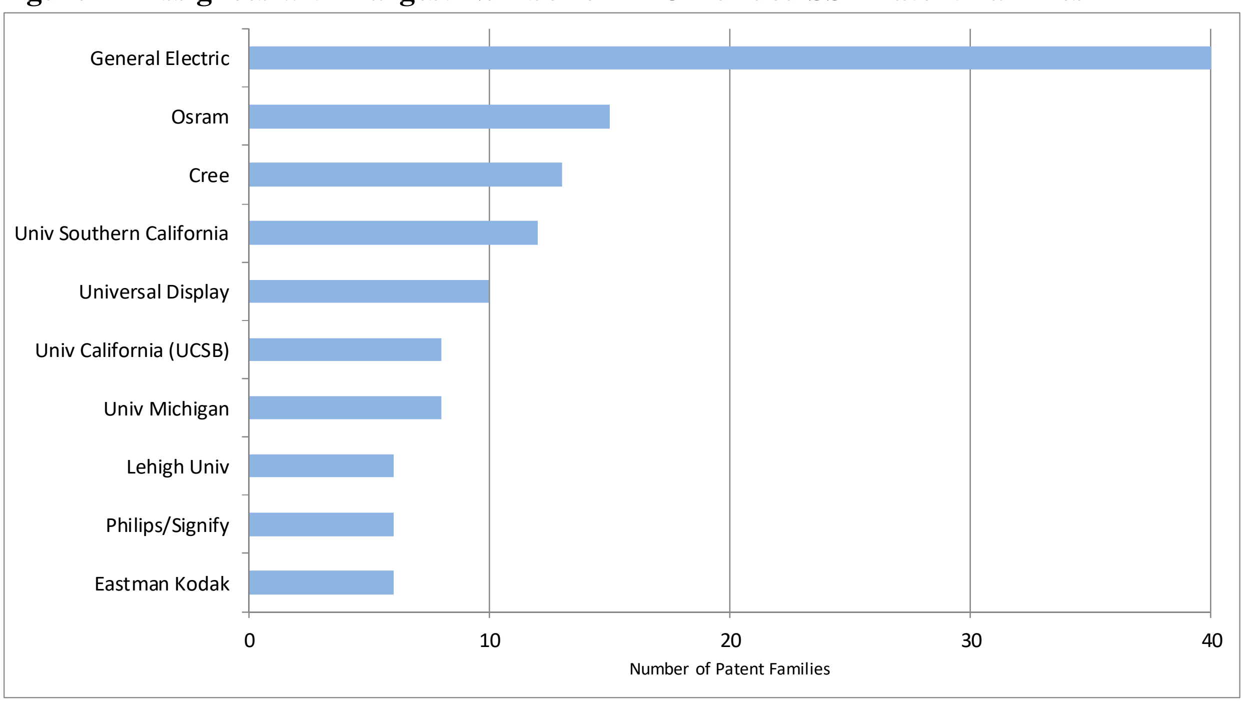
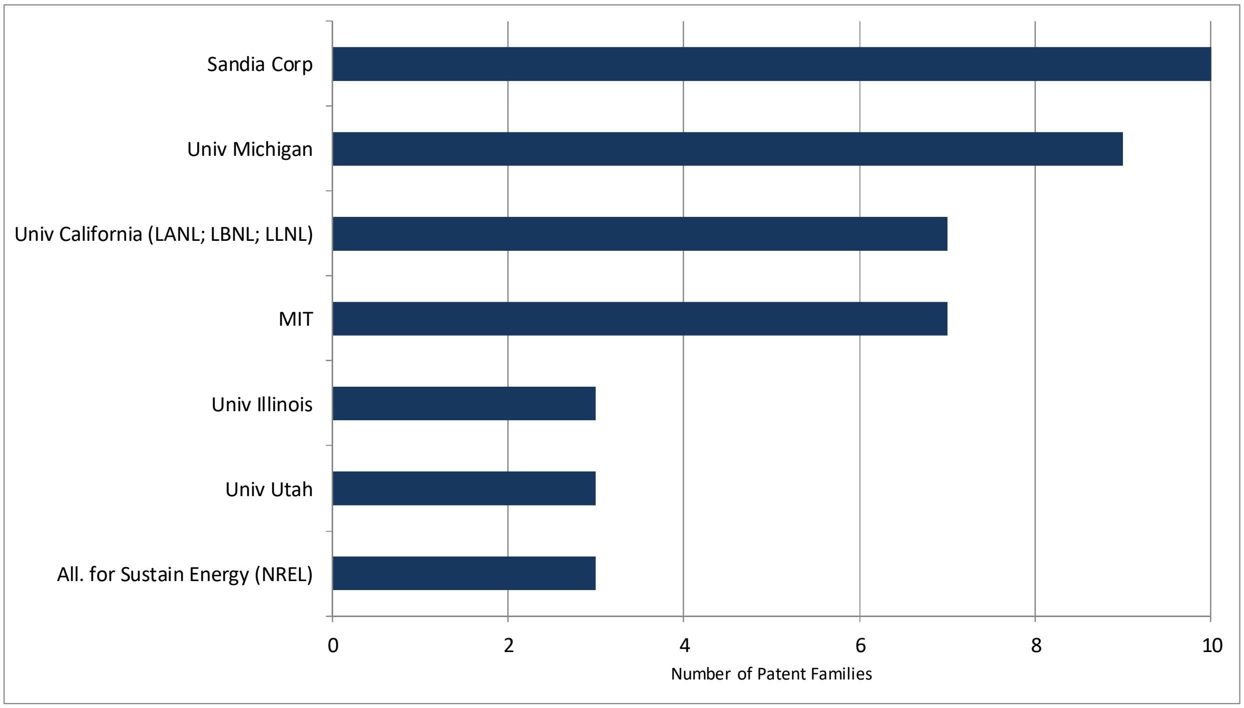


Figure 8 shows the leading assignees on Other DOE-funded SSL patent families. The numbers of patent families in this figure are lower than for the BTO-funded assignees in Figure 7, reflecting the fact that there are fewer Other DOE-funded patent families in general. Another notable difference between the two figures is that the Other DOE-funded assignees in Figure 8 are all either universities or DOE lab managers, with no companies present in this figure. The universities include Michigan, Illinois and Utah, while the DOE lab managers include Sandia Corp (Sandia National Laboratory), University of California (Los Alamos National Laboratory, Lawrence Berkeley National Laboratory and Lawrence Livermore National Laboratory) and the Alliance for Sustainable Energy (National Renewable Energy Laboratory).

Figure 8 - Assignees with Largest Number of Other DOE-funded SSL Patent Families



Distribution of SSL Patents across Patent Classifications

We analyzed the distribution of BTO-funded SSL U.S. patents across Cooperative Patent Classifications (CPCs).[9] We then compared this distribution to those associated with Other DOE-funded SSL patents; SSL patents assigned to the ten leading companies; and the universe of all SSL patents. This analysis provides insights into the technological focus of BTO funding in SSL, versus the focus of the rest of DOE, leading SSL companies, and SSL technology in general.

The results from this CPC analysis are shown in two separate charts, each from a different perspective. The first chart (Figure 9) is based on the six CPCs that are most prevalent among BTO-funded SSL patents. The purpose of this chart is thus to show the main focus areas of BTO-

[9] The CPC is a patent classification system. Patent offices attach numerous CPC classifications to a patent, covering the different aspects of the subject matter in the claimed invention. In generating these charts, all CPCs associated with each patent are included.

funded SSL research, and the extent to which these areas translate to other portfolios (Other DOE-funded; leading SSL companies; all SSL).

This figure shows that BTO-funded research includes relatively balanced coverage across the six CPCs (which is not particularly surprising, since the BTO-funded patent portfolio forms the basis for the CPCs included in the chart). The most common CPC among BTO-funded SSL patents is H01L 51, which appears on 42% of these patents (it also appears on 44% of Other DOE-funded SSL patents). This CPC is related to organic solid state devices, as is another prominent CPC in Figure 9 – H01L 2251. The portfolios of SSL patents owned by the leading companies, and SSL patents overall, have much less presence in these CPCs, suggesting organic solid state devices are a technology where DOE (and BTO) funding has had an important role. The same is true with respect to CPC C09K 11 (Luminescent materials), where BTO-funded and Other DOE-funded SSL patents have a much greater concentration than the other portfolios.

Figure 9 - Percentage of SSL U.S. Patents in Most Common Cooperative Patent Classifications (Among BTO-Funded Patents)

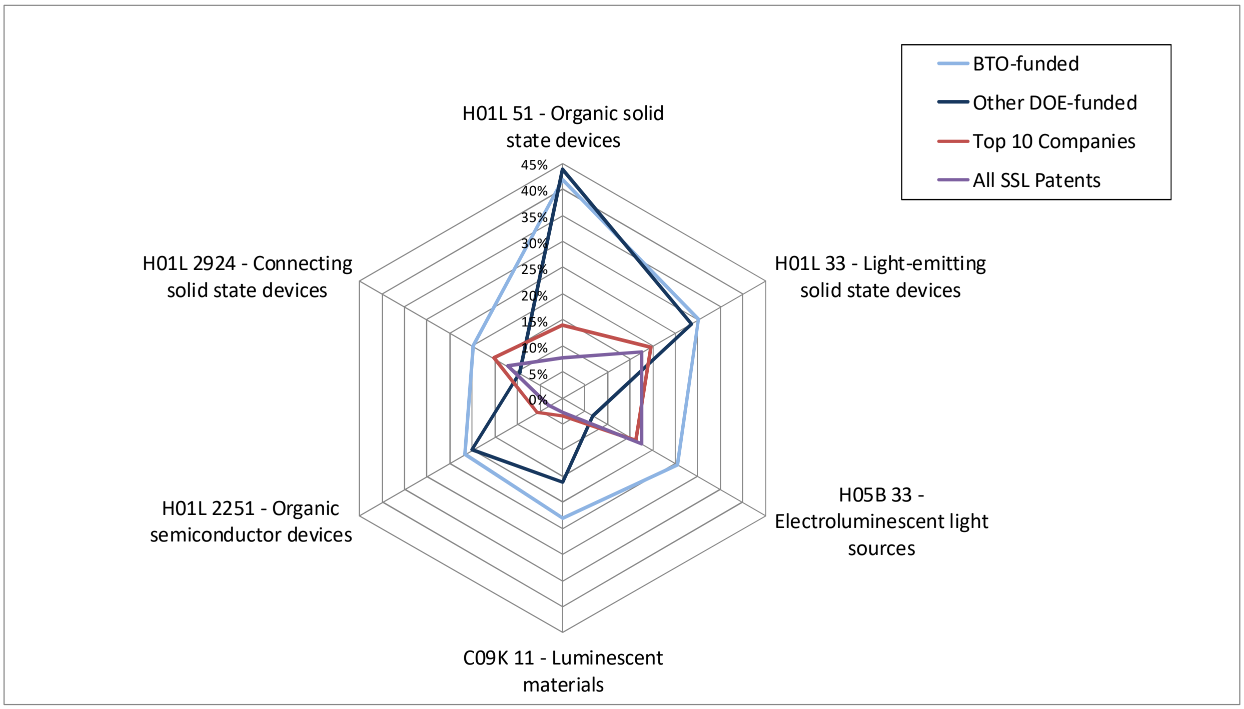


Figure 10 is similar to Figure 9, except that it is from the perspective of the most common CPCs among all SSL patents. Hence, the purpose of this chart is to show the main research areas within SSL as a whole, and how these areas are represented in selected SSL portfolios (BTO-funded; Other DOE-funded; leading SSL companies). The most common CPC among all SSL patents is F21Y 2115, which is related to semiconductor lighting elements. Over 30% of SSL patents include this CPC, as do 26% of patents assigned to the leading SSL companies. Another CPC that appears in Figure 10, but not Figure 9, is F21K 9 (Semiconductor light sources). These CPCs are primarily concerned with the mechanical and structural characteristics of lighting devices, rather than the materials and associated chemistries that go into these devices (which are a greater focus for BTO-funded and Other DOE-funded patents). As such, it appears that the leading companies, and SSL patents overall, have a stronger focus on improving the manufacture of lighting devices, which is understandable from a commercial perspective.

Figure 10 - Percentage of SSL U.S. Patents in Most Common Cooperative Patent Classifications (Among All SSL Patents)

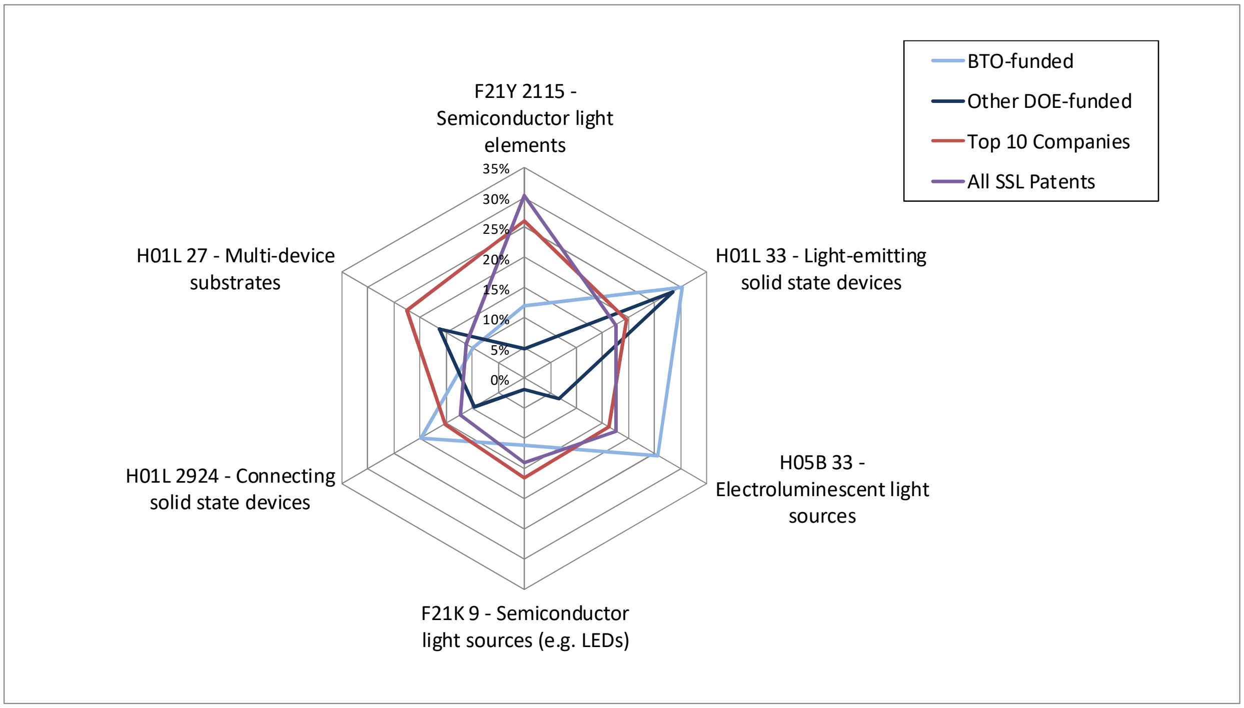


Figure 11 - Percentage of BTO-funded SSL U.S. Patents in Most Common Cooperative Patent Classifications across Two Time Periods

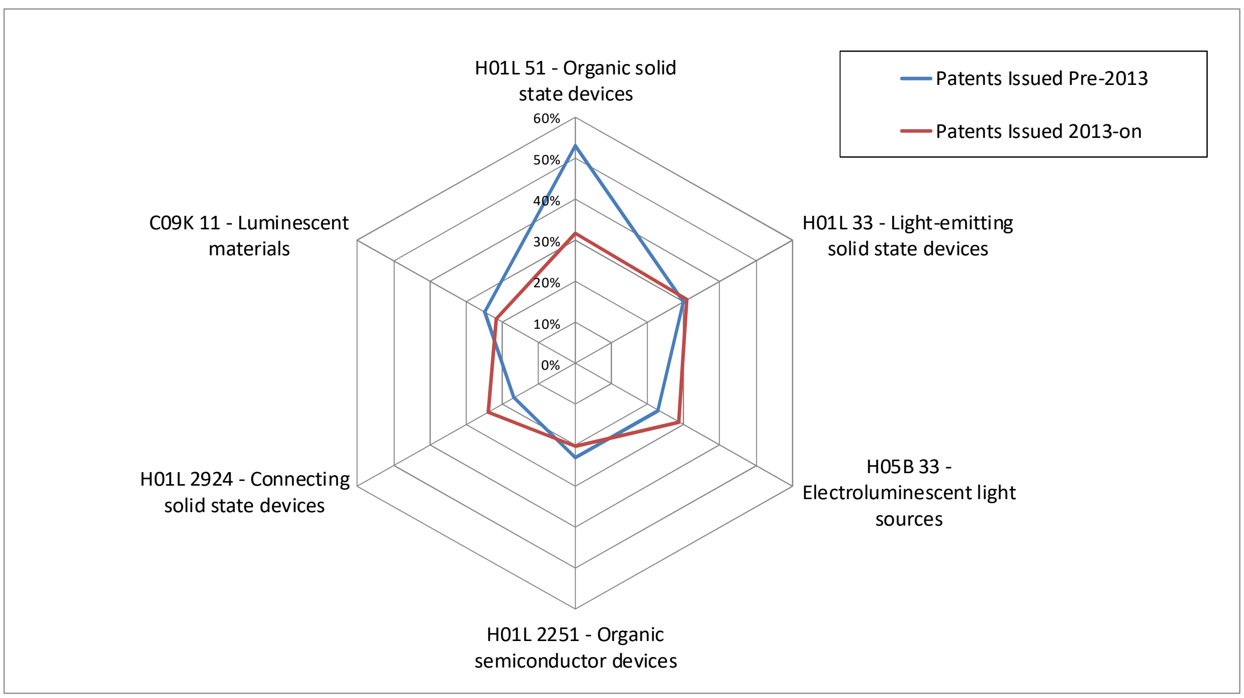


Figure 11 compares the CPC distribution of BTO-funded SSL U.S. patents across two time periods – patents issued through 2012, and those issued from 2013 onwards (these dates are selected to divide the patents into two groups of approximately equal size). This figure reveals that the CPCs associated with BTO-funded patents have been relatively consistent over time, with similar percentages of patents in each CPC across the two time periods. One exception is H01L 51 (Organic solid state devices). A higher percentage of BTO-funded patents issued through 2012 have that CPC attached than BTO-funded patents issued since that time.

Tracing Backwards from SSL Patents Owned by Leading Companies

This section reports the results of an analysis tracing backwards from SSL patents owned by leading companies in this technology to earlier research, including that funded by DOE. The results in this section are examined at two levels. First, we report results at the organizational level. These results reveal the extent to which BTO-funded (and Other DOE-funded) research forms a foundation for subsequent innovations associated with leading SSL companies. Second, we drill down to the level of individual patents, with a particular focus on BTO-funded SSL patents. These patent-level results highlight specific BTO-funded patents that have influenced subsequent patents owned by leading companies. They also highlight which SSL patents owned by these leading companies are linked particularly extensively to earlier BTO-funded research.

Organizational Level Results

In the organizational level results, we first compare the influence of BTO-funded and Other DOE-funded SSL research against the influence of leading SSL companies. We then look at which of these leading companies build particularly extensively on DOE-funded SSL research.

Figure 12 compares the influence of DOE-funded SSL research to the influence of research carried out by the top ten SSL companies. Specifically, this figure shows the number of SSL patent families owned by the leading companies that are linked via citations to earlier SSL patent families assigned to each of these leading companies (plus patent families funded by DOE). In other words, this figure shows the companies whose patents have had the strongest influence upon subsequent developments made by leading companies in SSL technology.[10]

In total, 782 leading company SSL patent families (i.e. 4.9% of their 16,018 families) are linked via citations to earlier DOE-funded SSL patents, out of which 496 are linked to BTO-funded SSL patents. This finding puts DOE-funded patents second-last in Figure 12. In comparison, 4,503 leading company patent families are linked via citations to earlier Philips/Signify patent families. At first glance, the finding in Figure 12 does not appear promising in terms of DOE's influence on SSL technology. However, this figure does not take into account the different sizes of the patent portfolios associated with the various companies. For example, it is not surprising

[10] This figure compares the influence of patents *funded* by BTO/DOE against patents *owned* by (i.e. assigned to) organizations. Such a comparison is reasonable, since patents funded by organizations through their R&D budgets will be assigned to those organizations. Also, organizations cannot choose to reference the patents of a non-competitor (such as DOE) rather than the patents of a competitor in order to reduce the "credit" given to that competitor. Such an omission could lead to the invalidation of their patents. Note that, as in Figure 6, there is some double-counting in Figure 12 and Figure 13, as some patent families assigned to Cree, General Electric, Philips/Signify, Osram and Samsung were also funded by DOE. Also, in Figures 12 and 14-16, leading company patent families linked to both BTO-funded and Other DOE-funded patents are allocated to the BTO-funded segment of the DOE column, in order to avoid double-counting these families.

that many more patent families are linked via citations to Philips/Signify than to DOE, since Philips/Signify has more than ten times as many patent families available to be cited as prior art.

