

# LED there be light The evolution in LED technology and dynamics of entry into the LED lighting market

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## 7. Impact

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### Research

The overarching objective of this research was to contribute to the vast body of literature about the role of technology in the economy, by providing new evidence on the relationship between technological change and the emergence of new markets. It has been chosen to study in-depth the evolution of a particular technology, LED, which had an enormous transformative power on the lighting industry. This thesis has illustrated how research in different technological fields evolved following distinct but interconnected paths. Knowledge in semiconductors and electrical components and innovations concerning the application of LED in vehicles, came together and proved to be instrumental in enhancing the LED technology towards its application for general lighting in the late 1990s. In turn, firms that had invested in those technological fields found themselves in a better position to enter the nascent LED lighting devices market earlier than others. These firms included companies that were already operating in the lighting industry (incumbents), but also new players diversifying from other sectors (e.g. from the manufacture of semiconductors, or electrical devices, or computer manufacturing), and newly established companies attracted by the commercialisation prospects offered by LED and, in some cases, supported by substantial public subsidies (as for Chinese companies involved in semiconductors and chip production).

### Relevance for science

The results of this research can have a direct impact on the fields of economics and strategic management. They inform the relationship between technological change, market dynamics, firm decision-making, and the direct and indirect links between the development of technological capabilities and the decision to enter emerging technology-based markets. Also, this thesis highlights the advantages of combining theories and methods from different disciplines to gain a richer view of the factors determining the firms' behaviour under uncertain and evolving market conditions.

The research generated two findings that can be of interest to science in general. First, it concurs at demonstrating the importance of investing in research and technological development to generate socio-economic benefits and stimulate growth in the long-run. The trial-and-error process behind technological change generates learning that develops along multiple directions and may generate spillovers along the way. The importance of new technology for the economy may not be immediately visible, but it emerges along cumulative pathways of explorations. In addition to research laboratories and universities, firms have a key

role in implementing fundamental research, too, due to the high private returns they can gain from research when it is translated into marketable applications. Second, the knowledge generation and innovation process are nurtured through dynamic feedback loops deriving from bottom-up experimentation and learning. Technological application in specific domains and market niches allows the technology to grow out of multiple generations of innovation. Capabilities developed in particular markets and profits gained from commercialisation were the two ingredients to provide further opportunities and means to help upgrade LED technology.

Another interesting takeaway from the LED history is worth highlighting because highly relevant to understanding how technology can develop. As previously mentioned, the potential for LED to replace traditional lighting sources for general illumination was conjectured by a few scientists and companies already at the origin of the technological evolution. LED could save money and energy compared to existing lighting bulbs (incandescent and fluorescent) and spur new approaches in lighting design. The long-term goal of increasing its lighting power and efficiency, reducing costs, and generating white-colour light triggered a race among researchers that lasted thirty years. The gamble paid off in the 1990s, when it became clear to everyone that LED could become the “green revolution” within lighting. Its contribution to reducing energy consumption and addressing climate change was recognised with the most prestigious prize in science and engineering. This story reinforces the idea that long-term investments in research and the formulation of specific targets are critical to steering science in strategic areas that could respond to major social, environmental, and economic challenges. The mission-oriented research and innovation policy, inspiring today the European policy agenda, makes explicit the responsibilities of policy-makers, scientists, industry and civil society to collaborate and catalyse efforts with a strategic orientation, to speed up technological transformation and increase the chances of success. Therefore, the results of this research can be of interest to institutions and policy-makers in charge of designing and implementing research and innovation policies. LED represents a concrete example of multi-purpose technology that evolved to pursue an ambitious but concrete goal and succeeded in generating spillovers and affecting other markets along its long transformation process.

## **Target groups**

This research can be of interest to academics, policy-makers and firms operating in any sector. On the one hand, it informs about the importance of securing access to foundational technologies, such as semiconductors, relevant for a wide range of industrial applications. The COVID-19 pandemic crisis, which caused the temporary disruption of global value chains, made it clear to governments and industry players

the strategic importance of securing an autonomous production or direct access to particular resources and technologies, with downstream applications in several industries. On the other hand, the analysis shows the importance for firms to be aware of the historical and ongoing evolution of particular technological fields. It can help them assess their own advantages over competing firms, anticipate upcoming technological changes, and detect related technology fields worth exploring.

## **Dissemination activities**

The results of the research will be disseminated to the academic and industry community and public officials. As to the first target group, we aim to get three research papers published in international scholarly journals, based on the empirical analysis in Chapters 3, 4 and 5. The papers derived from Chapters 3 and 4 have been already submitted for publication to the journals “Social Network Analysis and Mining” and the “Journal of Evolutionary Economics. At the moment of writing, the two papers are under review by the external reviewers and the editor. In addition to scientific publications, the research results will be disseminated through participation in workshops and conferences involving academics from the fields covered by the research. Examples of conferences that will be considered for participation include the International Schumpeter Society Conference and the Strategic Management Society conference.

As to the industry community, the PhD thesis will be shared with all the companies that accepted to be interviewed for this research. An article summarising the research findings in layman’s terms will be published in World Furniture, the quarterly magazine of economic information and market analysis published by CSIL. The magazine has a target audience of 22,000 manufacturers, suppliers and stakeholders of the furniture and furnishing industries in the world’s main producing, exporting and consuming countries. World Furniture is also circulated at major international fairs in the sectors of reference. News will also be posted on CSIL social media pages and websites, reaching a network of hundreds of contacts among consultants, firms, public officials, researchers and professors.

Finally, governmental and intergovernmental institutions and policymakers can be reached out through the research and consulting activity regularly carried out by the author of this thesis. Key messages of the research will feed into ongoing and future evaluation and analytical assignments in the fields of EU regional policy, industrial policy and research policy.