Figure 12 - Number of Leading Company SSL Patent Families Linked via Citations to Earlier SSL Patents from each Leading Company
e.g. 782 leading company families are linked to earlier BTO/Other DOE-funded families

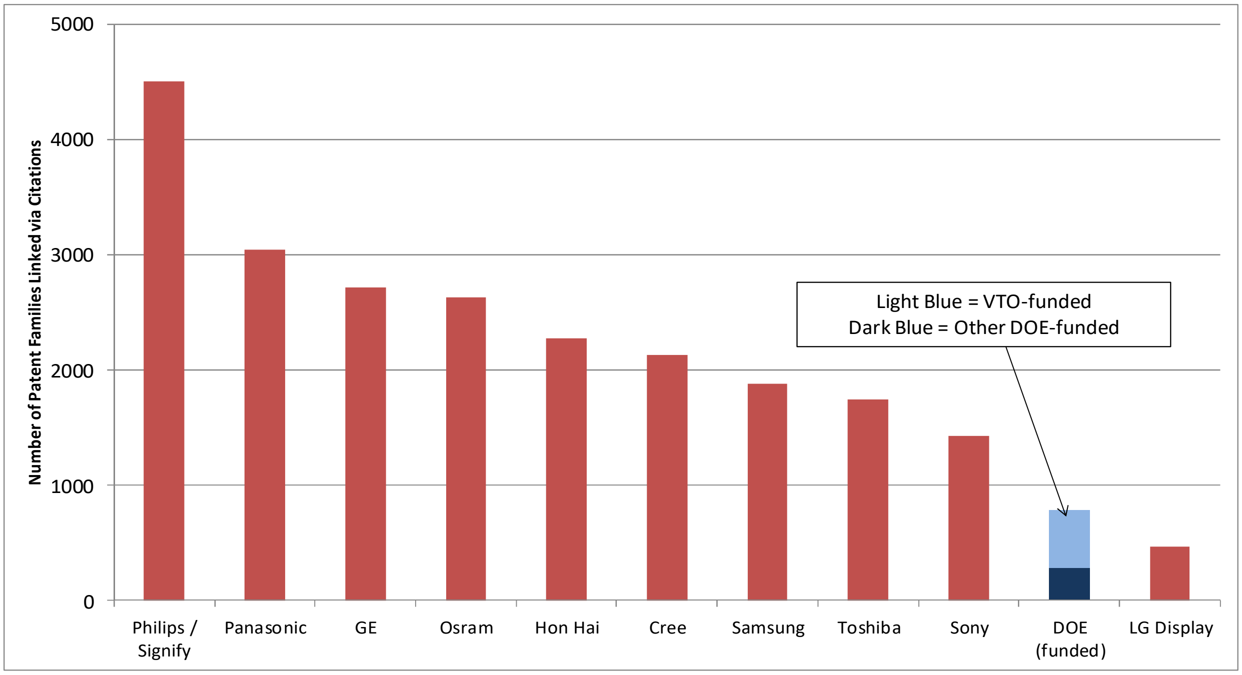


Figure 13 – Average Number of Leading Company SSL Patent Families Linked via Citations to SSL Families from Each Leading Company
e.g. on average, each DOE-funded patent family is linked to over three subsequent patent families assigned to leading companies

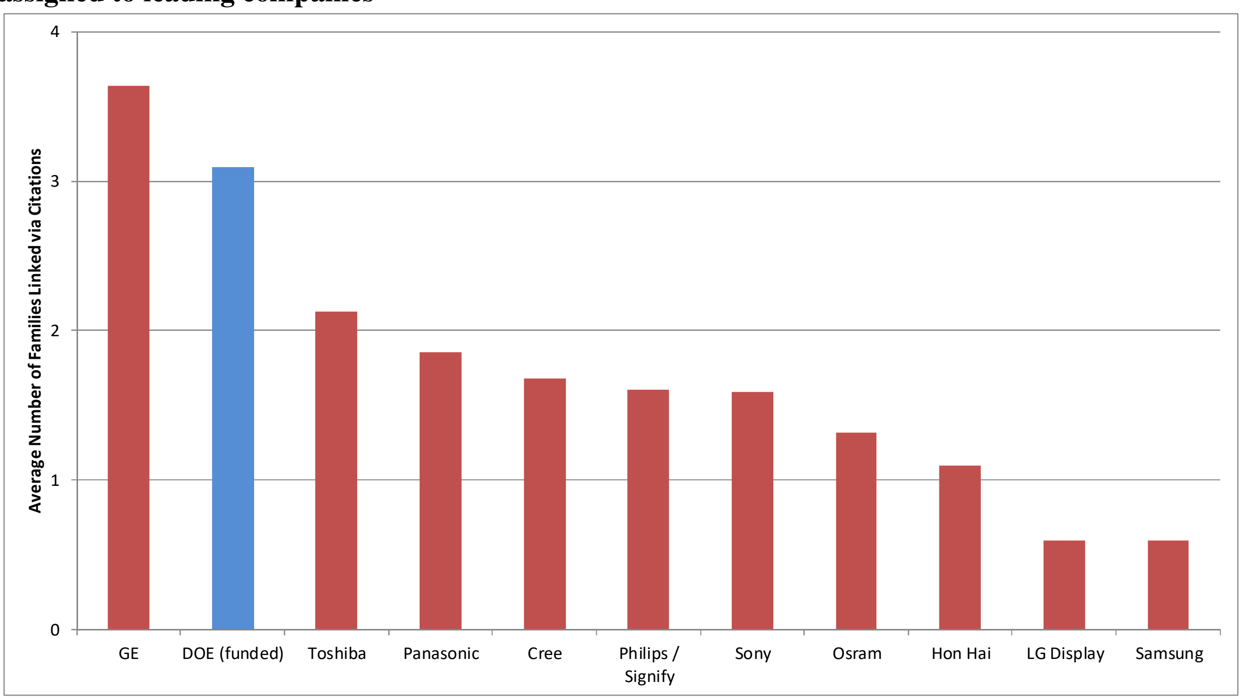


Figure 13 takes into account the differences in patent portfolio size. It shows the average (mean) number of leading company patent families linked to patent families associated with each of the leading companies, plus DOE. For example, on average, DOE-funded SSL patent families (the majority of which are BTO-funded) are each linked to over three patent families assigned to the leading companies. This puts DOE in second place in Figure 13, behind only General Electric. It means that, on average, more SSL patent families owned by leading companies are linked via citations to each DOE-funded SSL patent family than are linked to the SSL patent families assigned to any other leading company (with the exception of General Electric). Figure 13 thus suggests that, taking into account its relatively small size, the portfolio of DOE-funded SSL patents has helped form an important part of the foundation for SSL research carried out by the leading companies.

Figures 14 through 16 examine which of the leading companies build particularly extensively on earlier DOE-funded patents. Figure 14 shows how many SSL patent families owned by each of the leading companies are linked via citations to at least one earlier DOE-funded SSL patent. Out of the ten leading SSL companies, Cree is linked particularly strongly to earlier DOE-funded patents, suggesting that it builds most extensively on earlier DOE-funded SSL research. In total, 306 of Cree's SSL patent families are linked via citations to earlier DOE-funded SSL patents, 220 of which are linked to BTO-funded patents. Samsung is in second place in Figure 14, with 152 patent families linked to DOE–funded patents (61 to BTO-funded patents), followed by Osram (88 families linked to DOE; 53 to BTO) and Philips/Signify (73 families linked to DOE; 47 to BTO).

Figure 14 – Number of Patent Families Linked via Citations to Earlier BTO/Other DOE-funded SSL Patents for each Leading SSL Company

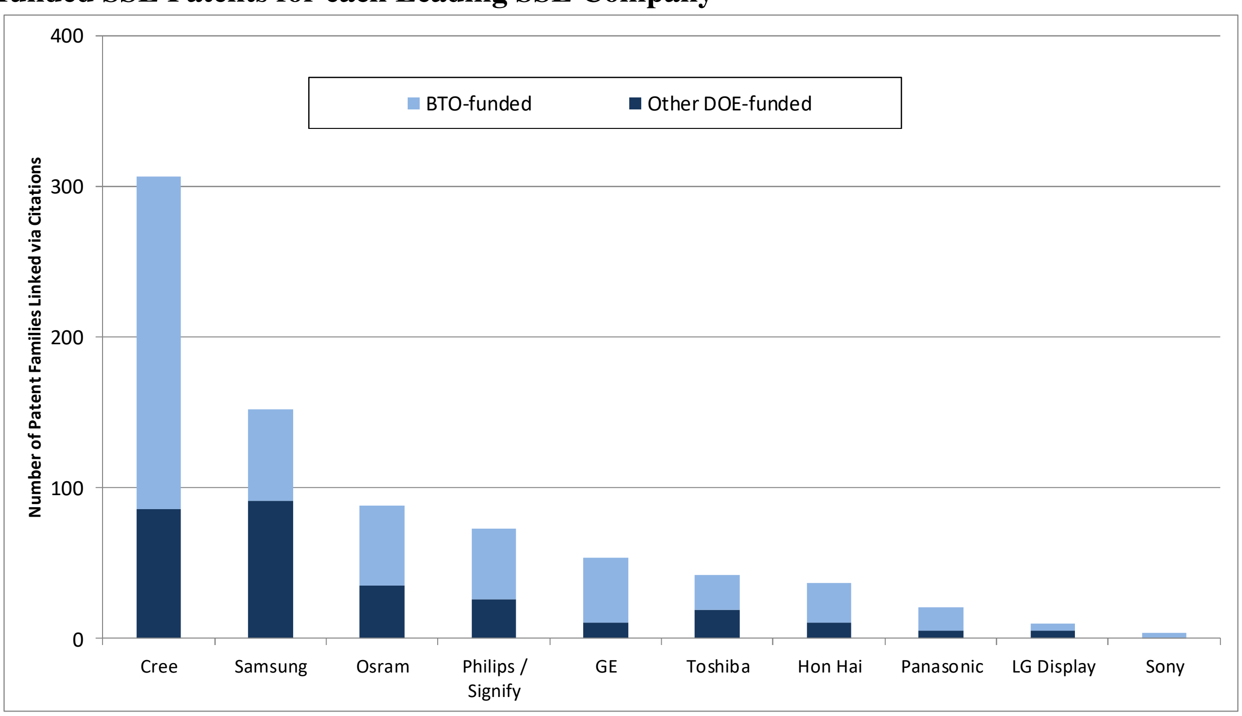
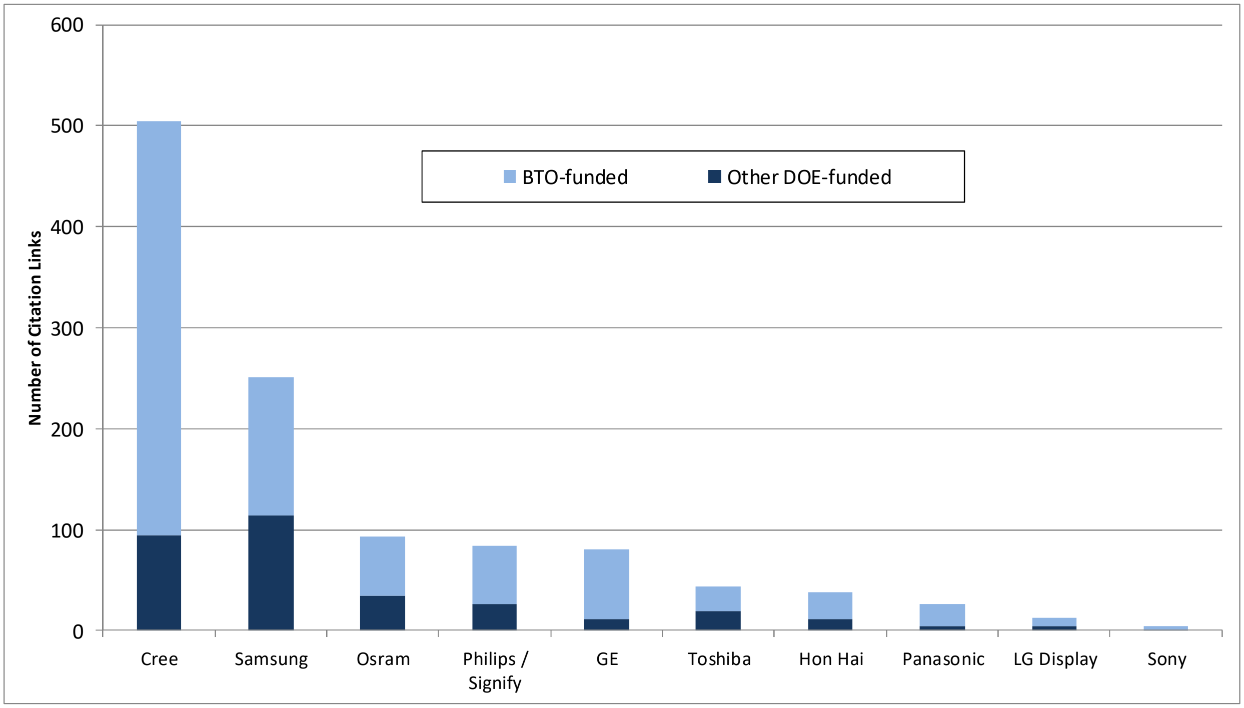


Figure 15 counts the total number of citation links from leading companies to earlier DOE-funded patents. This differs slightly from the count of linked families in Figure 14, since a single patent family can be linked to multiple earlier DOE-funded patents. The same four companies are at the head of Figure 15, reinforcing their close links to earlier DOE-funded SSL research. Cree is again at the head of this figure, with 505 citation links to earlier DOE-funded patents (411 of which are links to BTO-funded patents), followed by Samsung (251 links to DOE; 137 to BTO), Osram (93 links to DOE; 58 to BTO) and Philips/Signify (84 links to DOE; 58 to BTO).

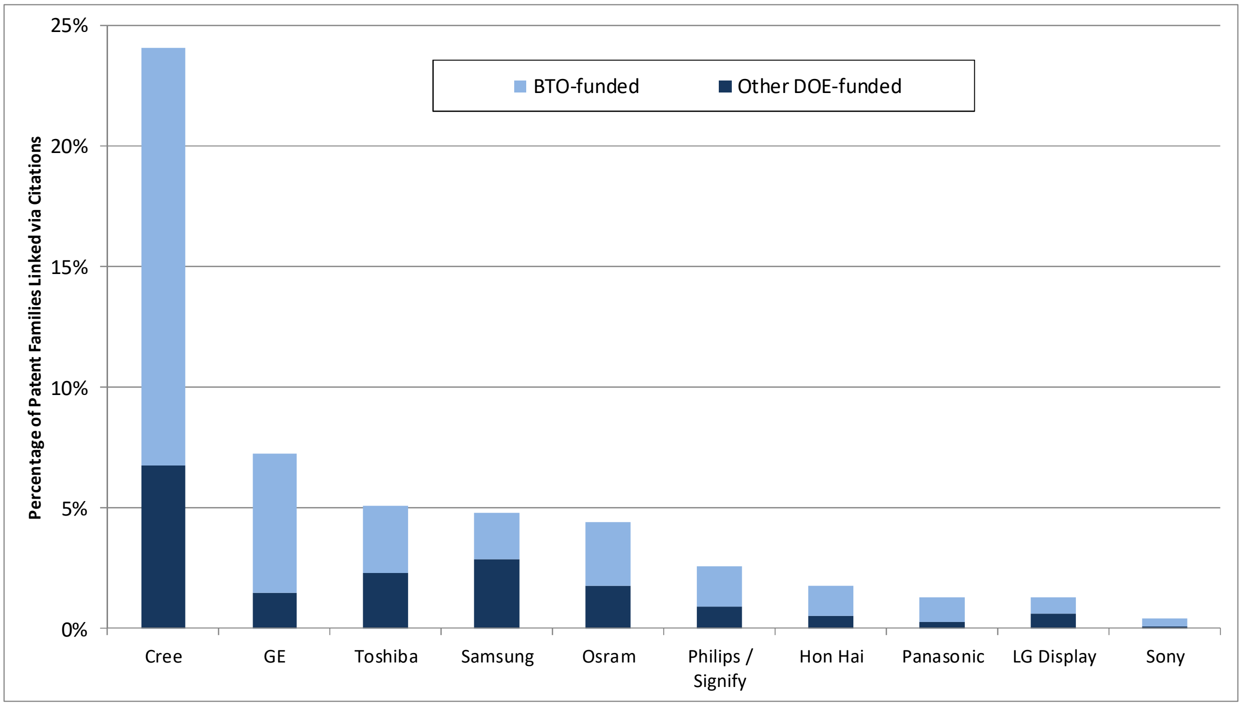
Figure 15 - Number of Citation Links from Leading SSL Company Patent Families to Earlier BTO/Other DOE-funded SSL Patents



There is an element of portfolio size bias in the patent family counts in Figures 14 and 15. Companies with larger SSL patent portfolios are likely to have more patent families linked to DOE, simply because they have more families overall. Figure 16 accounts for this portfolio size bias by calculating the percentage of each leading company's SSL patent families that are linked via citations to earlier DOE-funded SSL patents, rather than their absolute number. This is a measure of how extensively each company builds on DOE-funded research, relative to their overall patent output.

Figure 16 further emphasizes the strong links from Cree's SSL patent families to earlier DOE-funded research. In total, 24% of Cree's SSL patent families are linked via citations to DOE-funded SSL patents, 17.3% of which are linked to BTO-funded patents. General Electric becomes more prominent in Figure 16, with 7.2% of its SSL patent families linked to via citations to DOE-funded patents (5.8% to BTO-funded patents). Meanwhile, Samsung is somewhat less prominent in Figure 16, with its higher position in Figure 14 and Figure 15 resulting in part from the size of its patent portfolio.

Figure 16 - Percentage of Leading SSL Company Patent Families Linked via Citations to Earlier BTO/Other DOE-funded SSL Patents



Patent Level Results

The previous section of the report examined results at the level of entire patent portfolios. The purpose of this section is to drill down to identify individual DOE-funded SSL patent families (in particular BTO-funded families) that have had a particularly strong influence on subsequent SSL patents owned by leading companies in this technology. Looking in the opposite direction, it also identifies individual SSL patents owned by leading companies that have extensive links to earlier BTO-funded research.

Table 5 shows the BTO-funded SSL patent families linked via citations to the largest number of subsequent patent families owned by leading companies in this technology. These patents are mainly from the early 2000s, and so are among the oldest BTO-funded patents in the analysis. This is not surprising, since older patents have had a longer time period to become connected to subsequent generations of technology. As such, the patent families in Table 5 represent early BTO-funded technologies that are linked to many subsequent innovations associated with leading companies in the SSL industry.

The BTO-funded patent family linked to the most leading company families is assigned to Light Prescriptions Innovators. This patent family (whose representative patent[11] is US #7,286,296) describes a manifold for combining multiple LED outputs into a single package. It is linked via citations to 91 subsequent patent families assigned to the leading companies, including at least one family from each of these ten companies. Cree has the most patent families linked to this

[11] The representative patent is a single patent from a family, but it is not necessarily the priority filing.

BTO-funded family, many of them describing LED devices and packages. Cree itself is the assignee on the BTO-funded patent families in second and third place in Table 5 (representative patents US #7,821,023 and US #6,972,438). These Cree patent families describe LED devices, and are linked to 82 and 80 leading company patent families respectively. Meanwhile, the subsequent patent families are assigned to both Cree itself, and to a number of other leading companies. Also prominent in Table 5 is a patent family assigned to Rensselaer Polytechnic Institute (RPI). This patent family (representative patent US #7,819,549) outlines a solid state light source with a down-conversion material to improve performance. It is linked to 71 patent families assigned to eight out of the ten leading companies (all except LG Display and Toshiba).

Table 5 – BTO-Funded SSL Patent Families Linked via Citations to Most Subsequent Leading Company SSL Patent Families

Patent Family #	Representative Patent #	Priority Year	# Linked Families	Assignee	Title
35197575	7286296	2004	91	Light Prescriptions Innovators	Optical manifold for light-emitting diodes
41066696	7821023	2005	82	Cree Inc	Solid state lighting component
34422124	6972438	2003	80	Cree Inc	Light emitting diode with porous SiC substrate and method for fabricating
35320662	7819549	2004	71	Rensselaer Poly Inst	High efficiency light source using solid-state emitter and down-conversion material
28453526	6891330	2002	43	General Electric	Mechanically flexible organic electroluminescent device with directional light emission
32393040	6952079	2002	42	General Electric	Luminaire for light extraction from a flat light source
36940156	7321193	2005	31	Osram Opto Semics GmbH	Device structure for OLED light device having multi element light extraction and luminescence conversion layer
42005770	8075147	2003	28	Light Prescriptions Innovators	Optical device for LED-based lamp
33424117	6982045	2003	23	Phosphortech Corp	Light emitting device having silicate fluorescent phosphor
39339055	7897980	2006	23	Cree Inc	Expandable LED array interconnect

Table 5 lists BTO-funded patents linked to large numbers of subsequent SSL patent families owned by leading companies. Table 6 looks in the opposite direction, and lists SSL patent families owned by leading companies that are linked particularly extensively to earlier patents funded by BTO. This table is dominated by patent families assigned to Cree and Samsung. The patent family at the head of the table (representative patent US #9,929,325) is assigned to Samsung and describes a lighting device incorporating quantum dots. It is linked via citations to eight earlier BTO-funded patent families, including families assigned to General Electric, Osram and RPI describing luminescent materials and OLED devices. Table 6 also includes a series of patent families assigned to Cree (for example, representative patent US #9,920,901) describing various LED lighting technologies. These Cree patent families are linked via citations to earlier BTO-funded patents assigned to Light Prescriptions Innovators, General Electric and Osram describing LED packaging and OLED devices.

Table 6 - Leading Company SSL Patent Families Linked via Citations to Largest Number of BTO-Funded SSL Patent Families

Patent Family #	Representative Patent #	Priority Year	# BTO Fams	Assignee	Title
49945794	9929325	2012	8	Samsung	Lighting device including quantum dots
53881823	9920901	2013	7	Cree Inc	LED lensing arrangement
51222745	9869432	2013	7	Cree Inc	Luminaires using waveguide bodies and optical elements
49773645	9685585	2012	7	Cree Inc	Quantum dot narrow-band downconverters for high efficiency LEDs
43586548	8981339	2009	7	Samsung	Lighting devices, an optical component for a lighting device, and methods
42231599	8227979	2008	7	Samsung	Method of matching color in lighting applications
41416993	9167659	2008	7	Samsung	Solid state lighting devices including quantum confined semiconductor nanoparticles
51222768	9291320	2013	6	Cree Inc	Consolidated troffer
52998383	9018619	2006	6	Cree Inc	Quantum wells for light conversion
43066940	9951938	2009	6	General Electric	LED lamp
48446663	9841175	2012	6	General Electric	Optics system for solid state lighting apparatus

We also identified high-impact SSL patents owned by leading companies that have citation links back to BTO-funded patents.[12] The idea is to highlight important technologies owned by leading companies that are linked to earlier SSL research funded by BTO. Table 7 lists SSL patents owned by leading companies that have Citation Index values of five or over (i.e. they have been cited at least five times as frequently as expected), and are linked via citations to earlier BTO-funded SSL patents. The patents are listed in descending order based on their Citation Index.

Cree has a number of patents in Table 7, including the three at the head of this table. The first of these (US #9,360,185) describes a directional LED lighting system. This patent has been cited by 19 subsequent patents since it was issued in 2016, thirteen times as many citations as expected given its age and technology. In turn, this Cree patent is linked via citations to earlier BTO-funded General Electric and Light Prescriptions Innovators patents related to LED packages and luminaires. The second Cree patent (US #8,167,674) describes a method for distributing

[12] High-impact patents are identified using 1790's Citation Index metric. This metric is derived by first counting the number of times a patent is cited as prior art by subsequent patents. This number is then divided by the mean number of citations received by peer patents from the same issue year and technology (as defined by their first listed Cooperative Patent Classification). For example, the number of citations received by a 2010 patent in CPC C09K 11 (Luminescent Materials) is divided by the mean number of citations received by all patents in that CPC issued in 2010. The expected Citation Index for an individual patent is one. The extent to which a patent's Citation Index is greater or less than one reveals whether it has been cited more or less frequently than expected, and by how much. For example, a Citation Index of 1.5 shows a patent has been cited 50% more frequently than expected. Meanwhile a Citation Index of 0.7 reveals a patent has been cited 30% less frequently than expected. By extension, the expected Citation Index for a portfolio of patents is also one, with values above one showing that a portfolio has been cited more than expected, and values below one showing that a portfolio has been cited less frequently than expected. Note that the Citation Index is calculated for U.S. patents only, since citation rates differ across patent systems.

phosphors in LED lamps using centrifugal force. It has been cited by 25 subsequent patents (twelve times as many as expected). Meanwhile, the third Cree patent (US #9,000,470) outlines a high-density LED array, and has been cited by 24 subsequent patents (almost twelve times as many citations as expected). These patents are both in turn linked via citations to earlier BTO-funded Light Prescriptions Innovators patents related to LED packaging. Beyond Cree, there are also highly-cited patents in Table 7 assigned to Philips/Signify, Samsung and Osram that are linked via citations to earlier BTO-funded SSL patents.

Table 7 - Highly Cited Leading Company SSL Patents Linked via Citations to Earlier BTO-funded SSL Patents

Patent	Issue Year	# Cites Received	Citation Index	Assignee	Title
9360185	2016	19	13.70	Cree Inc	Variable beam angle directional lighting fixture assembly
8167674	2012	25	12.46	Cree Inc	Phosphor distribution in LED lamps using centrifugal force
9000470	2015	24	11.82	Cree Inc	Light emitter devices
8080819	2011	69	9.25	Philips/Signify	LED package methods and systems
8368100	2013	25	7.89	Cree Inc.	Semiconductor light emitting diodes having reflective structures and methods of fabricating
8182106	2012	19	7.37	Samsung	Surface light source using white light emitting diodes and liquid crystal display backlight unit
8083364	2011	102	6.53	Osram Licht	Remote phosphor LED illumination system
8021904	2011	43	6.52	Cree Inc	Ohmic contacts to nitrogen polarity GaN
7834550	2010	29	5.91	Samsung	Organic light emitting display and fabricating method of the same
8337071	2012	42	5.52	Cree Inc	Lighting device

While the patent-level results focus on BTO-funded SSL patent families, we also identified Other DOE-funded SSL families linked via citations to the largest number of patent families owned by the leading companies. These Other DOE-funded families are shown in Table 8.

Table 8 - Other DOE-Funded SSL Patent Families Linked via Citations to Most Subsequent Leading Company SSL Families

Patent Family #	Representative Patent #	Priority Year	# Linked Families	Assignee	Title
33564739	6909239	2003	106	Univ California (LBNL)	Dual LED/incandescent security fixture
22792387	6268695	1998	90	Battelle Memorial Inst (PNNL)	Environmental barrier material for organic light emitting device and method of making
34220935	6864626	1998	23	Univ California (LBNL)	Electronic displays using optically pumped luminescent semiconductor nanocrystals
35405159	6969874	2003	23	Sandia Corp	Flip-chip light emitting diode with resonant optical microcavity
38178725	7235190	2004	22	Sandia Corp	Nanocluster-based white-light-emitting material employing surface tuning
25036405	6599362	2001	18	Sandia Corp	Cantilever epitaxial process
40032188	7972875	2007	12	Univ Illinois	Optical systems fabricated by printing-based assembly
47388197	8342714	2009	10	Stray Light Optical Tech	Mobile lighting apparatus

Table 8 is dominated by two patent families in terms of the number of leading company patent families linked to them. It should be noted that both of these patent families are marked as "unknown" for BTO funding, rather than being marked as definitively not BTO-funded. As such, while both are defined as Other DOE-funded, one or both may in fact have been funded by BTO.

The first family (representative patent US #6,909,239) is assigned to the University of California, through its management of Lawrence Berkeley National Laboratory, and outlines a hybrid LED/incandescent security lighting fixture. It is linked via citations to 106 subsequent patent families assigned to the leading companies, including at least one family from eight of these ten companies (all except LG Display and Sony). The second Other DOE-funded patent family linked extensively to leading company patents is assigned to Battelle Memorial Institute, through its management of Pacific Northwest National Laboratory. This family (representative patent US #6,268,695) describes a barrier material for OLED devices. It is linked via citations to 90 subsequent patent families assigned to seven out of the ten leading companies (all except Hon Hai Precision, Sony and Toshiba).

Overall, the backward tracing element of the analysis suggests that, taking into account their relatively small size, the portfolios of BTO-funded and Other DOE-funded SSL patents have had an important influence on subsequent innovations associated with the leading SSL companies. This influence can be seen both over time and across technologies, with a number of DOE-funded patent families linked via citations to patents assigned to many of the leading companies.

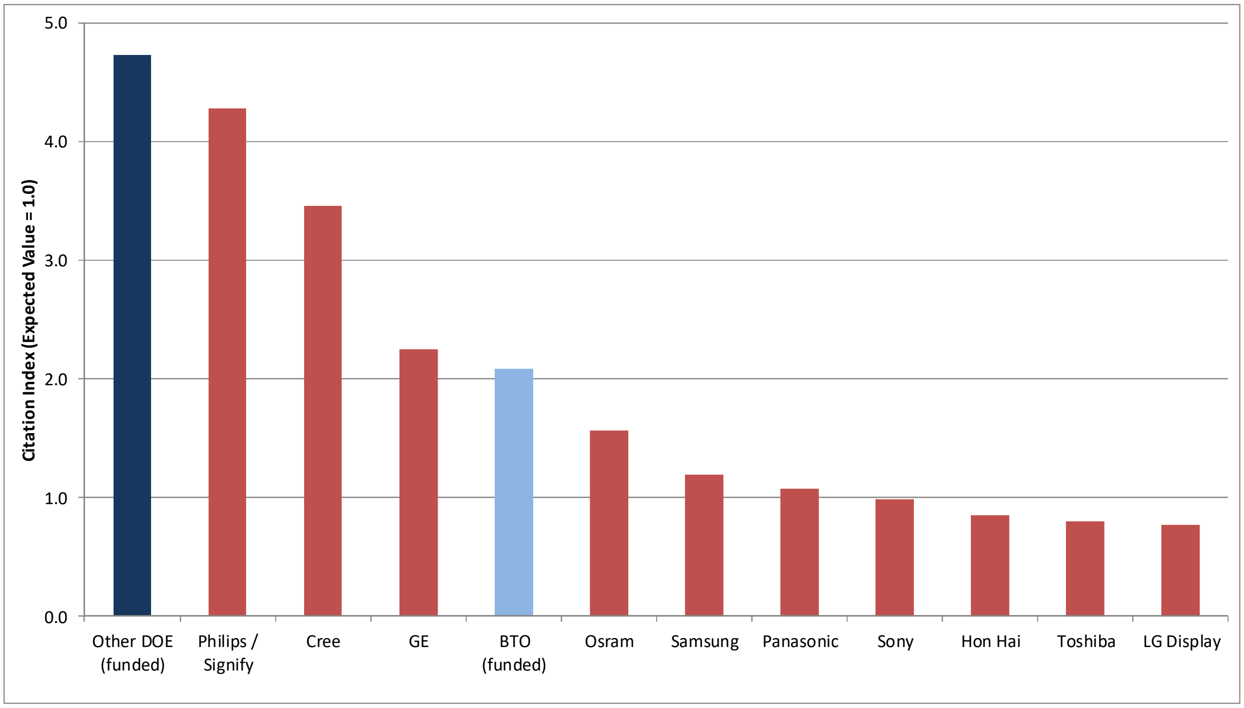
Tracing Forwards from DOE-funded SSL Patents

The previous section of the report examined the influence of DOE-funded SSL research upon technological developments associated with leading SSL companies. That analysis was based on tracing backwards from the patents of leading companies to previous generations of research. This section reports the results of an analysis tracing in the opposite direction – starting with BTO-funded (and Other DOE-funded) SSL patents, and tracing forwards in time through two generations of citations. Hence, while the previous section of the report focused on DOE's influence upon a specific patent set (i.e. patents owned by leading SSL companies), this section of the report examines on the broader influence of BTO-funded (and Other DOE-funded) SSL research, both within and beyond the SSL industry. Also, in order to avoid repeating earlier results, the forward tracing concentrates primarily on patents that are linked to DOE-funded SSL research, but are not owned by the leading SSL companies.

Organizational Level Results

We first generated Citation Index values for the portfolios of BTO-funded and Other DOE-funded SSL patents. We then compared these Citation Indexes against those of the ten leading SSL companies. The results are shown in Figure 17. This figure reveals that both the BTO-funded and Other DOE-funded SSL patent portfolios have high average Citation Index values compared to those of the ten leading companies. Indeed, the Other DOE-funded patents have a Citation Index of 4.72 (showing they have been cited almost five times as frequently as expected), which is higher than all of the leading companies. The Citation Index for BTO-funded SSL patents is lower at 2.08, but this still means that these patents have been cited more than twice as frequently as expected. Other companies with high Citation Index values in Figure 17 include Philips/Signify (4.28), Cree (3.46) and General Electric (2.25).

Figure 17 - Citation Index for Leading Companies' SSL Patents, plus BTO-funded and Other DOE-funded SSL Patents



The Citation Index measures the overall influence of the DOE-funded SSL patent portfolios, but does not necessarily address the breadth of this influence across technologies. To analyze this question, we therefore identified the Cooperative Patent Classifications (CPCs) of the patent families linked via citations to earlier DOE-funded SSL patent families.[13] These CPCs reflect the influence of DOE-funded research across technologies.

Figure 18 shows the CPCs with the largest number of patent families linked to BTO-funded SSL patents. Typically, a figure such as this shows CPCs in two different colors – i.e. those related to SSL technology and those beyond SSL technology. The former represent the influence of BTO-funded patents on SSL technology itself, while the latter represent spillovers of the influence of BTO-funded SSL research into other technology areas.

In Figure 18, all of the CPCs are shown in a single color, since they are all connected in some way to SSL. This suggests that SSL is a relatively self-contained technology, with successive generations of technology building upon earlier research. That said, there are a number of different SSL technologies represented in this figure, covering materials, devices and components associated with SSL applications. This reflects the influence of BTO-funded patents across many different areas of SSL technology.

[13] Patents typically have numerous CPCs attached to them, reflecting different aspects of the invention they describe. In this analysis, we include all CPCs attached to the patents linked to earlier DOE-funded SSL patent families.

Figure 18 - Number of Patent Families Linked via Citations to Earlier BTO-Funded SSL Patents by CPC

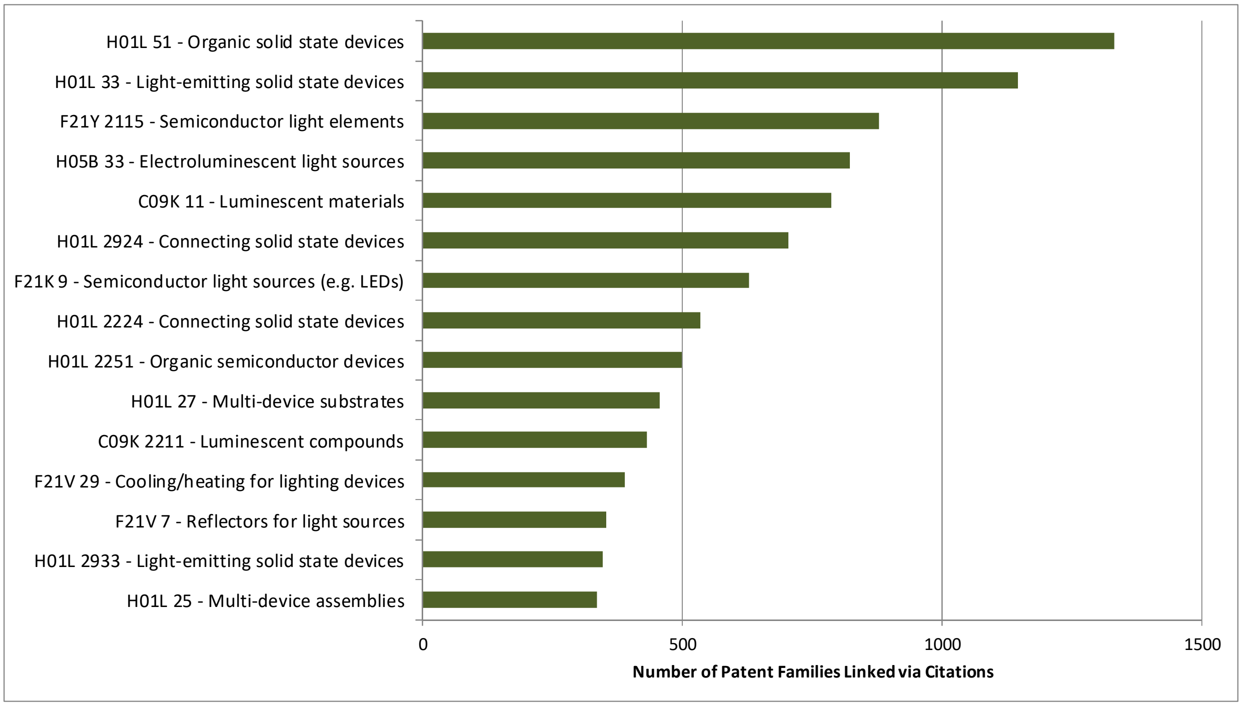


Figure 19 - Number of Patent Families Linked via Citations to Earlier Other DOE-Funded SSL Patents by CPC (Dark Green = SSL-Related; Light Green = Other)

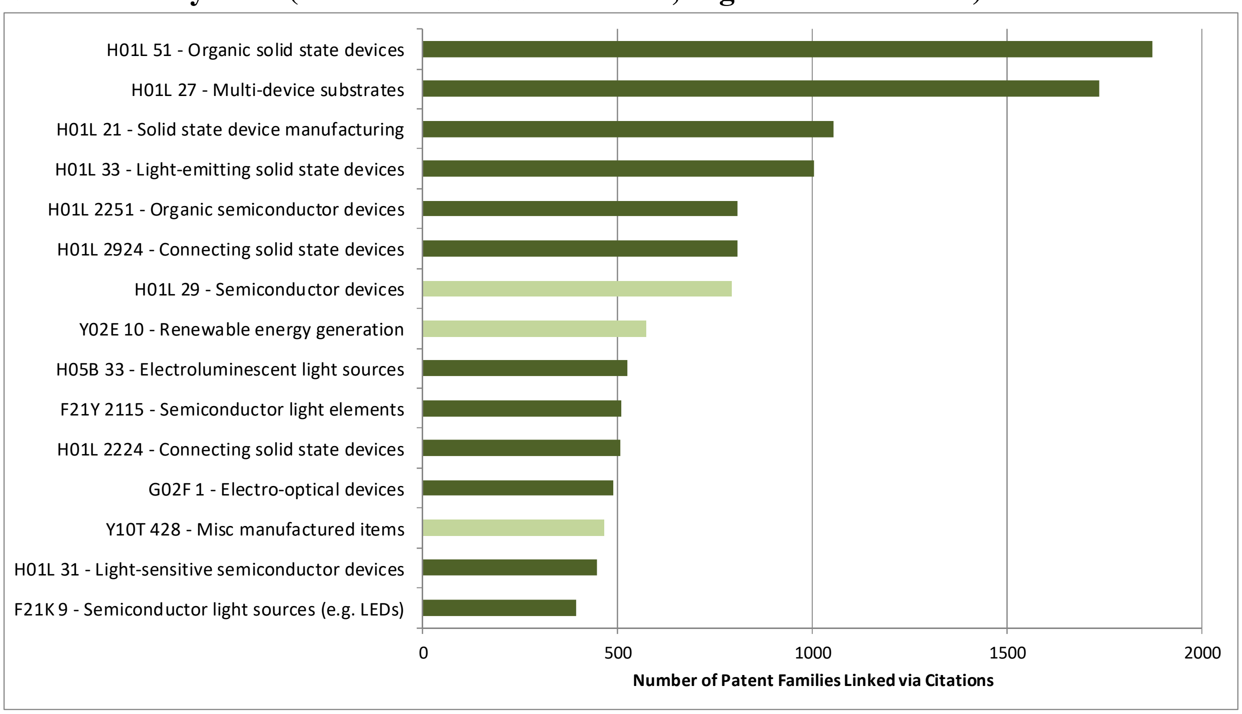
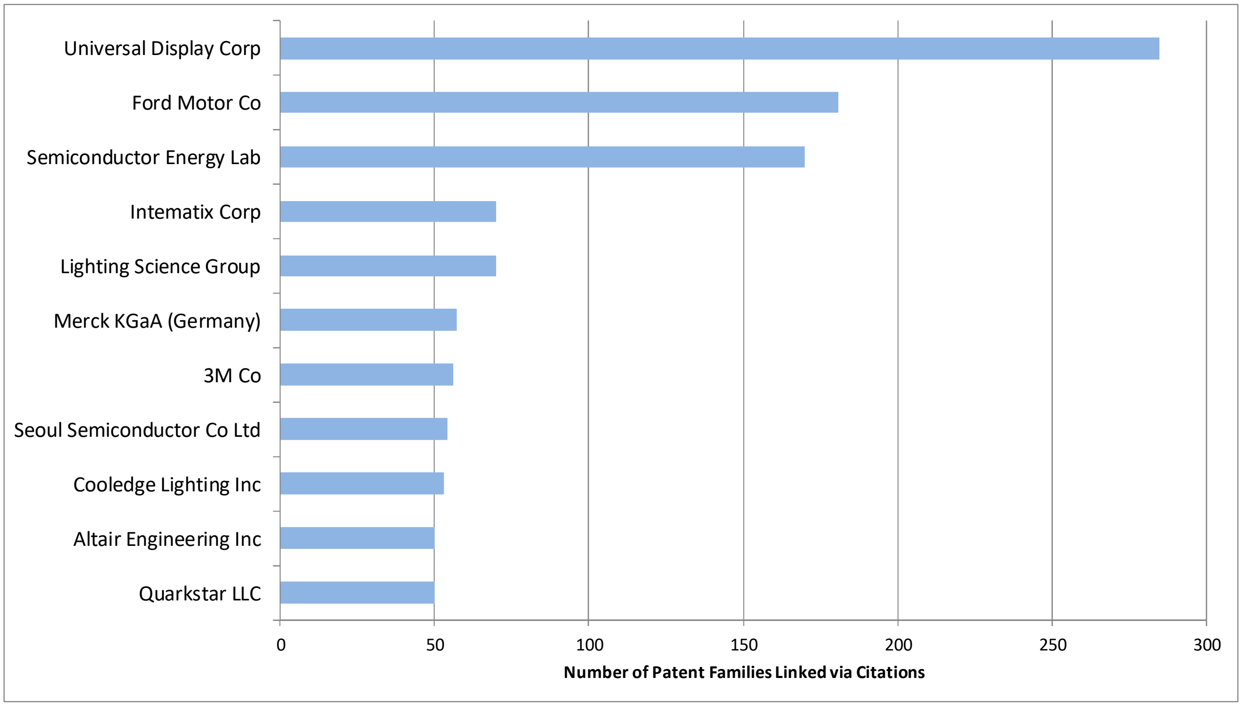


Figure 19 is similar to Figure 18, but is based on patent families linked to Other DOE-funded SSL patents, rather than BTO-funded SSL patents. Most of the CPCs are again related to SSL, and their distribution is similar to that of the families linked to BTO-funded patents. There are three CPCs in Figure 19 covering technologies beyond SSL, specifically semiconductor devices (H01L 29), renewable energy generation (Y02E 10), and manufactured items (Y10T 428). These are examples of Other DOE-funded SSL patents influencing adjacent technologies.

The organizations with the largest number of patent families linked via citations to earlier BTO-funded SSL patents are shown in Figure 20. To avoid repeating the results from earlier, this figure excludes the ten leading SSL companies used in the backward tracing element of the analysis. Also, note that Figure 20 includes all patent families assigned to these organizations, not just their patent families describing SSL technology.

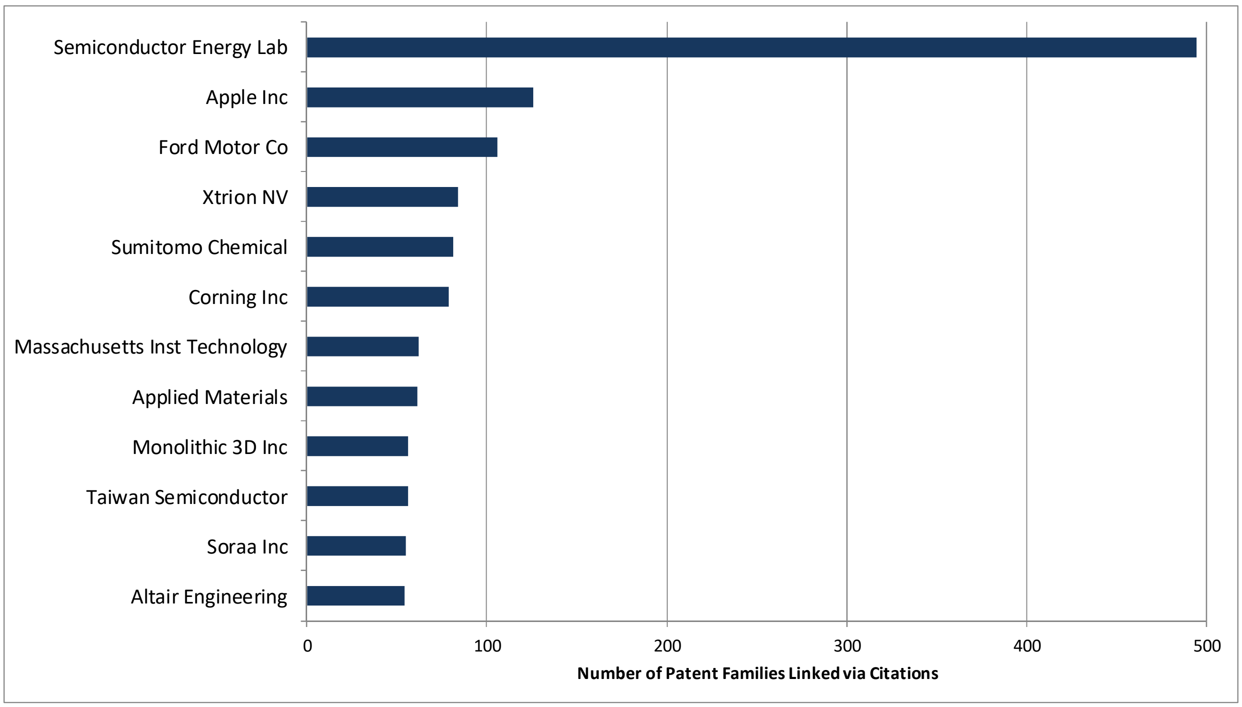
Figure 20 - Organizations with Largest Number of Patent Families Linked via Citations to BTO-funded SSL Patents (excluding leading SSL companies)



Three companies stand out in Figure 20 – Universal Display, Ford and Semiconductor Energy Laboratory (SEL). Universal Display has 285 patent families linked via citations to earlier BTO-funded SSL patents. These Universal Display families focus primarily on OLED devices and materials, and are linked via citations to many earlier BTO-funded patents, in particular patents for OLED devices assigned to General Electric and luminous materials assigned to the University of Southern California. Ford has 181 patent families linked via citations to earlier BTO-funded patent families. These Ford families are related to various vehicle lighting applications, including for compartments, tailgates and badges. They are linked to a variety of earlier BTO-funded patents, notably PhosphorTech patents describing lighting devices incorporating fluorescent phosphors. Meanwhile, SEL has 170 patent families that are linked via citations to earlier BTO-funded SSL patents, with many of these SEL families being related to light-emitting materials and devices. They are linked to numerous earlier BTO-funded OLED patents assigned to General Electric and Universal Display.

Figure 21 shows the organizations with the largest number of patent families linked to earlier Other DOE-funded SSL patents. This figure is headed by SEL, with 495 patent families linked via citations to earlier Other DOE-funded SSL patents. Many of these SEL families describe lighting and display devices, and are linked via citations to an earlier Battelle Memorial Institute (Pacific Northwest National Laboratory) patent family describing a barrier material for OLED devices. This Battelle family (representative patent US #6,268,695) was highlighted earlier in the backward tracing element of the analysis. Apple is in second place in Figure 21, with 126 patent families linked via citations to earlier Other DOE-funded SSL patents. Many of these Apple patent families describe displays for electronic devices, and are linked to the Battelle patent family referenced above, plus University of Illinois patents for ultra-thin printable LED arrays. These University of Illinois patents are also linked extensively via citations to subsequent patent families assigned to Ford (the third-place company in Figure 21), with many of these Ford families describing vehicle lighting applications.

Figure 21 - Organizations with Largest Number of Patent Families Linked via Citations to Other DOE-funded SSL Patents (excluding leading SSL companies)



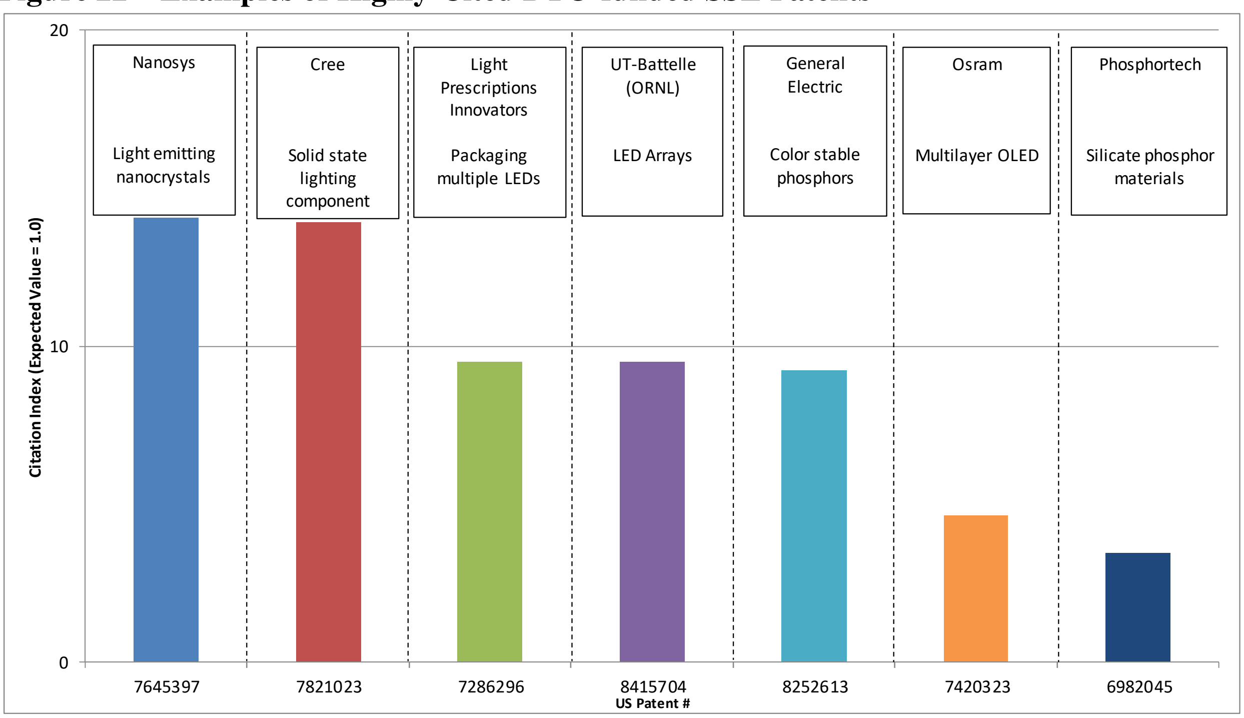
Patent Level Results

This section of the report drills down to identify individual DOE-funded (and particularly BTO-funded) SSL patents whose influence on subsequent technological developments has been particularly strong. It also highlights patents that have extensive citation links to earlier BTO-funded SSL research. The simplest way of identifying high-impact BTO-funded SSL patents is via overall Citation Indexes. The BTO-funded patents with the highest Citation Index values are shown in Table 9, with selected patents also presented in Figure 22. The patents in this table are a mix of older patents that have received large numbers of citations from subsequent generations of patents, and more recent patents that have attracted more citations than expected. One advantage of using Citation Indexes is that these two groups of patents can be compared directly, since each is benchmarked against peer patents of the same age and technology.

Table 9 – List of Highly Cited BTO-Funded SSL Patents

Patent #	Issue Year	# Cites Received	Citation Index	Assignee	Title
7645397	2010	76	14.06	Nanosys Inc	Nanocrystal doped matrices
7821023	2010	124	13.90	Cree Inc	Solid state lighting component
7286296	2007	125	9.48	Light Prescriptions Innovators	Optical manifold for light-emitting diodes
8415704	2013	34	9.47	UT-Battelle (ORNL)	Close-packed array of light emitting devices
8252613	2012	37	9.21	General Electric	Color stable manganese-doped phosphors
7420323	2008	32	4.60	Osram Opto Semics GmbH	Electroluminescent apparatus having a structured luminescence conversion layer
6891330	2005	46	4.42	General Electric	Mechanically flexible organic electroluminescent device with directional light emission
6982045	2006	48	3.42	PhosphorTech Corp	Light emitting device having silicate fluorescent phosphor
8075147	2011	48	3.08	Light Prescriptions Innovators	Optical device for LED-based lamp

Figure 22 – Examples of Highly-Cited BTO-funded SSL Patents



The patent at the head of Table 9 (US #7,645,397) was issued in 2010, and is assigned to Nanosys. It describes luminous nanomaterials that can be used in lighting applications. This patent has been cited by as prior art by 76 subsequent patents, more than fourteen times as many citations as expected given its age and technology. The second patent in Table 9 (US #7,821,023) is assigned to Cree, and outlines compact solid state lamps incorporating multiple lighting elements. This patent has been cited by 124 subsequent patents, almost fourteen times as many citations as expected (note that, while the two patents at the top of Table 9 were both issued in 2010, they are in different patent classifications – the Nanosys patent related to materials, the Cree patent related to lighting devices – hence their different Citation Index values). The third patent in Table 9 (US #7,286,296) describes LED packaging, and is assigned to Light Prescriptions Innovators. This patent, which has been cited as prior art by 125 subsequent patents (nine times as many as expected), was highlighted above in the backward tracing element of the analysis as having the most extensive citation links to the leading SSL companies (see Table 5).

The Citation Indexes in Table 9 are based on a single generation of citations to BTO-funded SSL patents. Table 10 extends this by examining a second generation of citations – i.e. it shows the BTO-funded SSL patents linked directly or indirectly to the largest number of subsequent patent families. These subsequent families are divided into two groups, based on whether they are within or beyond SSL technology. This highlights which BTO-funded patent families have been particularly influential within SSL technology, and which have had a wider impact beyond SSL.

Table 10 - BTO-funded SSL Patent Families Linked via Citations to Largest Number of Subsequent SSL/Other Patent Families

Family #	Priority Year	Rep. Patent #	# Linked Families	# Linked SSL Fams	Assignee	Title
35197575	2004	7286296	547	335	Light Prescriptions Innovators	Optical manifold for light-emitting diodes
33098185	2003	7338722	494	79	Univ Southern California	Phenyl and fluorenyl substituted phenyl-pyrazole complexes of Ir
35320662	2004	7819549	449	323	Rensselaer Poly Inst	High efficiency light source using solid-state emitter and down-conversion material
33424117	2003	6982045	431	182	Phosphortech Corp	Light emitting device having silicate fluorescent phosphor
28453526	2002	6891330	344	56	General Electric	Mechanically flexible organic electroluminescent device with directional light emission
32393040	2002	6952079	328	224	General Electric	Luminaire for light extraction from a flat light source
35732617	2004	7393599	321	63	Univ Southern California	Luminescent compounds with carbene ligands
41066696	2005	7821023	308	206	Cree Inc	Solid state lighting component
34422124	2003	6972438	260	157	Cree Inc	Light emitting diode with porous SiC substrate and method for fabricating
34108071	2003	6987353	229	62	Phosphortech Corp	Light emitting device having sulfoselenide fluorescent phosphor
38982009	2004	7645397	219	33	Nanosys Inc	Nanocrystal doped matrices
46301791	2003	7211823	110	9	Universal Display Corp	Organic light emitting device structure for obtaining chromaticity stability
36940156	2005	7321193	108	44	Osram Opto Semics GmbH	Device structure for OLED light device having multi element light extraction

The patent family at the head of Table 10 (representative patent US #7,286,296) is the Light Prescriptions Innovators LED packaging family highlighted above in both Table 5 and Table 9. This patent family is linked via citations to 547 subsequent patent families, 335 of which are within SSL technology. The second patent family in Table 10 (representative patent US #7,338,722) is assigned to the University of Southern California, and describes organic materials for use in OLEDs. It is linked via citations to 494 subsequent patent families, only 79 of which are within SSL technology, with many others related to advanced materials. The third place patent family in this table (representative patent US #7,819,549) outlines a solid state light source with a down-conversion material to improve performance. This patent family, assigned to Rensselaer Polytechnic Institute, is linked via citations to 449 subsequent families, 323 of which are related to SSL (including many families assigned to the leading SSL companies, as highlighted in the backward tracing element of the analysis).

The tables above identify BTO-funded patent families linked particularly strongly to subsequent technological developments. Table 11 looks in the opposite direction, and identifies highly-cited patents linked to earlier BTO-funded SSL patents. As such, these are examples where BTO-funded SSL research has formed part of the foundation for subsequent high-impact technologies. This table focuses on patent families not owned by the leading SSL companies, since those families were examined in the backward tracing element of the analysis.

Table 11 - Highly Cited Patents (not from leading SSL companies) Linked via Citations to Earlier BTO-funded SSL Patents

Patent #	Issue Year	# Cites Received	Citation Index	Assignee	Title
8415879	2013	43	15.32	Nth Degree Technologies	Diode for a printable composition
7894216	2011	114	13.84	Cirrus Logic	Switching power converter with efficient switching control signal period generation
7198832	2007	77	12.38	Vitex Systems	Method for edge sealing barrier films
7889421	2011	58	11.92	Rensselaer Polytech Inst	High-power white LEDs and manufacturing method thereof
8282250	2012	94	11.85	Elumigen LLC	Solid state lighting device using heat channels in a housing
6998776	2006	167	10.64	Corning Inc	Glass package that is hermetically sealed with a frit and method of fabrication
8573823	2013	57	10.06	Quarkstar LLC	Solid-state luminaire
7946729	2011	102	9.68	Altair Engineering	Fluorescent tube replacement having longitudinally oriented LEDs
7476002	2009	119	8.45	S.C. Johnson & Son	Color changing light devices with active ingredient and sound emission for mood enhancement
8128272	2012	66	8.19	Oree Inc	Illumination apparatus

The patent at the head of Table 11 (US #8,415,879) is assigned to Nth Degree Technologies and outlines a liquid or gel composition that can be used in printable devices for lighting and photovoltaic applications. Since being issued in 2013, it has been cited as prior art by 43 subsequent patents, which more than fifteen times as many citations as expected given its age and technology. The second patent in Table 11 (US #7,894,216) is assigned to Cirrus Logic, and describes a power converter for use with LED-based lighting systems. It has been cited by 114 subsequent patents, almost fourteen times as many citations as expected. The third-place patent in this table (US #7,198,832) details edge-sealed thin film composites, and is assigned to Vitex Systems. It has been cited by 77 later patents, twelve times as many as expected. In general, the patents in Table 11 are assigned to a variety of companies and describe a range of technologies, showing the breadth of influence of BTO-funded SSL research on subsequent developments.

As with the backward tracing element of the analysis, the patent-level results from the forward tracing focus on BTO-funded SSL patents. However, within the forward tracing, we did also identify Other DOE-funded SSL patent families linked to the largest number of subsequent patent families within and beyond SSL technology. These Other DOE-funded SSL families are shown in Table 12.

Table 12 - Other DOE-funded SSL Patent Families Linked via Citations to Largest Number of Subsequent SSL/Other Patent Families

Family #	Priority Year	Rep. Patent #	# Linked Families	# Linked SSL Fams	Assignee	Title
22792387	1998	6268695	2265	214	Battelle Memorial Inst (PNNL)	Environmental barrier material for organic light emitting device and method of making
40032188	2007	7972875	698	111	Univ Illinois	Optical systems fabricated by printing-based assembly
33564739	2003	6909239	508	376	Univ California (LBNL)	Dual LED/incandescent security fixture
43085312	2009	8865489	408	63	Univ Illinois	Printed assemblies of ultrathin, microscale inorganic light emitting diodes for deformable and semitransparent displays
34220935	1998	6864626	334	78	Univ California (LBNL)	Electronic displays using optically pumped luminescent semiconductor nanocrystals
25036405	2001	6599362	276	59	Sandia Corp	Cantilever Epitaxial Process
35405159	2003	6969874	134	48	Sandia Corp	Flip-chip light emitting diode with resonant optical microcavity
33419028	2001	6815736	122	3	MRIGlobal (NREL)	Isoelectronic co-doping
38178725	2004	7235190	116	90	Sandia Corp	Nanocluster-based white-light-emitting material employing surface tuning

The patent family at the head of Table 12 (representative patent US #6,268,695) is the Battelle Memorial Institute (Pacific Northwest National Laboratory) OLED barrier material family highlighted above in both the backward and forward tracing elements of the analysis (see the discussions associated with Table 8 and Figure 21). This patent family is linked via citations to 2,265 subsequent patent families, most of which are defined as being from beyond SSL technology, with many of them related to semiconductors, advanced materials and electronic devices. The University of Illinois has two of the next four patent families in Table 12. These patent families (representative patents US #7,972,875 and US #8,865,489) detail printable optical systems. They are linked via citations to 698 and 408 subsequent patent families respectively, with most of these linked families being related to semiconductors and electronics. The third-placed patent in Table 12 (representative patent US #6,909,239) is assigned to the University of California (through its management of Lawrence Berkeley National Laboratory) and describes a hybrid LED/incandescent security lighting system. This family has a somewhat different pattern of subsequent citation links, with many of the 508 later patents connected to it being from within SSL technology. As noted earlier, this patent family, plus the Battelle patent family at the head of Table 12, are marked as “unknown” in terms of their DOE funding source, so they may in fact have been funded by BTO.

Overall, the forward tracing element of the analysis shows that BTO-funded and Other DOE-funded SSL research has had a strong influence on subsequent technologies. This influence can be seen both within SSL, and in related technologies such as semiconductors, electronics and advanced materials.

5.0 Conclusions

This report describes the results of an analysis tracing links between SSL research funded by DOE (BTO plus Other DOE) and subsequent developments both within and beyond SSL technology. This tracing is carried out both backwards and forwards in time. The purpose of the backward tracing is to determine the extent to which BTO-funded (and Other DOE-funded) research forms a foundation for the technologies developed by leading SSL companies. The purpose of the forward tracing is to examine the influence of BTO-funded (and Other DOE-funded) SSL patents upon subsequent developments, both within and outside SSL technology.

The backward tracing element of the analysis shows that, taking into account their relatively small size, the portfolios of BTO-funded and Other DOE-funded SSL patents have had an important influence on subsequent innovations associated with the leading SSL companies. This influence can be seen both over time and across SSL technologies. Meanwhile, the forward tracing element of the analysis shows that BTO-funded and Other DOE-funded SSL research has had a strong influence on subsequent developments, both within SSL, and in related technologies such as semiconductors, electronics and advanced materials.

Overall, the analysis presented in this report reveals that SSL research funded by BTO, and by DOE in general, has had a significant influence on subsequent developments, both within and beyond SSL technology. This influence can be seen on innovations associated with the leading SSL companies, plus innovations across a range of other technologies.

Appendix A. BTO-funded SSL Patents used in the Analysis

Patent #	Application Year	Issue / Publication Year	Original Assignees	Title
6398384	2001	2002	UNIVERSITY OF CALIFORNIA	TABLE LAMP WITH DYNAMICALLY CONTROLLED LIGHTING DISTRIBUTION AND UNIFORMLY ILLUMINATED LUMINOUS SHADE
WO2003100832	2003	2003	GENERAL ELECTRIC CO	MECHANICALLY FLEXIBLE ORGANIC ELECTROLUMINESCENT DEVICE WITH DIRECTIONAL LIGHT EMISSION
6727660	2003	2004	GENERAL ELECTRIC CO	ORGANIC ELECTROLUMINESCENT DEVICES AND METHOD FOR IMPROVING ENERGY EFFICIENCY AND OPTICAL STABILITY THEREOF
6825054	2002	2004	UNASSIGNED	LIGHT EMITTING CERAMIC DEVICE AND METHOD FOR FABRICATING THE SAME
EP1431656	2003	2004	GENERAL ELECTRIC CO	LUMINAIRE FOR LIGHT EXTRACTION FROM A FLAT LIGHT SOURCE
EP1434284	2003	2004	GENERAL ELECTRIC CO	WHITE LIGHT-EMITTING ORGANIC ELECTROLUMINESCENT DEVICES
WO2004017678	2003	2004	UNIVERSAL DISPLAY CORP	ORGANIC LIGHT EMITTING DEVICES FOR ILLUMINATION
WO2004085450	2004	2004	UNIVERSITY OF SOUTHERN CALIFORNIA	PHENYL AND FLUORENYL SUBSTITUTED PHENYL-PYRAZOLE COMPLEXES OF IR
WO2004093210	2004	2004	UNIVERSITY OF SOUTHERN CALIFORNIA	ORGANIC LIGHT EMITTING DEVICES UTILIZING BINUCLEAR METAL-COMPOUNDS AS EMISSIVE MATERIAL
WO2004111156	2004	2004	PHOSPHORTECH CORP	LIGHT EMITTING DEVICES HAVING SILICATE FLUORESCENT PHOSPHORS
6885025	2003	2005	THE SCRIPPS RESEARCH INSTITUTE	ORGANIC LIGHT EMITTING DEVICE STRUCTURE FOR OBTAINING CHROMATICITY STABILITY
6891330	2002	2005	GENERAL ELECTRIC CO	MECHANICALLY FLEXIBLE ORGANIC ELECTROLUMINESCENT DEVICE WITH DIRECTIONAL LIGHT EMISSION
6903505	2001	2005	GENERAL ELECTRIC CO	LIGHT-EMITTING DEVICE WITH ORGANIC

				ELECTROLUMINESCENT MATERIAL AND PHOTOLUMINESCENT MATERIALS
6952079	2002	2005	GENERAL ELECTRIC CO	LUMINAIRE FOR LIGHT EXTRACTION FROM A FLAT LIGHT SOURCE
6972438	2003	2005	CREE INC	LIGHT EMITTING DIODE WITH POROUS SIC SUBSTRATE AND METHOD FOR FABRICATING
EP1493195	2003	2005	GENERAL ELECTRIC CO	MECHANICALLY FLEXIBLE ORGANIC ELECTROLUMINESCENT DEVICE WITH DIRECTIONAL LIGHT EMISSION
EP1576854	2003	2005	UNIVERSAL DISPLAY CORP	ORGANIC LIGHT EMITTING DEVICES FOR ILLUMINATION
EP1606296	2004	2005	UNIVERSITY OF SOUTHERN CALIFORNIA	PHENYL-PYRAZOLE COMPLEXES OF IR
EP1609197	2004	2005	UNIVERSITY OF SOUTHERN CALIFORNIA	ORGANIC LIGHT EMITTING DEVICES UTILIZING BINUCLEAR METAL-COMPOUNDS AS EMISSIVE MATERIAL
WO2005017062	2004	2005	PHOSPHORTECH CORP	LIGHT EMITTING DEVICES HAVING SULFOSELENIDE FLUORESCENT PHOSPHORS
WO2005018010	2004	2005	GENERAL ELECTRIC CO	ORGANIC ELECTROLUMINESCENT DEVICES HAVING IMPROVED LIGHT EXTRACTION
WO2005031884	2004	2005	UNIVERSITY OF CALIFORNIA	PLASMON ASSISTED ENHANCEMENT OF ORGANIC OPTOELECTRONIC DEVICES
WO2005034254	2004	2005	CREE INC	LIGHT EMITTING DIODE WITH POROUS SIC SUBSTRATE AND METHOD FOR FABRICATING
WO2005086628	2004	2005	MAXDEM INC	POLYMER MATRIX ELECTROLUMINESCENT MATERIALS AND DEVICES
WO2005103562	2005	2005	LIGHT PRESCRIPTIONS INNOVATORS	OPTICAL MANIFOLD FOR LIGHT-EMITTING DIODES
WO2005107420	2005	2005	RENSSELAER POLYTECHNIC INSTITUTE	HIGH EFFICIENCY LIGHT SOURCE USING SOLID-STATE EMITTER AND DOWN-CONVERSION MATERIAL
6982045	2003	2006	PHOSPHORTECH CORP	LIGHT EMITTING DEVICE HAVING SILICATE FLUORESCENT PHOSPHOR
6987353	2003	2006	PHOSPHORTECH CORP	LIGHT EMITTING DEVICE HAVING SULFOSELENIDE FLUORESCENT PHOSPHOR

6999222	2003	2006	UNIVERSITY OF CALIFORNIA	PLASMON ASSISTED ENHANCEMENT OF ORGANIC OPTOELECTRONIC DEVICES
7049757	2002	2006	GENERAL ELECTRIC CO	SERIES CONNECTED OLED STRUCTURE AND FABRICATION METHOD
7063900	2002	2006	GENERAL ELECTRIC CO	WHITE LIGHT-EMITTING ORGANIC ELECTROLUMINESCENT DEVICES
7090928	2003	2006	UNIVERSITY OF SOUTHERN CALIFORNIA	BINUCLEAR COMPOUNDS
7109648	2004	2006	PHOSPHORTECH CORP	LIGHT EMITTING DEVICE HAVING THIO-SELENIDE FLUORESCENT PHOSPHOR
7112921	2004	2006	PHOSPHORTECH CORP	LIGHT EMITTING DEVICE HAVING SELENIUM-BASED FLUORESCENT PHOSPHOR
7122128	2004	2006	GENERAL ELECTRIC CO	PHOSPHORS CONTAINING BORATE OF TERBIUM, ALKALINE-EARTH, AND GROUP-3 METALS, AND LIGHT SOURCES INCORPORATING THE SAME
EP1652242	2004	2006	GENERAL ELECTRIC CO	ORGANIC ELECTROLUMINESCENT DEVICES HAVING IMPROVED LIGHT EXTRACTION
EP1661964	2005	2006	GENERAL ELECTRIC CO	METHOD TO PRODUCE NANOCRYSTALLINE POWDERS OF OXIDE-BASED PHOSPHORS FOR LIGHTING APPLICATIONS
EP1668710	2004	2006	CREE INC	LIGHT EMITTING DIODE WITH POROUS SIC SUBSTRATE AND METHOD FOR FABRICATING
EP1705728	2006	2006	OSRAM OPTO SEMICONDUCTORS GMBH	NOVEL METHOD TO GENERATE HIGH EFFICIENT DEVICES WICH EMIT HIGH QUALITY LIGHT FOR ILLUMINATION
EP1705729	2006	2006	OSRAM OPTO SEMICONDUCTORS GMBH	POLYMER AND SMALL MOLECULE BASED HYBRID LIGHT SOURCE
EP1709840	2004	2006	MAXDEM INC	POLYMER MATRIX ELECTROLUMINESCENT MATERIALS AND DEVICES
WO2006014996	2005	2006	CREE INC	ULTRA-THIN OHMIC CONTACTS FOR P-TYPE NITRIDE LIGHT EMITTING DEVICES AND METHODS OF FORMING
WO2006016955	2005	2006	CREE INC	LED WITH SUBSTRATE MODIFICATIONS FOR

				ENHANCED LIGHT EXTRACTION AND METHOD OF MAKING SAME
WO2006093643	2006	2006	UNIVERSITY OF CALIFORNIA	HORIZONTAL EMITTING, VERTICAL EMITTING, BEAM SHAPED, DISTRIBUTED FEEDBACK (DFB) LASERS BY GROWTH OVER A PATTERNED SUBSTRATE
WO2006093937	2006	2006	UNIVERSITY OF CALIFORNIA	SINGLE OR MULTI-COLOR HIGH EFFICIENCY LIGHT EMITTING DIODE (LED) BY GROWTH OVER A PATTERNED SUBSTRATE
WO2006130883	2006	2006	PRINCETON UNIVERSITY	FLUORESCENT FILTERED ELECTROPHOSPHORESCENCE
7211823	2004	2007	UNIVERSAL DISPLAY CORP	ORGANIC LIGHT EMITTING DEVICE STRUCTURE FOR OBTAINING CHROMATICITY STABILITY
7242141	2004	2007	OSRAM OPTO SEMICONDUCTORS GMBH	INTEGRATED FUSES FOR OLED LIGHTING DEVICE
7245074	2004	2007	GENERAL ELECTRIC CO	ORGANIC ELECTROLUMINESCENT DEVICES HAVING IMPROVED LIGHT EXTRACTION
7286296	2005	2007	LIGHT PRESCRIPTIONS INNOVATORS	OPTICAL MANIFOLD FOR LIGHT-EMITTING DIODES
7291864	2005	2007	UNIVERSITY OF CALIFORNIA	SINGLE OR MULTI-COLOR HIGH EFFICIENCY LIGHT EMITTING DIODE (LED) BY GROWTH OVER A PATTERNED SUBSTRATE
7311859	2004	2007	GENERAL ELECTRIC CO	METHOD TO PRODUCE NANOCRYSTALLINE POWDERS OF OXIDE-BASED PHOSPHORS FOR LIGHTING APPLICATIONS
EP1738107	2005	2007	LIGHT PRESCRIPTIONS INNOVATORS	OPTICAL MANIFOLD FOR LIGHT-EMITTING DIODES
EP1760801	2006	2007	OSRAM OPTO SEMICONDUCTORS GMBH	USING PRISMATIC MICROSTRUCTURED FILMS FOR IMAGE BLENDING IN OLEDS
EP1769193	2005	2007	RENSSELAER POLYTECHNIC INSTITUTE	HIGH EFFICIENCY LIGHT SOURCE USING SOLID-STATE EMITTER AND DOWN-CONVERSION MATERIAL
EP1770799	2006	2007	OSRAM OPTO SEMICONDUCTORS GMBH	ORGANIC ELECTROPHOSPHORESCENCE DEVICE
EP1771893	2005	2007	CREE INC	ULTRA-THIN OHMIC CONTACTS FOR P-TYPE

				NITRIDE LIGHT EMITTING DEVICES AND METHODS OF FORMING
EP1787335	2005	2007	CREE INC	METHOD OF MANUFACTURING A LED WITH SUBSTRATE FOR ENHANCED LIGHT EXTRACTION
EP1852528	2007	2007	FAIRFIELD CRYSTAL TECHNOLOGY	METHOD AND APPARATUS FOR ALUMINUM NITRIDE MONOCRYSTAL BOULE GROWTH
EP1854130	2006	2007	UNIVERSITY OF CALIFORNIA	HORIZONTAL EMITTING, VERTICAL EMITTING, BEAM SHAPED, DISTRIBUTED FEEDBACK (DFB) LASERS BY GROWTH OVER A PATTERNED SUBSTRATE
EP1854156	2006	2007	UNIVERSITY OF CALIFORNIA	SINGLE OR MULTI-COLOR HIGH EFFICIENCY LIGHT EMITTING DIODE (LED) BY GROWTH OVER A PATTERNED SUBSTRATE
WO2007051499	2006	2007	OSRAM OPTO SEMICONDUCTORS GMBH	STRUCTURED LUMINESCENCE CONVERSION LAYER
WO2007082021	2007	2007	LIGHT PRESCRIPTIONS INNOVATORS	OPTICAL MANIFOLD FOR LIGHT-EMITTING DIODES
WO2007089371	2006	2007	OSRAM SYLVANIA INC	RARE EARTH-ACTIVATED ALUMINUM NITRIDE POWDERS AND METHOD OF MAKING
WO2007120788	2007	2007	UNIVERSITY OF SOUTHERN CALIFORNIA	ORGANIC ELECTRONIC DEVICES USING PHTHALIMIDE COMPOUNDS
WO2007127870	2007	2007	UNIVERSITY OF CALIFORNIA	ORGANIC LIGHT EMITTING DIODES WITH STRUCTURED ELECTRODES
WO2007145719	2007	2007	PRINCETON UNIVERSITY	ORGANIC LIGHT-EMITTING DEVICE WITH A PHOSPHOR-SENSITIZED FLUORESCENT EMISSION LAYER
7321193	2006	2008	OSRAM OPTO SEMICONDUCTORS GMBH	DEVICE STRUCTURE FOR OLED LIGHT DEVICE HAVING MULTI ELEMENT LIGHT EXTRACTION AND LUMINESCENCE CONVERSION LAYER
7338722	2004	2008	UNIVERSITY OF SOUTHERN CALIFORNIA	PHENYL AND FLUORENYL SUBSTITUTED PHENYL-PYRAZOLE COMPLEXES OF IR
7345298	2005	2008	UNIVERSITY OF CALIFORNIA	HORIZONTAL EMITTING, VERTICAL EMITTING, BEAM SHAPED, DISTRIBUTED

				FEEDBACK (DFB) LASERS BY GROWTH OVER A PATTERNED SUBSTRATE
7348738	2004	2008	GENERAL ELECTRIC CO	OLED AREA ILLUMINATION SOURCE
7368659	2002	2008	GENERAL ELECTRIC CO	ELECTRODES MITIGATING EFFECTS OF DEFECTS IN ORGANIC ELECTRONIC DEVICES
7375011	2007	2008	EASTMAN KODAK CO	EX-SITU DOPED SEMICONDUCTOR TRANSPORT LAYER
7380962	2006	2008	LIGHT PRESCRIPTIONS INNOVATORS	OPTICAL MANIFOLD FOR LIGHT-EMITTING DIODES
7393599	2004	2008	UNIVERSITY OF SOUTHERN CALIFORNIA	LUMINESCENT COMPOUNDS WITH CARBENE LIGANDS
7420323	2005	2008	OSRAM OPTO SEMICONDUCTO RS GMBH	ELECTROLUMINESCENT APPARATUS HAVING A STRUCTURED LUMINESCENCE CONVERSION LAYER
EP1885003	2007	2008	CREE INC	LIGHT EMITTING DIODE PACKAGE ELEMENT WITH INTERNAL MENISCUS FOR BUBBLE FREE LENS PLACEMENT
EP1955376	2006	2008	OSRAM OPTO SEMICONDUCTO RS GMBH	STRUCTURED LUMINESCENCE CONVERSION LAYER
EP1974166	2007	2008	LIGHT PRESCRIPTIONS INNOVATORS	OPTICAL MANIFOLD FOR LIGHT-EMITTING DIODES
EP1989158	2006	2008	OSRAM SYLVANIA INC	RARE EARTH-ACTIVATED ALUMINUM NITRIDE POWDERS AND METHOD OF MAKING
EP2005500	2007	2008	UNIVERSITY OF SOUTHERN CALIFORNIA	ORGANIC ELECTRONIC DEVICES USING PHTHALIMIDE COMPOUNDS
WO2008013780	2007	2008	NANOSYS INC	NANOCRYSTAL DOPED MATRIXES
WO2008014037	2007	2008	GENERAL ELECTRIC CO	ORGANIC IRIDIUM COMPOSITIONS AND THEIR USE IN ELECTRONIC DEVICES
WO2008054578	2007	2008	UNIVERSITY OF SOUTHERN CALIFORNIA / UNIVERSITY OF MICHIGAN	MATERIALS AND ARCHITECTURES FOR EFFICIENT HARVESTING OF SINGLET AND TRIPLET EXCITONS FOR WHITE LIGHT EMITTING OLEDS
WO2008066933	2007	2008	UNIVERSITY OF CALIFORNIA	ENHANCING PERFORMANCE CHARACTERISTICS OF ORGANIC SEMICONDUCTING FILMS BY IMPROVED

				SOLUTION PROCESSING
WO2008088446	2007	2008	PRINCETON UNIVERSITY; UNIVERSITY OF MICHIGAN	ORGANIC VAPOR JET DEPOSITION USING AN EXHAUST
WO2008103161	2007	2008	EASTMAN KODAK CO	EX-SITU DOPED SEMICONDUCTOR TRANSPORT LAYER
WO2008105863	2007	2008	EASTMAN KODAK CO	DOPED NANOPARTICLE-BASED SEMICONDUCTOR JUNCTION
WO2008140644	2008	2008	EASTMAN KODAK CO	ELECTROLUMINESCENT DEVICE HAVING IMPROVED LIGHT OUTPUT
WO2008157604	2008	2008	UNIVERSITY OF FLORIDA	INKJET PRINTING OF MICROLENSES FOR PHOTONIC APPLICATIONS
7474048	2005	2009	UNIVERSITY OF SOUTHERN CALIFORNIA	FLUORESCENT FILTERED ELECTROPHOSPHORESCENCE
7518139	2006	2009	LEHIGH UNIVERISTY	GALLIUM NITRIDE-BASED DEVICE AND METHOD
7524376	2007	2009	FAIRFIELD CRYSTAL TECHNOLOGY	METHOD AND APPARATUS FOR ALUMINUM NITRIDE MONOCRYSTAL BOULE GROWTH
7534633	2005	2009	CREE INC	LED WITH SUBSTRATE MODIFICATIONS FOR ENHANCED LIGHT EXTRACTION AND METHOD OF MAKING SAME
7534633	2005	2009	CREE INC	LED WITH SUBSTRATE MODIFICATIONS FOR ENHANCED LIGHT EXTRACTION AND METHOD OF MAKING SAME
7554257	2005	2009	OSRAM OPTO SEMICONDUCTO RS GMBH	NOVEL METHOD TO GENERATE HIGH EFFICIENT DEVICES, WHICH EMIT HIGH QUALITY LIGHT FOR ILLUMINATION
7579773	2006	2009	PRINCETON UNIVERSITY	ORGANIC LIGHT-EMITTING DEVICE WITH A PHOSPHOR-SENSITIZED FLUORESCENT EMISSION LAYER
7586245	2005	2009	OSRAM OPTO SEMICONDUCTO RS GMBH	USING PRISMATIC MICROSTRUCTURED FILMS FOR IMAGE BLENDING IN OLEDS
7605062	2007	2009	EASTMAN KODAK CO	DOPED NANOPARTICLE-BASED SEMICONDUCTOR JUNCTION
7608677	2006	2009	GENERAL ELECTRIC CO	METHOD FOR PREPARING POLYMERIC ORGANIC IRIDIUM COMPOSITIONS
7635792	2008	2009	GENERAL	2,5-LINKED POLYFLUORENES

			ELECTRIC CO	FOR OPTOELECTRONIC DEVICES
EP2013926	2007	2009	UNIVERSITY OF CALIFORNIA	ORGANIC LIGHT EMITTING DIODES WITH STRUCTURED ELECTRODES
EP2025016	2007	2009	PRINCETON UNIVERSITY	ORGANIC LIGHT-EMITTING DEVICE WITH A PHOSPHOR-SENSITIZED FLUORESCENT EMISSION LAYER
EP2049555	2007	2009	GENERAL ELECTRIC CO	ORGANIC IRIDIUM COMPOSITIONS AND THEIR USE IN ELECTRONIC DEVICES
EP2059391	2007	2009	NANOSYS INC	NANOCRYSTAL DOPED MATRIXES
EP2062908	2004	2009	UNIVERSITY OF SOUTHERN CALIFORNIA	TRANSITION METAL COMPLEXES COMPRISING PYRAZOLYLCARBAZOLE LIGANDS
EP2076928	2007	2009	UNIVERSITY OF SOUTHERN CALIFORNIA / UNIVERSITY OF MICHIGAN	ARCHITECTURES FOR EFFICIENT HARVESTING OF SINGLET AND TRIPLET EXCITONS FOR WHITE LIGHT EMITTING OLEDS
EP2087537	2007	2009	UNIVERSITY OF CALIFORNIA	ENHANCING PERFORMANCE CHARACTERISTICS OF ORGANIC SEMICONDUCTING FILMS BY IMPROVED SOLUTION PROCESSING
EP2094495	2007	2009	PRINCETON UNIVERSITY; UNIVERSITY OF MICHIGAN	ORGANIC VAPOR JET DEPOSITION USING AN EXHAUST
EP2115780	2007	2009	EASTMAN KODAK CO	DOPED NANOPARTICLE-BASED SEMICONDUCTOR JUNCTION
EP2122673	2007	2009	EASTMAN KODAK CO	EX-SITU DOPED SEMICONDUCTOR TRANSPORT LAYER
WO2009009695	2008	2009	UNIVERSITY OF FLORIDA	TOP-EMISSION ORGANIC LIGHT-EMITTING DEVICES WITH MICROLENS ARRAYS
WO2009014588	2008	2009	EASTMAN KODAK CO	LIGHT-EMITTING NANOCOMPOSITE PARTICLES
WO2009048951	2008	2009	KONINKLIJKE PHILIPS N V	METHODS AND APPARATUS FOR CONTROLLING RESPECTIVE LOAD CURRENTS OF MULTIPLE SERIES-CONNECTED LOADS
WO2009048956	2008	2009	KONINKLIJKE PHILIPS N V	INTEGRATED LED-BASED LUMINAIRE FOR GENERAL LIGHTING
WO2009058172	2008	2009	EASTMAN KODAK CO	DEVICE CONTAINING NON-BLINKING QUANTUM DOTS
WO2009061922	2008	2009	UNIVERSITY OF MICHIGAN	STABLE BLUE PHOSPHORESCENT ORGANIC LIGHT EMITTING DEVICES

WO2009070382	2008	2009	UNIVERSITY OF MICHIGAN	ORGANIC LIGHT EMITTING DEVICE HAVING MULTIPLE SEPARATE EMISSIVE LAYERS
WO2009072058	2008	2009	KONINKLIJKE PHILIPS N V	LED LAMP POWER MANAGEMENT SYSTEM AND METHOD
WO2009072059	2008	2009	KONINKLIJKE PHILIPS N V	LED LAMP COLOR CONTROL SYSTEM AND METHOD
WO2009099705	2009	2009	UNIVERSAL DISPLAY CORP	ORGANIC LICHT EMITTING DEVICE WITH A NON-EMISSIVE ORGANOMETALLIC LAYER
WO2009111790	2009	2009	BOSTON UNIVERSITY	OPTICAL DEVICES FEATURING NONPOLAR TEXTURED SEMICONDUCTOR LAYERS
WO2009142675	2009	2009	CREE INC	SOLID STATE LIGHTING COMPONENT
WO2009148483	2009	2009	CREE INC	SOLID STATE LIGHTING COMPONENT
7645397	2006	2010	NANOSYS INC	NANOCRYSTAL DOPED MATRICES
7652151	2006	2010	GENERAL ELECTRIC CO	KETOPYRROLES USEFUL AS LIGANDS IN ORGANIC IRIDIUM COMPOSITIONS
7655322	2005	2010	UNIVERSITY OF SOUTHERN CALIFORNIA / PRINCETON UNIVERSITY	OLEDS UTILIZING MACROCYCLIC LIGAND SYSTEMS
7663300	2002	2010	UNIVERSAL DISPLAY CORP	ORGANIC LIGHT-EMITTING DEVICES FOR ILLUMINATION
7665858	2007	2010	LIGHT PRESCRIPTIONS INNOVATORS	OPTICAL MANIFOLD
7667383	2006	2010	OSRAM OPTO SEMICONDUCTORS GMBH	LIGHT SOURCE COMPRISING A COMMON SUBSTRATE, A FIRST LED DEVICE AND A SECOND LED DEVICE
7670933	2007	2010	SANDIA CORP	NANOWIRE-TEMPLATED LATERAL EPITAXIAL GROWTH OF NON-POLAR GROUP III NITRIDES
7679282	2005	2010	OSRAM OPTO SEMICONDUCTORS GMBH	POLYMER AND SMALL MOLECULE BASED HYBRID LIGHT SOURCE
7691292	2006	2010	GENERAL ELECTRIC CO	ORGANIC IRIDIUM COMPOSITIONS AND THEIR USE IN ELECTRONIC DEVICES
7691494	2006	2010	GENERAL ELECTRIC CO	ELECTRONIC DEVICES COMPRISING ORGANIC IRIDIUM COMPOSITIONS
7695640	2006	2010	GENERAL ELECTRIC CO	ORGANIC IRIDIUM COMPOSITIONS AND THEIR USE IN ELECTRONIC DEVICES
7704610	2006	2010	GENERAL	ELECTRONIC DEVICES

			ELECTRIC CO	COMPRISING ORGANIC IRIDIUM COMPOSITIONS
7718087	2006	2010	GENERAL ELECTRIC CO	ORGANIC IRIDIUM COMPOSITIONS AND THEIR USE IN ELECTRONIC DEVICES
7718277	2006	2010	GENERAL ELECTRIC CO	ELECTRONIC DEVICES COMPRISING ORGANIC IRIDIUM COMPOSITIONS
7719186	2004	2010	UNASSIGNED	LIGHT EMITTING CERAMIC DEVICE
7723745	2008	2010	UNIVERSITY OF CALIFORNIA	HORIZONTAL EMITTING, VERTICAL EMITTING, BEAM SHAPED, DISTRIBUTED FEEDBACK (DFB) LASERS BY GROWTH OVER A PATTERNED SUBSTRATE
7755096	2007	2010	UNIVERSITY OF CALIFORNIA	SINGLE OR MULTI-COLOR HIGH EFFICIENCY LIGHT EMITTING DIODE (LED) BY GROWTH OVER A PATTERNED SUBSTRATE
7755838	2007	2010	LIGHT PRESCRIPTIONS INNOVATORS	OPTICAL DEVICES
7759682	2005	2010	CREE INC	LED WITH SUBSTRATE MODIFICATIONS FOR ENHANCED LIGHT EXTRACTION AND METHOD OF MAKING SAME
7768194	2006	2010	UNIVERSITY OF SOUTHERN CALIFORNIA	FLUORESCENT FILTERED ELECTROPHOSPHORESCENCE
7768210	2007	2010	GENERAL ELECTRIC CO	HYBRID ELECTROLUMINESCENT DEVICES
7772761	2005	2010	OSRAM OPTO SEMICONDUCTORS GMBH	ORGANIC ELECTROPHOSPHORESCENCE DEVICE HAVING INTERFACIAL LAYERS
7777233	2007	2010	EASTMAN KODAK CO	DEVICE CONTAINING NON-BLINKING QUANTUM DOTS
7790298	2007	2010	UNIVERSITY OF SOUTHERN CALIFORNIA	ORGANIC ELECTRONIC DEVICES USING PHTHALIMIDE COMPOUNDS
7804147	2006	2010	CREE INC	LIGHT EMITTING DIODE PACKAGE ELEMENT WITH INTERNAL MENISCUS FOR BUBBLE FREE LENS PLACEMENT
7819549	2005	2010	RENSSELAER POLYTECHNIC INSTITUTE	HIGH EFFICIENCY LIGHT SOURCE USING SOLID-STATE EMITTER AND DOWN-CONVERSION MATERIAL
7821023	2008	2010	CREE INC	SOLID STATE LIGHTING COMPONENT
7824778	2006	2010	UNIVERSITY OF	BINUCLEAR COMPOUNDS

			SOUTHERN CALIFORNIA	
7834546	2007	2010	OSRAM OPTO SEMICONDUCTORS GMBH	OLED LIGHTING DEVICES HAVING MULTI ELEMENT LIGHT EXTRACTION AND LUMINESCENCE CONVERSION LAYER
7842531	2009	2010	LEHIGH UNIVERSITY	GALLIUM NITRIDE-BASED DEVICE AND METHOD
7857994	2007	2010	GENERAL ELECTRIC CO	NOVEL GREEN EMITTING PHOSPHORS AND BLENDS THEREOF
7859754	2007	2010	LIGHT PRESCRIPTIONS INNOVATORS	WIDE BAND DICHROIC-FILTER DESIGN FOR LED-PHOSPHOR BEAM COMBINING
EP2143157	2008	2010	EASTMAN KODAK CO	ELECTROLUMINESCENT DEVICE HAVING IMPROVED LIGHT OUTPUT
EP2163135	2008	2010	EASTMAN KODAK CO	LIGHT-EMITTING NANOCOMPOSITE PARTICLES
EP2180032	2009	2010	GENERAL ELECTRIC CO	BLUE-GREEN AND GREEN PHOSPHORS FOR LIGHTING APPLICATIONS
EP2198669	2008	2010	KONINKLIJKE PHILIPS N V	METHODS AND APPARATUS FOR CONTROLLING RESPECTIVE LOAD CURRENTS OF MULTIPLE SERIES-CONNECTED LOADS
EP2207998	2008	2010	KONINKLIJKE PHILIPS N V	INTEGRATED LED-BASED LUMINAIRE FOR GENERAL LIGHTING
EP2212398	2008	2010	EASTMAN KODAK CO	DEVICE CONTAINING NON-BLINKING QUANTUM DOTS
EP2215670	2008	2010	UNIVERSITY OF MICHIGAN	ORGANIC LIGHT EMITTING DEVICE HAVING MULTIPLE SEPARATE EMISSIVE LAYERS
EP2220914	2008	2010	KONINKLIJKE PHILIPS N V	LED LAMP POWER MANAGEMENT SYSTEM AND METHOD
EP2232951	2008	2010	KONINKLIJKE PHILIPS N V	LED LAMP COLOR CONTROL SYSTEM AND METHOD
EP2241570	2004	2010	UNIVERSITY OF SOUTHERN CALIFORNIA	BIPHENYL- AND FLUORENYL-PYRAZOLE DERIVATIVES AND IRIDIUM COMPLEXES THEREOF
WO2010016990	2009	2010	UNIVERSITY OF NORTH TEXAS	ORGANIC LIGHT-EMITTING DIODES FROM HOMOLEPTIC SQUARE PLANAR COMPLEXES
WO2010028262	2009	2010	UNIVERSAL DISPLAY CORP	WHITE PHOSPHORESCENT ORGANIC LIGHT EMITTING DEVICES
WO2010030898	2009	2010	LIGHT PRESCRIPTIONS INNOVATORS	OPTICAL DEVICE FOR LED-BASED LAMP

WO2010044940	2009	2010	GENERAL ELECTRIC CO	2,5-LINKED POLYFLUORENES FOR OPTOELECTRONIC DEVICES
WO2010062643	2009	2010	UNIVERSITY OF MICHIGAN	STACKED WHITE OLED HAVING SEPARATE RED, GREEN AND BLUE SUB-ELEMENTS
WO2010083236	2010	2010	DOW CORNING CORPORATION	FLEXIBLE BARRIER FILM, METHOD OF FORMING SAME, AND ORGANIC ELECTRONIC DEVICE INCLUDING SAME
WO2010111495	2010	2010	UNIVERSITY OF MICHIGAN	CONCAVE-HEMISPHERE-PATTERNED ORGANIC TOP-LIGHT EMITTING DEVICE
WO2010144591	2010	2010	SINMAT INC; UNIV FLORIDA	HIGH LIGHT EXTRACTION EFFICIENCY SOLID STATE LIGHT SOURCES
WO2010151430	2010	2010	ARKEMA INC	CHEMICAL VAPOR DEPOSITION USING N,O POLYDENTATE LIGAND COMPLEXES OF METALS
7879401	2006	2011	UNIVERSITY OF SOUTHERN CALIFORNIA	ORGANIC VAPOR JET DEPOSITION USING AN EXHAUST
7893430	2009	2011	PACIFIC NORTHWEST NATIONAL LABORATORY	OLED DEVICES
7897980	2006	2011	CREE INC	EXPANDABLE LED ARRAY INTERCONNECT
7907269	2010	2011	KLA TENCOR CORP	SCATTERED LIGHT SEPERATION
7910386	2006	2011	GENERAL ELECTRIC CO	METHOD OF MAKING ORGANIC LIGHT EMITTING DEVICES
7911133	2007	2011	GLOBAL OLED TECHNOLOGY LLC	ELECTROLUMINESCENT DEVICE HAVING IMPROVED LIGHT OUTPUT
7932106	2006	2011	CREE INC	LIGHT EMITTING DIODE WITH HIGH ASPECT RATIO SUBMICRON ROUGHNESS FOR LIGHT EXTRACTION AND METHODS OF FORMING
7932534	2010	2011	SINMAT INC	HIGH LIGHT EXTRACTION EFFICIENCY SOLID STATE LIGHT SOURCES
7935325	2006	2011	UNIVERSITY OF CALIFORNIA	RARE EARTH ALUMINUM NITRIDE POWDERS AND METHOD OF MAKING
7960037	2005	2011	LAWRENCE BERKELEY NATIONAL LABORATORY	CARBON NANOTUBE POLYMER COMPOSITION AND DEVICES
7968004	2008	2011	GENERAL ELECTRIC CO	2,5-LINKED POLYFLUORENES FOR OPTOELECTRONIC DEVICES

7973126	2007	2011	GENERAL ELECTRIC CO	EMISSIVE POLYMERIC MATERIALS FOR OPTOELECTRONIC DEVICES
8007926	2008	2011	UNIVERSITY OF SOUTHERN CALIFORNIA	LUMINESCENT COMPOUNDS WITH CARBENE LIGANDS
8034647	2010	2011	CREE INC	LED WITH SUBSTRATE MODIFICATIONS FOR ENHANCED LIGHT EXTRACTION AND METHOD OF MAKING SAME
8035113	2006	2011	BOSTON UNIVERSITY	OPTICAL DEVICES FEATURING TEXTURED SEMICONDUCTOR LAYERS
8040053	2008	2011	UNIVERSAL DISPLAY CORP	ORGANIC LIGHT EMITTING DEVICE ARCHITECTURE FOR REDUCING THE NUMBER OF ORGANIC MATERIALS
8040058	2008	2011	UNIVERSITY OF FLORIDA	INKJET PRINTING OF MICROLENSES FOR PHOTONIC APPLICATIONS
8043724	2008	2011	UNIVERSITY OF SOUTHERN CALIFORNIA	PHENYL AND FLUORENYL SUBSTITUTED PHENYL-PYRAZOLE COMPLEXES OF IR
8052892	2008	2011	GENERAL ELECTRIC CO	2,5-LINKED POLYFLUORENES FOR OPTOELECTRONIC DEVICES
8053536	2008	2011	GENERAL ELECTRIC CO	FUNCTIONALIZED POLYFLUORENES FOR USE IN OPTOELECTRONIC DEVICES
8075147	2008	2011	LIGHT PRESCRIPTIONS INNOVATORS	OPTICAL DEVICE FOR LED-BASED LAMP
EP2291860	2009	2011	CREE INC	SOLID STATE LIGHTING COMPONENT
EP2304817	2009	2011	CREE INC	WHITE LIGHT EMITTING PACKAGE COMPRISING LED ARRAY
EP2318472	2009	2011	UNIVERSITY OF NORTH TEXAS	ORGANIC LIGHT-EMITTING DIODES FROM HOMOLEPTIC SQUARE PLANAR COMPLEXES
EP2329544	2009	2011	UNIVERSAL DISPLAY CORP	WHITE PHOSPHORESCENT ORGANIC LIGHT EMITTING DEVICES
EP2345096	2009	2011	UNIVERSITY OF MICHIGAN	STACKED WHITE OLED HAVING SEPARATE RED, GREEN AND BLUE SUB-ELEMENTS
EP2349965	2009	2011	GENERAL ELECTRIC CO	2,5-LINKED POLYFLUORENES FOR OPTOELECTRONIC DEVICES
EP2352362	2008	2011	KONINKLIJKE PHILIPS N V	LED LAMP COLOR CONTROL SYSTEM AND METHOD
EP2355200	2011	2011	MOSER BAER	METHOD OF

			INDIA LTD	MANUFACTURING ORGANIC LIGHTING DEVICE
EP2378586	2007	2011	UNIVERSITY OF SOUTHERN CALIFORNIA	ORGANIC ELECTRONIC DEVICES USING PHTHALIMIDE COMPOUNDS
WO2011005859	2010	2011	UNIVERSITY OF FLORIDA	STABLE AND ALL SOLUTION PROCESSABLE QUANTUM DOT LIGHT-EMITTING DIODES
WO2011028221	2010	2011	CREE INC	HIGH REFLECTIVITY MIRROR, LIGHT EMITTING DIODE INCORPORATING THE SAME AND METHOD FOR MAKING SAME
WO2011030252	2010	2011	KONINKLIJKE PHILIPS N V	ZENER DIODE PROTECTION NETWORK IN SUBMOUNT FOR LEDS CONNECTED IN SERIES
WO2011031947	2010	2011	UT-BATTELLE LLC	METHOD FOR MORPHOLOGICAL CONTROL AND ENCAPSULATION OF MATERIALS FOR ELECTRONICS AND ENERGY APPLICATIONS
WO2011033407	2010	2011	KONINKLIJKE PHILIPS N V	LED MODULE WITH HIGH INDEX LENS
WO2011068682	2010	2011	RESEARCH TRIANGLE INSTITUTE	REFLECTIVE NANOFIBER LIGHTING DEVICES
WO2011072011	2010	2011	LEHIGH UNIVERSITY	SURFACE PLASMON DISPERSION ENGINEERING VIA DOUBLE-METALLIC AU/AG LAYERS FOR NITRIDE LIGHT-EMITTING DIODES
WO2011079099	2010	2011	GENERAL ELECTRIC CO	COATED PHOSPHORS, METHODS OF MAKING THEM, AND ARTICLES COMPRISING THE SAME
WO2011096923	2010	2011	UNIVERSAL DISPLAY CORP	ORGANIC LIGHT EMITTING DEVICE WITH CONDUCTING COVER
WO2011106069	2010	2011	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM
WO2011109096	2011	2011	CREE INC	LED LAMP INCORPORATING REMOTE PHOSPHOR WITH HEAT DISSIPATION FEATURES
WO2011136943	2011	2011	GENERAL ELECTRIC CO	COLOR STABLE PHOSPHORS
WO2011137031	2011	2011	OSRAM SYLVANIA INC	THERMAL TRIM FOR A LUMINAIRE
WO2011142770	2010	2011	LIGHTSCAPE MATERIALS INC	CARBONITRIDE BASED PHOSPHORS AND LIGHT EMITTING DEVICES USING THE SAME

WO2011142880	2011	2011	LIGHTSCAPE MATERIALS INC	OXYCARBONITRIDE PHOSPHORS AND LIGHT EMITTING DEVICES USING THE SAME
WO2011153480	2011	2011	UNIVERSITY OF MICHIGAN	ULTRABRIGHT FLUORESCENT OLEDS USING TRIPLET SINKS
WO2011159615	2011	2011	APPLIED MATERIALS INC	METHOD AND APPARATUS FOR INDUCING TURBULENT FLOW OF A PROCESSING CHAMBER CLEANING GAS
8088499	2006	2012	AGILTRON	OPTOELECTONIC DEVICE WITH NANOPARTICLE EMBEDDED HOLE INJECTION/TRANSPORT LAYER
8089090	2005	2012	CREE INC	ULTRA-THIN OHMIC CONTACTS FOR P-TYPE NITRIDE LIGHT EMITTING DEVICES
8100734	2006	2012	UNIVERSAL DISPLAY CORP	ORGANIC LIGHT EMITTING DEVICES FOR ILLUMINATION
8143613	2007	2012	UNIVERSITY OF SOUTHERN CALIFORNIA	ORGANIC LIGHT EMITTING DEVICE HAVING MULTIPLE SEPARATE EMISSIVE LAYERS
8206838	2003	2012	MAXDEM INC	POLYMER MATRIX ELECTROLUMINESCENT MATERIALS AND DEVICES
8217412	2010	2012	CREE INC	SOLID STATE LIGHTING COMPONENT
8237175	2011	2012	BOSTON UNIVERSITY	OPTICAL DECIVES FEATURING TEXTURED SEMICONDUCTOR LAYERS
8242515	2010	2012	EASTMAN KODAK CO	DEVICE CONTAINING NON-BLINKING QUANTUM DOTS
8252613	2011	2012	GENERAL ELECTRIC CO	COLOR STABLE MANGANESE-DOPED PHOSPHORS
8273599	2007	2012	UNIVERSITY OF CALIFORNIA	ENHANCING PERFORMANCE CHARACTERISTICS OF ORGANIC SEMICONDUCTING FILMS BY IMPROVED SOLUTION PROCESSING
8293385	2010	2012	UNIVERSITY OF SOUTHERN CALIFORNIA	ORGANIC ELECTRONIC DEVICES USING PHTHALIMIDE COMPOUNDS
8308982	2010	2012	GENERAL ELECTRIC CO	ALKALINE AND ALKALINE EARTH METAL PHOSPHATE HALIDES AND PHOSPHORS
8318532	2007	2012	UNIVERSITY OF CALIFORNIA	ENHANCING PERFORMANCE CHARACTERISTICS OF ORGANIC SEMICONDUCTING FILMS BY IMPROVED SOLUTION PROCESSING
8324651	2007	2012	LAWRENCE BERKELEY	ORGANIC LIGHT EMITTING DIODES WITH STRUCTURED

			NATIONAL LABORATORY	ELECTRODES
8329060	2008	2012	GENERAL ELECTRIC CO	BLUE-GREEN AND GREEN PHOSPHORS FOR LIGHTING APPLICATIONS
8330348	2006	2012	OSRAM OPTO SEMICONDUCTORS GMBH	STRUCTURED LUMINESCENCE CONVERSION LAYER
8338201	2011	2012	MOSER BAER INDIA LTD	METHOD OF MANUFACTURING ORGANIC LIGHTING DEVICE
EP2452372	2010	2012	UNIVERSITY OF FLORIDA	STABLE AND ALL SOLUTION PROCESSABLE QUANTUM DOT LIGHT-EMITTING DIODES
EP2476294	2010	2012	KONINKLIJKE PHILIPS N V	ZENER DIODE PROTECTION NETWORK IN SUBMOUNT FOR LEDS CONNECTED IN SERIES
EP2478575	2010	2012	KONINKLIJKE PHILIPS N V	LED MODULE WITH HOUSING BODY HAVING TWO OPENINGS FOR LENS AND LED
EP2507052	2010	2012	RESEARCH TRIANGLE INSTITUTE	REFLECTIVE NANOFIBER LIGHTING DEVICES
WO2012003304	2011	2012	CRYSTAL IS INC	GROWTH OF LARGE ALUMINUM NITRIDE SINGLE CRYSTALS WITH THERMAL-GRADIENT CONTROL
WO2012003440	2011	2012	UNIVERSITY OF MICHIGAN	GAS CUSHION CONTROL OF OVJP PRINT HEAD POSITION
WO2012005854	2011	2012	OSRAM SYLVANIA INC	LAMP WITH A TRUNCATED REFLECTOR CUP
WO2012015726	2011	2012	GENERAL ELECTRIC CO	PHOSPHOR SUSPENDED IN SILICONE, MOLDED/FORMED AND USED IN A REMOTE PHOSPHOR CONFIGURATION
WO2012016074	2011	2012	UNIVERSITY OF SOUTHERN CALIFORNIA	CO-DEPOSITION METHODS FOR THE FABRICATION OF ORGANIC OPTOELECTRONIC DEVICES
WO2012024582	2011	2012	RESEARCH TRIANGLE INSTITUTE	COLOR-TUNABLE LIGHTING DEVICES AND METHODS FOR TUNNING COLOR OUTPUT OF LIGHTING DEVICES
WO2012024591	2011	2012	RESEARCH TRIANGLE INSTITUTE	PHOTOLUMINESCENT NANOFIBER COMPOSITES, METHODS FOR FABRICATION, AND RELATED LIGHTING DEVICES
WO2012033557	2011	2012	LIGHTSCAPE MATERIALS INC	SILICON CARBIDONITRIDE BASED PHOSPHORS AND LIGHTING DEVICES USING THE SAME
WO2012040172	2011	2012	UT-BATTELLE	CLOSE-PACKED ARRAY OF

			LLC	LIGHT EMITTING DEVICES
WO2012040637	2011	2012	UNIVERSITY OF CALIFORNIA	NANOWIRE-POLYMER COMPOSITE ELECTRODES
WO2012044746	2011	2012	UT-BATTELLE LLC	LUMINESCENT SYSTEMS WITH SURFACE CHARGE COMPENSATION AND METHOD OF MAKING
WO2012054114	2011	2012	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH HEAT DISTRIBUTION FACE PLATE
WO2012054115	2011	2012	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM HAVING POINT CONTACT SYNTHETIC JETS
WO2012088260	2011	2012	UNIVERSAL DISPLAY CORP	LIGHT EXTRACTION BLOCK WITH CURVED SURFACE
WO2012118985	2012	2012	SANDIA CORP	SOLID STATE LIGHTING DEVICES AND METHODS WITH ROTARY COOLING STRUCTURES
WO2012128837	2012	2012	GENERAL ELECTRIC CO	COLOR STABLE MANGANESE-DOPED PHOSPHORS
WO2012148521	2012	2012	GENERAL ELECTRIC CO	MATERIALS FOR OPTOELECTRONIC DEVICES
WO2012154289	2012	2012	CREE INC	RECIPIENT LUMINOPHORIC MEDIUMS HAVING NARROW-SPECTRUM LUMINESCENT MATERIALS AND RELATED SEMICONDUCTOR LIGHT EMITTING DEVICES AND METHODS
WO2012162196	2012	2012	APPLIED MATERIALS INC	METHODS FOR IMPROVED GROWTH OF GROUP III NITRIDE BUFFER LAYERS
WO2012162197	2012	2012	APPLIED MATERIALS INC	METHODS FOR IMPROVED GROWTH OF GROUP III NITRIDE SEMICONDUCTORS
WO2012177316	2012	2012	CREE INC	LED STRUCTURE WITH ENHANCED MIRROR REFLECTIVITY
8361823	2007	2013	EASTMAN KODAK CO	LIGHT-EMITTING NANOCOMPOSITE PARTICLES
8368315	2008	2013	KONINKLIJKE PHILIPS N V	LED LAMP COLOR CONTROL SYSTEM AND METHOD
8372526	2008	2013	UNIVERSAL DISPLAY CORP	INTERMEDIATE CONNECTOR FOR STACKED ORGANIC LIGHT EMITTING DEVICES
8372528	2011	2013	UNIVERSITY OF SOUTHERN CALIFORNIA	PHENYL AND FLUORENYL SUBSTITUTED PHENYL-PYRAZOLE COMPLEXES OF IR
8373341	2008	2013	UNIVERSITY OF FLORIDA	TOP-EMISSION ORGANIC LIGHT-EMITTING DEVICES WITH MICROLENS ARRAYS
8376593	2010	2013	OSRAM	THERMAL TRIM FOR A

			SYLVANIA INC	LUMINAIRE
8377334	2009	2013	GENERAL ELECTRIC CO	COATED PHOSPHORS, METHODS OF MAKING THEM, AND ARTICLES COMPRISING THE SAME
8390011	2010	2013	UNIVERSITY OF CALIFORNIA	SINGLE OR MULTI-COLOR HIGH EFFICIENCY LIGHT EMITTING DIODE (LED) BY GROWTH OVER A PATTERNED SUBSTRATE
8390207	2008	2013	KONINKLIJKE PHILIPS N V	INTEGRATED LED-BASED LUMINARE FOR GENERAL LIGHTING
8399109	2012	2013	UNIVERSITY OF SOUTHERN CALIFORNIA	ORGANIC ELECTRONIC DEVICES USING PHTHALIMIDE COMPOUNDS
8400064	2009	2013	LUMILEDS LLC	ZENER DIODE PROTECTION NETWORK IN SUBMOUNT FOR LEDS CONNECTED IN SERIES
8400071	2008	2013	KONINKLIJKE PHILIPS N V	LED LAMP POWER MANAGEMENT SYSTEM AND METHOD
8405233	2010	2013	DOW CORNING CORPORATION	FLEXIBLE BARRIER FILM, METHOD OF FORMING SAME, AND ORGANIC ELECTRONIC DEVICE INCLUDING SAME
8415704	2010	2013	UT-BATTELLE LLC	CLOSE-PACKED ARRAY OF LIGHT EMITTING DEVICES
8425803	2009	2013	SAMSUNG ELECTRONICS CO LTD	NANOCRYSTAL DOPED MATRIXES
8434906	2010	2013	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM
8434906	2010	2013	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM
8440104	2009	2013	GENERAL ELECTRIC CO	KIMZEYITE GARNET PHOSPHORS
8450730	2011	2013	UNIVERSITY OF MICHIGAN	LIGHT EMITTING DEVICE HAVING PERIPHERAL EMISSIVE REGION
8456081	2011	2013	UNIVERSITY OF SOUTHERN CALIFORNIA / UNIVERSITY OF MICHIGAN	ULTRABRIGHT FLUORESCENT OLEDS USING TRIPLET SINKS
8461600	2009	2013	UT-BATTELLE LLC	METHOD FOR MORPHOLOGICAL CONTROL AND ENCAPSULATION OF MATERIALS FOR ELECTRONICS AND ENERGY APPLICATIONS
8506104	2012	2013	GENERAL ELECTRIC CO	PHOSPHORS FOR LED LAMPS

8507924	2011	2013	CREE INC	LIGHT EMITTING DIODE WITH HIGH ASPECT RATIO SUBMICRON ROUGHNESS FOR LIGHT EXTRACTION AND METHODS OF FORMING
8512599	2010	2013	LIGHTSCAPE MATERIALS INC	CARBONITRIDE BASED PHOSPHORS AND LIGHT EMITTING DEVICES USING THE SAME
8513658	2009	2013	UNIVERSAL DISPLAY CORP	WHITE PHOSPHORESCENT ORGANIC LIGHT EMITTING DEVICES
8529097	2010	2013	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH HEAT DISTRIBUTION FACE PLATE
8535566	2011	2013	LIGHTSCAPE MATERIALS INC	SILICON CARBIDONITRIDE BASED PHOSPHORS AND LIGHTING DEVICES USING THE SAME
8536777	2012	2013	LIGHTSCAPE MATERIALS INC	OXYCARBIDONITRIDE BASED PHOSPHORS AND LED LIGHTING DEVICES
8541252	2010	2013	LEHIGH UNIVERSITY	ABBREVIATED EPITAXIAL GROWTH MODE (AGM) METHOD FOR REDUCING COST AND IMPROVING QUALITY OF LEDS AND LASERS
8551361	2011	2013	LIGHTSCAPE MATERIALS INC	OXYCARBONITRIDE PHOSPHORS AND LIGHT EMITTING DEVICES USING THE SAME
8556473	2010	2013	OSRAM SYLVANIA INC	LAMP WITH A TRUNCATED REFLECTOR CUP
8579451	2011	2013	OSRAM SYLVANIA INC	LED LAMP
8580397	2009	2013	UNIVERSITY OF NORTH TEXAS	ORGANIC LIGHT-EMITTING DIODES FROM HOMOLEPTIC SQUARE PLANAR COMPLEXES
8585259	2013	2013	OSRAM SYLVANIA INC	THERMAL TRIM FOR A LUMINAIRE
8586963	2010	2013	LEHIGH UNIVERSITY	SEMICONDUCTOR LIGHT-EMITTING DEVICES HAVING CONCAVE MICROSTRUCTURES PROVIDING IMPROVED LIGHT EXTRACTION EFFICIENCY AND METHOD FOR PRODUCING SAME
8592037	2011	2013	SAMSUNG ELECTRONICS CO LTD	NANOCRYSTAL DOPED MATRIXES
8592800	2009	2013	BOSTON UNIVERSITY	OPTICAL DEVICES FEATURING NONPOLAR TEXTURED SEMICONDUCTOR

				LAYERS
8593062	2011	2013	GENERAL ELECTRIC CO	COLOR STABLE PHOSPHORS FOR LED LAMPS AND METHODS FOR PREPARING THEM
8602607	2010	2013	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM HAVING POINT CONTACT SYNTHETIC JETS
8617909	2009	2013	CREE INC	LED WITH SUBSTRATE MODIFICATIONS FOR ENHANCED LIGHT EXTRACTION AND METHOD OF MAKING SAME
EP2539634	2010	2013	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM
EP2564113	2011	2013	OSRAM SYLVANIA INC	THERMAL TRIM FOR A LUMINAIRE
EP2569247	2010	2013	LIGHTSCAPE MATERIALS INC	CARBONITRIDE BASED PHOSPHORS AND LIGHT EMITTING DEVICES USING THE SAME
EP2569395	2011	2013	LIGHTSCAPE MATERIALS INC	OXYCARBONITRIDE PHOSPHORS AND LIGHT EMITTING DEVICES USING THE SAME
EP2588562	2011	2013	GENERAL ELECTRIC CO	COLOR STABLE PHOSPHORS
EP2588651	2011	2013	CRYSTAL IS INC	GROWTH OF LARGE ALUMINUM NITRIDE SINGLE CRYSTALS WITH THERMAL-GRADIENT CONTROL
EP2588802	2011	2013	OSRAM SYLVANIA INC	LAMP WITH A TRUNCATED REFLECTOR CUP
EP2599364	2011	2013	GENERAL ELECTRIC CO	PHOSPHOR SUSPENDED IN SILICONE, MOLDED/FORMED AND USED IN A REMOTE PHOSPHOR CONFIGURATION
EP2606275	2011	2013	RESEARCH TRIANGLE INSTITUTE	COLOR-TUNABLE LIGHTING DEVICES AND METHODS FOR TUNNING COLOR OUTPUT OF LIGHTING DEVICES
EP2610887	2003	2013	UNIVERSAL DISPLAY CORP	ORGANIC LIGHT EMITTING DEVICES FOR ILLUMINATION
EP2614683	2011	2013	LIGHTSCAPE MATERIALS INC	SILICON CARBIDONITRIDE BASED PHOSPHORS AND LIGHTING DEVICES USING THE SAME
EP2619816	2011	2013	UNIVERSITY OF CALIFORNIA	NANOWIRE-POLYMER COMPOSITE ELECTRODES
EP2630409	2011	2013	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM HAVING POINT CONTACT SYNTHETIC JETS
WO2013040131	2012	2013	OSRAM	LED LAMP

			SYLVANIA INC	
WO2013059102	2012	2013	APPLIED MATERIALS INC	MULTIPLE COMPLEMENTARY GAS DISTRIBUTION ASSEMBLIES
WO2013074543	2012	2013	KLA TENCOR CORP	HIGH THROUGHPUT HOT TESTING METHOD AND SYSTEM FOR HIGH BRIGHTNESS LIGHT EMITTING DIODES
WO2013173081	2013	2013	OSRAM SYLVANIA INC	DRIVER CIRCUIT FOR SOLID STATE LIGHT SOURCES
WO2013173442	2013	2013	KLA TENCOR CORP	SUBSTRATE INSPECTION
8633497	2010	2014	UNIVERSITY OF MICHIGAN	CONCAVE-HEMISPHERE-PATTERNED ORGANIC TOP-LIGHT EMITTING DEVICE
8685767	2010	2014	LEHIGH UNIVERSITY	SURFACE PLASMON DISPERSION ENGINEERING VIA DOUBLE-METALLIC AU/AG LAYERS FOR NITRIDE LIGHT-EMITTING DIODES
8686429	2011	2014	CREE INC	LED STRUCTURE WITH ENHANCED MIRROR REFLECTIVITY
8698171	2012	2014	CREE INC	SOLID STATE LIGHTING COMPONENT
8710487	2012	2014	GENERAL ELECTRIC CO	COLOR STABLE MANGANESE-DOPED PHOSPHORS
8723169	2012	2014	UNIVERSITY OF CALIFORNIA	ENHANCING PERFORMING CHARACTERISTICS OF ORGANIC SEMICONDUCTING FILMS BY IMPROVED SOLUTION PROCESSING
8736197	2008	2014	KONINKLIJKE PHILIPS N V	METHODS AND APPARATUS FOR CONTROLLING RESPECTIVE LOAD CURRENTS OF MULTIPLE SERIES-CONNECTED LOADS
8736831	2012	2014	KLA TENCOR CORP	SUBSTRATE INSPECTION
8759868	2011	2014	CREE INC	ULTRA-THIN OHMIC CONTACTS FOR P-TYPE NITRIDE LIGHT EMITTING DEVICES
8766291	2009	2014	UNIVERSITY OF MICHIGAN	STACKED WHITE OLED HAVING SEPARATE RED, GREEN AND BLUE SUB-ELEMENTS
8766517	2010	2014	UNIVERSAL DISPLAY CORP	ORGANIC LIGHT EMITTING DEVICE WITH CONDUCTING COVER
8771547	2013	2014	LIGHTSCAPE MATERIALS INC	OXYCARBONITRIDE PHOSPHORS AND LIGHT EMITTING DEVICES USING THE SAME

8778226	2010	2014	UT-BATTELLE LLC	LUMINESCENT SYSTEMS BASED ON THE ISOLATION OF CONJUGATED PI SYSTEMS AND EDGE CHARGE COMPENSATION WITH POLAR MOLECULES ON A CHARGED NANOSTRUCTURED SURFACE
8778783	2012	2014	APPLIED MATERIALS INC	METHODS FOR IMPROVED GROWTH OF GROUP III NITRIDE BUFFER LAYERS
8784703	2011	2014	EASTMAN KODAK CO	METHOD OF MAKING HIGHLY-CONFINED SEMICONDUCTOR NANOCRYSTALS
8808881	2013	2014	UNIVERSITY OF SOUTHERN CALIFORNIA	PHENYL AND FLUORENYL SUBSTITUTED PHENYL-PYRAZOLE COMPLEXES OF IR
8815121	2012	2014	LIGHTSCAPE MATERIALS INC	HALOGENATED OXYCARBIDONITRIDE PHOSPHOR AND DEVICES USING SAME
8815411	2008	2014	UNIVERSITY OF SOUTHERN CALIFORNIA	STABLE BLUE PHOSPHORESCENT ORGANIC LIGHT EMITTING DEVICES
8822042	2011	2014	UNIVERSITY OF SOUTHERN CALIFORNIA	LUMINESCENT CYCLOMETALLATED IRIDIUM(III) COMPLEXES HAVING ACETYLIDE LIGANDS
8835199	2011	2014	GENERAL ELECTRIC CO	PHOSPHOR SUSPENDED IN SILICONE, MOLDED/FORMED AND USED IN A REMOTE PHOSPHOR CONFIGURATION
8836223	2012	2014	UNIVERSAL DISPLAY CORP	OLED PANEL WITH FUSES
8851597	2011	2014	UNIVERSITY OF MICHIGAN	GAS CUSHION CONTROL OF OVJP PRINT HEAD POSITION
8882284	2011	2014	CREE INC	LED LAMP OR BULB WITH REMOTE PHOSPHOR AND DIFFUSER CONFIGURATION WITH ENHANCED SCATTERING PROPERTIES
8884507	2010	2014	RESEARCH TRIANGLE INSTITUTE	REFLECTIVE NANOFIBER LIGHTING DEVICES
8907321	2010	2014	LEHIGH UNIVERISTY	NITRIDE BASED QUANTUM WELL LIGHT-EMITTING DEVICES HAVING IMPROVED CURRENT INJECTION EFFICIENCY
8910644	2011	2014	APPLIED MATERIALS INC	METHOD AND APPARATUS FOR INDUCING TURBULENT FLOW OF A PROCESSING

				CHAMBER CLEANING GAS
8921875	2011	2014	CREE INC	RECIPIENT LUMINOPHORIC MEDIUMS HAVING NARROW SPECTRUM LUMINESCENT MATERIALS AND RELATED SEMICONDUCTOR LIGHT EMITTING DEVICES AND METHODS
EP2688978	2012	2014	GENERAL ELECTRIC CO	COLOR STABLE MANGANESE-DOPED PHOSPHORS
EP2702084	2012	2014	GENERAL ELECTRIC CO	MATERIALS FOR OPTOELECTRONIC DEVICES
EP2707909	2012	2014	CREE INC	SEMICONDUCTOR LIGHT EMITTING DEVICES COMPRISING RECIPIENT LUMINOPHORIC MEDIUMS HAVING NARROW-SPECTRUM LUMINESCENT MATERIALS
EP2713678	2013	2014	OSRAM SYLVANIA INC	SOLID STATE LIGHT SOURCE DRIVER ESTABLISHING BUCK OR BOOST OPERATION
EP2724386	2012	2014	CREE INC	LED STRUCTURE WITH ENHANCED MIRROR REFLECTIVITY
EP2780679	2012	2014	KLA TENCOR CORP	HIGH THROUGHPUT HOT TESTING METHOD AND SYSTEM FOR HIGH BRIGHTNESS LIGHT EMITTING DIODES
EP2803898	2005	2014	RENSSELAER POLYTECHNIC INSTITUTE	A LIGHT-EMITTING APPARATUS
WO2014031977	2013	2014	ARIZONA STATE UNIVERSITY	METAL COMPOUNDS AND METHODS AND USES THEREOF
WO2014051900	2013	2014	GENERAL ELECTRIC CO	OLED DEVICES WITH INTERNAL OUTCOUPLING
WO2014158969	2014	2014	PPG INDUSTRIES OHIO INC	ORGANIC LIGHT EMITTING DIODE WITH LIGHT EXTRACTING LAYER
8927308	2011	2015	UNIVERSAL DISPLAY CORP	GENERAL BUS LINE DESIGN RULES FOR LARGE-AREA OLED LIGHTING
8927944	2012	2015	KLA TENCOR CORP	HIGH THROUGHPUT HOT TESTING METHOD AND SYSTEM FOR HIGH-BRIGHTNESS LIGHT-EMITTING DIODES
8940411	2011	2015	GENERAL ELECTRIC CO	MATERIALS FOR OPTOELECTRONIC DEVICES
8945722	2006	2015	UNIVERSITY OF SOUTHERN CALIFORNIA	MATERIALS AND ARCHITECTURES FOR EFFICIENT HARVESTING OF SINGLET AND TRIPLET

				EXCITONS FOR WHITE LIGHT EMITTING OLEDS
8960972	2013	2015	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM
8969856	2012	2015	GENERAL ELECTRIC CO	OLED DEVICES WITH INTERNAL OUTCOUPLING
8980002	2012	2015	APPLIED MATERIALS INC	METHODS FOR IMPROVED GROWTH OF GROUP III NITRIDE SEMICONDUCTORS
9017574	2012	2015	LIGHTSCAPE MATERIALS INC	CARBIDONITRIDE PHOSPHORS AND LED LIGHTING DEVICES USING THE SAME
9028612	2011	2015	CRYSTAL IS INC	GROWTH OF LARGE ALUMINUM NITRIDE SINGLE CRYSTALS WITH THERMAL-GRADIENT CONTROL
9054330	2010	2015	UNIVERSITY OF FLORIDA	STABLE AND ALL SOLUTION PROCESSABLE QUANTUM DOT LIGHT-EMITTING DIODES
9054335	2013	2015	UNIVERSITY OF MICHIGAN	CONCAVE-HEMISPHERE-PATTERNED ORGANIC TOP-LIGHT EMITTING DEVICE
9065067	2014	2015	UNIVERSITY OF MICHIGAN	STACKED WHITE OLED HAVING SEPARATE RED, GREEN AND BLUE SUB-ELEMENTS
9076940	2013	2015	CREE INC	SOLID STATE LIGHTING COMPONENT
9101036	2011	2015	RESEARCH TRIANGLE INSTITUTE	PHOTOLUMINESCENT NANOFIBER COMPOSITES, METHODS AND FABRICATION, AND RELATED LIGHTING DEVICES.
9118017	2012	2015	UNIVERSAL DISPLAY CORP	NOVEL HOST COMPOUNDS FOR RED PHOSPHORESCENT OLEDS
9119246	2014	2015	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM
9119247	2014	2015	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM
9153731	2014	2015	SUNY BUFFALO	COLLOIDAL NANOCRYSTALS AND METHOD OF MAKING
9217105	2014	2015	LIGHTSCAPE MATERIALS INC	OXYCARBONITRIDE PHOSPHORS AND LIGHT EMITTING DEVICES USING THE SAME
EP2850385	2013	2015	KLA TENCOR CORP	SUBSTRATE INSPECTION
EP2850916	2013	2015	OSRAM SYLVANIA INC	DRIVER CIRCUIT FOR SOLID STATE LIGHT SOURCES

EP2857479	2011	2015	LIGHTSCAPE MATERIALS INC	OXYCARBONITRIDE PHOSPHORS AND LIGHT EMITTING DEVICES USING THE SAME
EP2894396	2014	2015	CREE INC	EXTRACTION FILM FOR OPTICAL WAVEGUIDE AND METHOD OF PRODUCING SAME
WO2015021290	2014	2015	NEW YORK STATE UNIVERSITY	COLLOIDAL NANOCRYSTALS AND METHOD OF MAKING
WO2015099871	2014	2015	PPG INDUSTRIES OHIO INC	ORGANIC LIGHT EMITTING DIODE WITH LIGHT EXTRACTING ELECTRODE
WO2015110875	2014	2015	KONINKLIJKE PHILIPS N V	HYBRID CHIP-ON-BOARD LED MODULE WITH PATTERNED ENCAPSULATION
WO2015164191	2015	2015	PPG INDUSTRIES OHIO INC	ORGANIC LIGHT EMITTING DIODE WITH SURFACE MODIFICATION LAYER
9265114	2012	2016	OSRAM SYLVANIA INC	DRIVER CIRCUIT FOR SOLID STATE LIGHT SOURCES
9293734	2010	2016	UNIVERSAL DISPLAY CORP	LIGHT EXTRACTION BLOCKS FOR THIN FORM FACTOR OLED LIGHTING WITH IMPROVED POWER EFFICACY
9303318	2012	2016	APPLIED MATERIALS INC	MULTIPLE COMPLEMENTARY GAS DISTRIBUTION ASSEMBLIES
9312502	2013	2016	ARIZONA STATE UNIVERSITY	IRIDIUM COMPLEXES DEMONSTRATING BROADBAND EMISSION THROUGH CONTROLLED GEOMETRIC DISTORTION AND APPLICATIONS THEREOF
9362459	2009	2016	CREE INC	HIGH REFLECTIVITY MIRRORS AND METHOD FOR MAKING SAME
9366787	2014	2016	PPG INDUSTRIES OHIO INC	ORGANIC LIGHT EMITTING DIODE WITH LIGHT EXTRACTING LAYER
9379346	2015	2016	UNIVERSITY OF MICHIGAN	STACKED WHITE OLED HAVING SEPARATE RED, GREEN AND BLUE SUB-ELEMENTS
9385285	2009	2016	LUMILEDS LLC	LED MODULE WITH HIGH INDEX LENS
9423106	2013	2016	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM HAVING POINT CONTACT SYNTHETIC JETS
9429279	2013	2016	KONINKLIJKE PHILIPS N V	INTEGRATED LED-BASED LUMINAIRE FOR GENERAL LIGHTING
9429302	2013	2016	GENERAL	LIGHTING SYSTEM WITH

			ELECTRIC CO	THERMAL MANAGEMENT SYSTEM HAVING POINT CONTACT SYNTHETIC JETS
9435021	2011	2016	UNIVERSITY OF SOUTHERN CALIFORNIA	CO-DEPOSITION METHODS FOR THE FABRICATION OF ORGANIC OPTOELECTRONIC DEVICES
9450027	2014	2016	UNIVERSAL DISPLAY CORP	METHOD OF FORMING BUS LINE DESIGNS FOR LARGE-AREA OLED LIGHTING
9468047	2014	2016	GENERAL ELECTRIC CO	LIGHTING SYSTEM WITH THERMAL MANAGEMENT SYSTEM
9500325	2011	2016	CREE INC	LED LAMP INCORPORATING REMOTE PHOSPHOR WITH HEAT DISSIPATION FEATURES
9508957	2008	2016	UNIVERSITY OF MICHIGAN	OLED WITH IMPROVED LIGHT OUTCOUPLING
9515283	2012	2016	BOE TECHNOLOGY GROUP CO LTD	OLED DEVICES WITH INTERNAL OUTCOUPLING
9519033	2015	2016	KLA TENCOR CORP	HIGH THROUGHPUT HOT TESTING METHOD AND SYSTEM FOR HIGH-BRIGHTNESS LIGHT-EMITTING DIODES
9528182	2010	2016	ARKEMA INC	CHEMICAL VAPOR DEPOSITION USING N,O POLYDENTATE LIGAND COMPLEXES OF METALS
EP2973774	2014	2016	PPG INDUSTRIES OHIO INC	ORGANIC LIGHT EMITTING DIODE WITH LIGHT EXTRACTING LAYER
EP3051586	2008	2016	KONINKLIJKE PHILIPS N V	INTEGRATED LED-BASED LUMINAIRE FOR GENERAL LIGHTING
EP3095832	2012	2016	GENERAL ELECTRIC CO	COLOR STABLE MANGANESE-DOPED PHOSPHORS
EP3097588	2014	2016	KONINKLIJKE PHILIPS N V	HYBRID CHIP-ON-BOARD LED MODULE WITH PATTERNED ENCAPSULATION
EP3109238	2004	2016	UNIVERSITY OF SOUTHERN CALIFORNIA	PHENYL-PYRAZOLE COMPLEXES OF IRIDIUM
9562671	2011	2017	RESEARCH TRIANGLE INSTITUTE	COLOR TUNABLE LIGHTING DEVICES AND METHODS FOR TUNING COLOR OUTPUT OF LIGHTING DEVICES
9580833	2015	2017	CRYSTAL IS INC	GROWTH OF LARGE ALUMINUM NITRIDE SINGLE CRYSTALS WITH THERMAL-GRADIENT CONTROL
9583720	2014	2017	UNIVERSITY OF SOUTHERN	PHENYL AND FLUORENYL SUBSTITUTED PHENYL-

			CALIFORNIA	PYRAZOLE COMPLEXES OF IR
9599328	2012	2017	SANDIA CORP	SOLID STATE LIGHTING DEVICES AND METHODS WITH ROTARY COOLING STRUCTURES
9627652	2014	2017	VITRO SAB DE C V	ORGANIC LIGHT EMITTING DIODE WITH LIGHT EXTRACTING ELECTRODE
9651740	2014	2017	CREE INC	EXTRACTION FILM FOR OPTICAL WAVEGUIDE AND METHOD OF PRODUCING SAME
9699866	2016	2017	MOJO LABS	WAND GESTURE
9711741	2013	2017	ARIZONA STATE UNIVERSITY	METAL COMPOUNDS AND METHODS AND USES THEREOF
9711748	2012	2017	BOE TECHNOLOGY GROUP CO LTD	OLED DEVICES WITH INTERNAL OUTCOUPLING
9748858	2012	2017	OSRAM SYLVANIA INC	SOLID STATE LIGHT SOURCE DRIVER ESTABLISHING BUCK OR BOOST OPERATION
9755124	2016	2017	KONINKLIJKE PHILIPS N V	LED MODULE WITH HIGH INDEX LENS
9761841	2015	2017	VITRO SAB DE C V	ORGANIC LIGHT EMITTING DIODE WITH SURFACE MODIFICATION LAYER
9793247	2008	2017	CREE INC	SOLID STATE LIGHTING COMPONENT
9824789	2013	2017	UNIVERSITY OF CALIFORNIA	NANOWIRE-POLYMER COMPOSITE ELECTRODES
EP3134928	2015	2017	VITRO SAB DE C V	ORGANIC LIGHT EMITTING DIODE WITH SURFACE MODIFICATION LAYER
9905737	2014	2018	LUMILEDS LLC	HYBRID CHIP-ON-BOARD LED MODULE WITH PATTERNED ENCAPSULATION
9985251	2015	2018	PRINCETON UNIVERSITY	PROCESS FOR FABRICATING A POROUS FILM IN A SCATTERING LAYER
10014485	2016	2018	UNIVERSITY OF MICHIGAN	STACKED WHITE OLED HAVING SEPARATE RED, GREEN AND BLUE SUB-ELEMENTS
10056530	2017	2018	EIE MATERIALS INC	PHOSPHOR-CONVERTED WHITE LIGHT EMITTING DIODES HAVING NARROW-BAND GREEN PHOSPHORS
10096799	2017	2018	VITRO SAB DE C V	ORGANIC LIGHT EMITTING DIODE WITH SURFACE MODIFICATION LAYER
10106913	2017	2018	CRYSTAL IS INC	SYSTEM FOR GROWTH OF LARGE ALUMINUM NITRIDE SINGLE CRYSTALS WITH THERMAL-GRADIENT

				CONTROL
10145026	2013	2018	SORAA INC	PROCESS FOR LARGE-SCALE AMMONOTHERMAL MANUFACTURING OF SEMIPOLAR GALLIUM NITRIDE BOULES
10165640	2017	2018	LUMILEDS LLC	PRINTED CIRCUIT BOARD FOR INTEGRATED LED DRIVER
WO2018009269	2017	2018	LUMILEDS LLC	PRINTED CIRCUIT BOARD FOR INTEGRATED LED DRIVER
10186981	2016	2019	OSRAM SYLVANIA INC	SYSTEMS AND METHODS OF DELIVERING RECTIFIED VOLTAGE TO A LOAD
10490710	2018	2019	LUMILEDS LLC	HYBRID CHIP-ON-BOARD LED MODULE WITH PATTERNED ENCAPSULATION
EP3553835	2012	2019	CREE INC	SEMICONDUCTOR LIGHT EMITTING DEVICES COMPRISING RECIPIENT LUMINOPHORIC MEDIUMS HAVING NARROW-SPECTRUM LUMINESCENT MATERIALS
WO2019027643	2018	2019	EIE MATERIALS INC	PHOSPHOR-CONVERTED WHITE LIGHT EMITTING DIODES HAVING NARROW-BAND GREEN PHOSPHORS
EP3657558	2009	2020	CREE INC	SOLID STATE LIGHTING COMPONENT

Appendix B. Other DOE-Funded SSL Patents used in the Analysis

Patent #	Application Year	Issue / Publication Year	Original Assignees	Title
6268695	1998	2001	BATTELLE MEMORIAL INSTITUTE	ENVIRONMENTAL BARRIER MATERIAL FOR ORGANIC LIGHT EMITTING DEVICE AND METHOD OF MAKING
6497598	2001	2002	BATTELLE MEMORIAL INSTITUTE	ENVIRONMENTAL BARRIER MATERIAL FOR ORGANIC LIGHT EMITTING DEVICE AND METHOD OF MAKING
WO2002058110	2002	2002	UNIVERSITY OF UTAH	IMPROVED PERFORMANCE OF ORGANIC LIGHT-EMITTING DEVICES USING SPIN-DEPENDENT PROCESSES
6522067	1999	2003	BATTELLE MEMORIAL INSTITUTE	ENVIRONMENTAL BARRIER MATERIAL FOR ORGANIC LIGHT EMITTING DEVICE AND METHOD OF MAKING
6599362	2001	2003	SANDIA CORP	CANTILEVER EPITAXIAL PROCESS
6665329	2002	2003	SANDIA CORP	BROADBAND VISIBLE LIGHT SOURCE BASED ON ALLNGAN LIGHT EMITTING DIODES
6774560	2000	2004	UNIVERSITY OF CALIFORNIA	MATERIAL SYSTEM FOR TAILORABLE WHITE LIGHT EMISSION AND METHOD FOR MAKING THEREOF
6815736	2001	2004	MIDWEST RESEARCH INSTITUTE	ISOELECTRONIC CO-DOPING
WO2004007634	2003	2004	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	EMISSIVE, HIGH CHARGE TRANSPORT POLYMERS
6864626	1999	2005	UNIVERSITY OF CALIFORNIA	ELECTRONIC DISPLAYS USING OPTICALLY PUMPED LUMINESCENT SEMICONDUCTOR NANOCRYSTALS
6909239	2003	2005	UNIVERSITY OF CALIFORNIA	DUAL LED/INCANDESCENT SECURITY FIXTURE
6969874	2003	2005	SANDIA CORP	FLIP-CHIP LIGHT EMITTING DIODE WITH RESONANT OPTICAL MICROCAVITY
WO2005056499	2004	2005	NORTHWESTERN UNIVERSITY	OLIGO(P-PHENYLENE VINYLENE)

				AMPHIPHILES AND METHODS FOR SELF-ASSEMBLY
WO2005104236	2005	2005	BOSTON UNIVERSITY	OPTICAL DEVICES FEATURING TEXTURED SEMICONDUCTOR LAYERS
WO2005117124	2005	2005	UNIVERSITY OF CALIFORNIA	NON-CONTACT PUMPING OF LIGHT EMITTERS VIA NON-RADIATIVE ENERGY TRANSFER
7041910	2003	2006	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	EMISSIVE, HIGH CHARGE TRANSPORT POLYMERS
7135241	2002	2006	UNIVERSITY OF TEXAS	LIGHT-EMITTING BLOCK COPOLYMERS COMPOSITION, PROCESS AND USE
EP1735838	2005	2006	BOSTON UNIVERSITY	OPTICAL DEVICES FEATURING TEXTURED SEMICONDUCTOR LAYERS
7235190	2004	2007	SANDIA CORP	NANOCLUSTER-BASED WHITE-LIGHT-EMITTING MATERIAL EMPLOYING SURFACE TUNING
WO2007134280	2007	2007	UNIVERSITY OF UTAH	P-CONJUGATED HEAVY-METAL POLYMERS FOR ORGANIC WHITE-LIGHT-EMITTING DIODES
WO2007134285	2007	2007	UNIVERSITY OF UTAH	P-CONJUGATED HEAVY-METAL POLYMERS PARTICULARLY SUITED TO HYDROPONIC APPLICATIONS
7371887	2004	2008	NORTHWESTERN UNIVERSITY	OLIGO(P-PHENYLENE VINYLENE) AMPHIPHILES AND METHODS FOR SELF-ASSEMBLY
7419846	2004	2008	PRINCETON UNIVERSITY	METHOD OF FABRICATING AN OPTOELECTRONIC DEVICE HAVING A BULK HETEROJUNCTION
7435617	2004	2008	PRINCETON UNIVERSITY	METHOD OF FABRICATING AN OPTOELECTRONIC DEVICE HAVING A BULK

				HETEROJUNCTION
WO2008112115	2008	2008	UNASSIGNED	NOVEL, SEMICONDUCTOR-BASED, LARGE-AREA, FLEXIBLE, ELECTRONIC DEVICES
WO2008143635	2007	2008	UNIVERSITY OF ILLINOIS	OPTICAL SYSTEMS FABRICATED BY PRINTING-BASED ASSEMBLY
7535029	2004	2009	LAWRENCE LIVERMORE NATIONAL SECURITY LLC	MATERIAL SYSTEM FOR TAILORABLE WHITE LIGHT EMISSION AND METHOD FOR MAKING THEREOF
EP2104954	2007	2009	UNIVERSITY OF ILLINOIS; SEMPRIUS INC; X CELEPRINT LTD	OPTICAL SYSTEMS FABRICATED BY PRINTING-BASED ASSEMBLY
WO2009082404	2007	2009	LEHIGH UNIVERSITY	STAGGERED COMPOSITION QUANTUM WELL METHOD AND DEVICE
WO2009099605	2009	2009	LIGHT PRESCRIPTIONS INNOVATORS	TRANSPARENT HEAT-SPREADER FOR OPTOELECTRONIC APPLICATIONS
7642557	2004	2010	LOS ALAMOS NATIONAL SECURITY LLC	NON-CONTACT PUMPING OF LIGHT EMITTERS VIA NON-RADIATIVE ENERGY TRANSFER
7682707	2005	2010	UNIVERSITY OF UTAH	ORGANIC LIGHT-EMITTING DEVICES USING SPIN-DEPENDENT PROCESSES
7696684	2007	2010	UNIVERSITY OF CALIFORNIA	ELECTRONIC DISPLAYS USING OPTICALLY PUMPED LUMINESCENT SEMICONDUCTOR NANOCRYSTALS
7777241	2005	2010	BOSTON UNIVERSITY	OPTICAL DEVICES FEATURING TEXTURED SEMICONDUCTOR LAYERS
WO2010036776	2009	2010	ALLIANCE FOR SUSTAINABLE ENERGY LLC	THIN FILM ELECTRONIC DEVICES WITH CONDUCTIVE AND TRANSPARENT GAS AND MOISTURE PERMEATION BARRIERS
WO2010088419	2010	2010	UNIVERSITY OF WASHINGTON	CROSS-CONJUGATED POLYMERS FOR ORGANIC ELECTRONIC

				DEVICES AND RELATED METHODS
WO2010111125	2010	2010	DOW GLOBAL TECHNOLOGIES LLC	OPTOELECTRONIC DEVICE
WO2010121057	2010	2010	ALLIANCE FOR SUSTAINABLE ENERGY LLC	LATTICE-MISMATCHED GAINP LED DEVICES AND METHODS OF FABRICATING SAME
WO2010124212	2010	2010	UNIVERSITY OF CHICAGO	MATERIALS AND METHODS FOR THE PREPARATION OF NANOCOMPOSITES
WO2010132552	2010	2010	UNIVERSITY OF ILLINOIS	PRINTED ASSEMBLIES OF ULTRATHIN, MICROSCALE INORGANIC LIGHT EMITTING DIODES FOR DEFORMABLE AND SEMITRANSPARENT DISPLAYS
WO2010148024	2010	2010	UNIVERSITY OF HOUSTON	WRAPPED OPTOELECTRONIC DEVICES AND METHODS FOR MAKING SAME
7906229	2007	2011	UNASSIGNED	SEMICONDUCTOR-BASED, LARGE-AREA, FLEXIBLE, ELECTRONIC DEVICES
7972875	2007	2011	UNIVERSITY OF ILLINOIS	OPTICAL SYSTEMS FABRICATED BY PRINTING-BASED ASSEMBLY
8026661	2009	2011	UNIVERSITY OF CALIFORNIA	ELECTRONIC DISPLAYS USING OPTICALLY PUMPED LUMINESCENT SEMICONDUCTOR NANOCRYSTALS
8034745	2008	2011	UNASSIGNED	HIGH PERFORMANCE DEVICES ENABLED BY EPITAXIAL, PREFERENTIALLY ORIENTED, NANODOTS AND/OR NANORODS
8053376	2009	2011	GEORGIA TECH RESEARCH CORP	ONE-STEP SYNTHESIS AND PATTERNING OF ALIGNED POLYMER NANOWIRES ON A SUBSTRATE
WO2011050179	2010	2011	STANFORD UNIVERSITY	OPTOELECTRONIC SEMICONDUCTOR DEVICE AND METHOD OF FABRICATION
WO2011123349	2011	2011	VANDERBILT UNIVERSITY	SURFACE STRUCTURES FOR ENHANCEMENT OF QUANTUM YIELD IN

				BROAD SPECTRUM EMISSION NANOCRYSTALS
8119571	2006	2012	UNASSIGNED	HIGH PERFORMANCE ELECTRICAL, MAGNETIC, ELECTROMAGNETIC AND ELECTROOPTICAL DEVICES ENABLED BY THREE DIMENSIONALLY ORDERED NANODOTS AND NANORODS
8158247	2009	2012	LOS ALAMOS NATIONAL SECURITY LLC	POROUS LIGHT-EMITTING COMPOSITIONS
8178221	2008	2012	UNASSIGNED	{100}<100> OR 45.DEGREE.-ROTATED {100}<100>, SEMICONDUCTOR-BASED, LARGE-AREA, FLEXIBLE, ELECTRONIC DEVICES
EP2417631	2010	2012	DOW GLOBAL TECHNOLOGIES LLC	OPTOELECTRONIC DEVICE
EP2430112	2010	2012	UNIVERSITY OF CHICAGO	MATERIALS AND METHODS FOR THE PREPARATION OF NANOCOMPOSITES
EP2430652	2010	2012	UNIVERSITY OF ILLINOIS	PRINTED ASSEMBLIES OF ULTRATHIN, MICROSCALE INORGANIC LIGHT EMITTING DIODES FOR DEFORMABLE AND SEMITRANSPARENT DISPLAYS
EP2443683	2010	2012	UNIVERSITY OF HOUSTON	WRAPPED OPTOELECTRONIC DEVICES AND METHODS FOR MAKING SAME
WO2012024592	2011	2012	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	COMPOSITIONS, METHODS, AND SYSTEMS COMPRISING FLUOROUS-SOLUBLE POLYMERS
WO2012051324	2011	2012	ALLIANCE FOR SUSTAINABLE ENERGY LLC	HIGH BANDGAP III-V ALLOYS FOR HIGH EFFICIENCY OPTOELECTRONICS
WO2012051337	2011	2012	UNIVERSITY OF MICHIGAN	PHOTOACTIVE DEVICES INCLUDING PORPHYRINOIDS COORDINATING ADDITIVES

WO2012103292	2012	2012	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	DEVICE AND METHOD FOR LUMINESCENCE ENHANCEMENT BY RESONANT ENERGY TRANSFER FROM AN ABSORPTIVE THIN FILM
WO2012134124	2012	2012	ROHM & HAAS ELECTRONICS MATERIALS KOREA LTD	NOVEL COMPOUNDS FOR ORGANIC ELECTRONIC MATERIAL AND ORGANIC ELECTROLUMINESCENT DEVICE USING THE SAME
WO2012158709	2012	2012	UNIVERSITY OF ILLINOIS	THERMALLY MANAGED LED ARRAYS ASSEMBLED BY PRINTING
8342714	2010	2013	STRAY LIGHT OPTICAL TECHNOLOGIES	MOBILE LIGHTING APPARATUS
8367001	2010	2013	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	EMISSIVE SENSORS AND DEVICES INCORPORATING THESE SENSORS
8439534	2010	2013	STRAY LIGHT OPTICAL TECHNOLOGIES	MOBILE LIGHTING APPARATUS
8536098	2011	2013	UNASSIGNED	HIGH PERFORMANCE SUPERCONDUCTING DEVICES ENABLED BY THREE DIMENSIONALLY ORDERED NANODOTS AND/OR NANORODS
8552419	2011	2013	UNIVERSITY OF WASHINGTON	CROSS-CONJUGATED POLYMERS FOR ORGANIC ELECTRONIC DEVICES AND RELATED METHODS
8609994	2009	2013	ALLIANCE FOR SUSTAINABLE ENERGY LLC	THIN FILM ELECTRONIC DEVICES WITH CONDUCTIVE AND TRANSPARENT GAS AND MOISTURE PERMEATION BARRIERS
EP2628183	2011	2013	ALLIANCE FOR SUSTAINABLE ENERGY LLC	HIGH BANDGAP III-V ALLOYS FOR HIGH EFFICIENCY OPTOELECTRONICS
WO2013086445	2012	2013	UNIVERSITY OF CALIFORNIA	SWITCHED-CAPACITOR ISOLATED LED DRIVER
WO2013169364	2013	2013	UT-BATTELLE LLC	METHOD OF MICROBIALLY PRODUCING METAL GALLATE SPINEL NANO-OBJECTS, AND

				COMPOSITIONS PRODUCED THEREBY
8648524	2011	2014	UNIVERSITY OF CALIFORNIA	ELECTRONIC DISPLAYS USING OPTICALLY PUMPED LUMINESCENT SEMICONDUCTOR NANOCRYSTALS
8653500	2011	2014	SANDIA CORP	VOLUME-SCALABLE HIGH-BRIGHTNESS THREE-DIMENSIONAL VISIBLE LIGHT SOURCE
8659005	2007	2014	LEHIGH UNIVERSITY	STAGGERED COMPOSITION QUANTUM WELL METHOD AND DEVICE
8678871	2011	2014	UNIVERSITY OF CALIFORNIA	ELECTRONIC DISPLAYS USING OPTICALLY PUMPED LUMINESCENT SEMICONDUCTOR NANOCRYSTALS
8690391	2012	2014	STRAY LIGHT OPTICAL TECHNOLOGIES	MULTI-EMITTER LIGHTING APPARATUS
8722458	2011	2014	UNIVERSITY OF ILLINOIS	OPTICAL SYSTEMS FABRICATED BY PRINTING-BASED ASSEMBLY
8742406	2012	2014	IOWA STATE UNIVERSITY	SOFT LITHOGRAPHY MICROLENS FABRICATION AND ARRAY FOR ENHANCED LIGHT EXTRACTION FROM ORGANIC LIGHT EMITTING DIODES (OLEDS)
8784698	2011	2014	VANDERBILT UNIVERSITY	SURFACE STRUCTURES FOR ENHANCEMENT OF QUANTUM YIELD IN BROAD SPECTRUM EMISSION NANOCRYSTALS
8785905	2013	2014	SANDIA CORP	AMBER LIGHT-EMITTING DIODE COMPRISING A GROUP III-NITRIDE NANOWIRE ACTIVE REGION
8786179	2012	2014	UNIVERSAL DISPLAY CORP	LIGHT EMITTING DEVICE COMPRISING PHOSPHORESCENT MATERIALS FOR WHITE LIGHT GENERATION
8829634	2010	2014	DOW GLOBAL TECHNOLOGIES LLC	OPTOELECTRONIC DEVICE
8865489	2010	2014	UNIVERSITY OF ILLINOIS	PRINTED ASSEMBLIES OF ULTRATHIN, MICROSCALE INORGANIC LIGHT

				EMITTING DIODES FOR DEFORMABLE AND SEMITRANSPARENT DISPLAYS
8866146	2010	2014	NATIONAL RENEWABLE ENERGY LABORATORY	LATTICE-MISMATCHED GAINP LED DEVICES AND METHODS OF FABRICATING SAME
8879253	2009	2014	LIGHT PRESCRIPTIONS INNOVATORS	TRANSPARENT HEAT-SPREADER FOR OPTOELECTRONIC APPLICATIONS
8895337	2013	2014	SANDIA CORP	METHOD OF FABRICATING VERTICALLY ALIGNED GROUP III-V NANOWIRES
8896077	2010	2014	STANFORD UNIVERSITY	OPTOELECTRONIC SEMICONDUCTOR DEVICE AND METHOD OF FABRICATION
8908261	2012	2014	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	DEVICE AND METHOD FOR LUMINESCENCE ENHANCEMENT BY RESONANT ENERGY TRANSFER FROM AN ABSORPTIVE THIN FILM
EP2678335	2012	2014	ROHM & HAAS ELECTRONICS MATERIALS KOREA LTD	NOVEL COMPOUNDS FOR ORGANIC ELECTRONIC MATERIAL AND ORGANIC ELECTROLUMINESCENT DEVICE USING THE SAME
WO2014008429	2013	2014	UNIVERSITY OF UTAH	SPIN-POLARIZED LIGHT-EMITTING DIODES BASED ON ORGANIC BIPOLAR SPIN VALVES
WO2014085469	2013	2014	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	DEPOSITION OF SEMICONDUCTOR NANOCRYSTALS FOR LIGHT EMITTING DEVICES
WO2014093322	2013	2014	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	NEAR-INFRARED LIGHT EMITTING DEVICE USING SEMICONDUCTOR NANOCRYSTALS
WO2014107426	2013	2014	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	METHODS AND APPARATUS FOR TRANSPARENT DISPLAY USING UP-CONVERTING NONOPARTICLES

8952362	2012	2015	UNIVERSITY OF MICHIGAN	HIGH EFFICIENCY AND BRIGHTNESS FLUORESCENT ORGANIC LIGHT EMITTING DIODE BY TRIPLET-TRIPLET FUSION
8987736	2008	2015	UNASSIGNED	[100] OR [110] ALIGNED, SEMICONDUCTOR-BASED, LARGE-AREA, FLEXIBLE, ELECTRONIC DEVICES
9029837	2011	2015	UNIVERSITY OF MICHIGAN	PHOTOACTIVE DEVICES INCLUDING PORPHYRINOIDS WITH COORDINATING ADDITIVES
9059356	2014	2015	SANDIA CORP	LATERALLY INJECTED LIGHT-EMITTING DIODE AND LASER DIODE
9063363	2014	2015	UNIVERSITY OF CALIFORNIA	ELECTRONIC DISPLAYS USING OPTICALLY PUMPED LUMINESCENT SEMICONDUCTOR NANOCRYSTALS
9076972	2013	2015	ARIZONA STATE UNIVERSITY	SOLUBLE PORPHYRIN POLYMERS
9093661	2013	2015	ALLIANCE FOR SUSTAINABLE ENERGY LLC	THIN FILM ELECTRONIC DEVICES WITH CONDUCTIVE AND TRANSPARENT GAS AND MOISTURE PERMEATION BARRIERS
9117940	2014	2015	UNIVERSITY OF ILLINOIS	OPTICAL SYSTEMS FABRICATED BY PRINTING-BASED ASSEMBLY
9136484	2012	2015	ROHM & HAAS ELECTRONICS MATERIALS KOREA LTD	COMPOUNDS FOR ORGANIC ELECTRONIC MATERIAL AND ORGANIC ELECTROLUMINESCENT DEVICE USING THE SAME
9156938	2011	2015	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	COMPOSITIONS, METHODS, AND SYSTEMS COMPRISING FLUOROUS-SOLUBLE POLYMERS
9178160	2014	2015	NORTHWESTERN UNIVERSITY	FUSED THIOPHENE-BASED CONJUGATED POLYMERS AND THEIR USE IN OPTOELECTRONIC DEVICES

9182621	2015	2015	UNIVERSITY OF CALIFORNIA	ELECTRONIC DISPLAYS USING OPTICALLY PUMPED LUMINESCENT SEMICONDUCTOR NANOCRYSTALS
9184402	2014	2015	UNIVERSITY OF MICHIGAN	PHOSPHORESCENT ORGANIC LIGHT EMITTING DIODES WITH HIGH EFFICIENCY AND BRIGHTNESS
EP2870645	2013	2015	UNIVERSITY OF UTAH	SPIN-POLARIZED LIGHT-EMITTING DIODES BASED ON ORGANIC BIPOLAR SPIN VALVES
EP2887417	2014	2015	UNIVERSITY OF MICHIGAN	EXTENDED OLED OPERATIONAL LIFETIME THROUGH PHOSPHORESCENT DOPANT PROFILE MANGEMENT
WO2015081289	2014	2015	UNIVERSITY OF MICHIGAN	DEVICES COMBINING THIN FILM INORGANIC LEDS WITH ORGANIC LEDS AND FABRICATION THEREOF
WO2015175680	2015	2015	HARVARD UNIVERSITY	ORGANIC LIGHT-EMITTING DIODE MATERIALS
9295116	2014	2016	UNIVERSITY OF CALIFORNIA	SWITCHED-CAPACITOR ISOLATED LED DRIVER
9315618	2014	2016	UNIVERSITY OF MICHIGAN	COMPOSITIONS FOR DIRECTED ALIGNMENT OF CONJUGATED POLYMERS
9335027	2013	2016	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	METHODS AND APPARATUS FOR TRANSPARENT DISPLAY USING SCATTERING NANOPARTICLES
9346998	2010	2016	UNIVERSITY OF CHICAGO	MATERIALS AND METHODS FOR THE PREPARATION OF NANOCOMPOSITES
9349910	2014	2016	LEHIGH UNIVERSITY	STAGGERED COMPOSITION QUANTUM WELL METHOD AND DEVICE
9368677	2014	2016	SANDIA CORP	SELECTIVE LAYER DISORDERING IN III-NITRIDES WITH A CAPPING LAYER
9385348	2015	2016	UNIVERSITY OF MICHIGAN	ORGANIC ELECTRONIC DEVICES WITH MULTIPLE SOLUTION-

				PROCESSED LAYERS
9444065	2007	2016	UNIVERSITY OF UTAH	?-CONJUGATED HEAVY-METAL POLYMERS FOR ORGANIC WHITE-LIGHT-EMITTING DIODES
9458989	2013	2016	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	METHODS AND APPARATUS FOR TRANSPARENT DISPLAY USING UP-CONVERTING NANOPARTICLES
9472723	2013	2016	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	DEPOSITION OF SEMICONDUCTOR NANOCRYSTALS FOR LIGHT EMITTING DEVICES
9537024	2016	2017	STANFORD UNIVERSITY	METAL-DIELECTRIC HYBRID SURFACES AS INTEGRATED OPTOELECTRONIC INTERFACES
9543468	2011	2017	ALLIANCE FOR SUSTAINABLE ENERGY LLC	HIGH BANDGAP III-V ALLOYS FOR HIGH EFFICIENCY OPTOELECTRONICS
9601671	2015	2017	UNIVERSITY OF ILLINOIS	OPTICAL SYSTEMS FABRICATED BY PRINTING-BASED ASSEMBLY
9647171	2014	2017	UNIVERSITY OF ILLINOIS	PRINTED ASSEMBLIES OF ULTRATHIN, MICROSCALE INORGANIC LIGHT EMITTING DIODES FOR DEFORMABLE AND SEMITRANSPARENT DISPLAYS
9666822	2014	2017	UNIVERSITY OF MICHIGAN	EXTENDED OLED OPERATIONAL LIFETIME THROUGH PHOSPHORESCENT DOPANT PROFILE MANAGEMENT
9671536	2015	2017	UNIVERSITY OF CALIFORNIA	ELECTRONIC DISPLAYS USING OPTICALLY PUMPED LUMINESCENT SEMICONDUCTOR NANOCRYSTALS
9677741	2016	2017	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	METHODS AND APPARATUS FOR TRANSPARENT DISPLAY USING SCATTERING NANOPARTICLES
9705103	2010	2017	UNIVERSITY OF	WRAPPED

			HOUSTON	OPTOELECTRONIC DEVICES AND METHODS FOR MAKING SAME
9711728	2015	2017	NORTHWESTERN UNIVERSITY	FUSED THIOPHENE-BASED CONJUGATED POLYMERS AND THEIR USE IN OPTOELECTRONIC DEVICES
9741945	2014	2017	NATIONAL TECHNOLOGY & ENGINEERING SOLUTIONS OF SANDIA LLC	TUNABLE PHOTOLUMINESCENT METAL-ORGANIC-FRAMEWORKS AND METHOD OF MAKING THE SAME
9765934	2012	2017	UNIVERSITY OF ILLINOIS	THERMALLY MANAGED LED ARRAYS ASSEMBLED BY PRINTING
9799842	2013	2017	UNIVERSITY OF UTAH	SPIN-POLARIZED LIGHT-EMITTING DIODES BASED ON ORGANIC BIPOLAR SPIN VALVES
9841544	2014	2017	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	DEVICE AND METHOD FOR LUMINESCENCE ENHANCEMENT BY RESONANT ENERGY TRANSFER FROM AN ABSORPTIVE THIN FILM
9852927	2016	2017	UNIVERSITY OF CALIFORNIA	NEAR-UNITY PHOTOLUMINESCENCE QUANTUM YIELD IN MOS(SUB)2
9868899	2013	2018	UT-BATTELLE LLC	METHOD OF MICROBIALLY PRODUCING METAL GALLATE SPINEL NANO-OBJECTS, AND COMPOSITIONS PRODUCED THEREBY
9927616	2016	2018	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	METHODS AND APPARATUS FOR TRANSPARENT DISPLAY USING SCATTERING NANOPARTICLES
9929365	2015	2018	UNIVERSITY OF MICHIGAN	EXCITED STATE MANAGEMENT
9935240	2013	2018	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	NEAR-INFRARED LIGHT EMITTING DEVICE USING SEMICONDUCTOR NANOCRYSTALS
9972795	2015	2018	HARVARD	ORGANIC LIGHT-

			UNIVERSITY	EMITTING DIODE MATERIALS
10062738	2014	2018	UNIVERSITY OF MICHIGAN	DEVICES COMBINING THIN FILM INORGANIC LEDS WITH ORGANIC LEDS AND FABRICATION THEREOF
10074815	2016	2018	UNIVERSITY OF MICHIGAN	ORGANIC ELECTROLUMINESCENT DEVICES
10121952	2016	2018	UNIVERSITY OF CHICAGO	MATERIALS AND METHODS FOR THE PREPARATION OF NANOCOMPOSITES
10128387	2016	2018	NATIONAL TECHNOLOGY & ENGINEERING SOLUTIONS OF SANDIA LLC	OPTOELECTRONIC APPARATUS ENABLED BY DIELECTRIC METAMATERIALS
10229958	2018	2019	UNIVERSITY OF MICHIGAN	DEVICES COMBINING THIN FILM INORGANIC LEDS WITH ORGANIC LEDS AND FABRICATION THEREOF
10361180	2017	2019	UNIVERSITY OF ILLINOIS; SEMPRIUS INC; X CELEPRINT LTD	OPTICAL SYSTEMS FABRICATED BY PRINTING-BASED ASSEMBLY
10361250	2018	2019	NATIONAL TECHNOLOGY & ENGINEERING SOLUTIONS OF SANDIA LLC	ACTIVE OPTICAL DEVICE ENABLED BY DIELECTRIC METAMATERIALS
10424572	2017	2019	UNIVERSITY OF ILLINOIS; SEMPRIUS INC; X CELEPRINT LTD	OPTICAL SYSTEMS FABRICATED BY PRINTING-BASED ASSEMBLY
10483477	2018	2019	UNIVERSITY OF SOUTHERN CALIFORNIA / UNIVERSITY OF MICHIGAN	EXCITED STATE MANAGEMENT
10504882	2017	2019	UNIVERSITY OF ILLINOIS; SEMPRIUS INC; X CELEPRINT LTD	OPTICAL SYSTEMS FABRICATED BY PRINTING-BASED ASSEMBLY
10546841	2017	2020	UNIVERSITY OF ILLINOIS	PRINTED ASSEMBLIES OF ULTRATHIN, MICROSCALE INORGANIC LIGHT EMITTING DIODES FOR DEFORMABLE AND SEMITRANSPARENT DISPLAYS

An Analysis of the Influence of BTO-funded Solid State Lighting Patents

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