



ENRICH

EUROPEAN NETWORK OF
RESEARCH AND INNOVATION
CENTRES AND HUBS, USA

Powered by



A Study on the US Innovation Ecosystem and Market – Nanotechnologies



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Executive Summary

This study is a product of ENRICH in the USA, which is a European Network of Research and Innovation Centers and Hubs. Promoted by the European Commission (EC) through Horizon 2020, ENRICH in the USA acts as a central contact point for European research and innovation actors seeking to grow and reinforce collaboration across the Atlantic. The mission of the Network is to provide standardized as well as various tailor-made, research & innovation internationalization support services to European researchers and innovators, to accelerate access to the United States (US) market, and maximize chances of success.

This study provides relevant information on the US innovation and market landscape in regard to nanotechnologies.

The Study identifies US key innovation hubs/facilitators and industry related centers, as well as the US main nanotechnology market opportunities and barriers. The Study also provides some of the key nanotechnology related networks and events, and assesses the existing funding initiatives and programs at both federal and state level that promote nanotechnology innovation. Overall, this study aims to be an effective tool for EU research and business representatives in the nanotechnologies related fields to gain knowledge on the US nanotechnology innovation and market landscapes, and therefore facilitate their initial approaches to establishing innovation and business collaborative activities with their US counterparties.

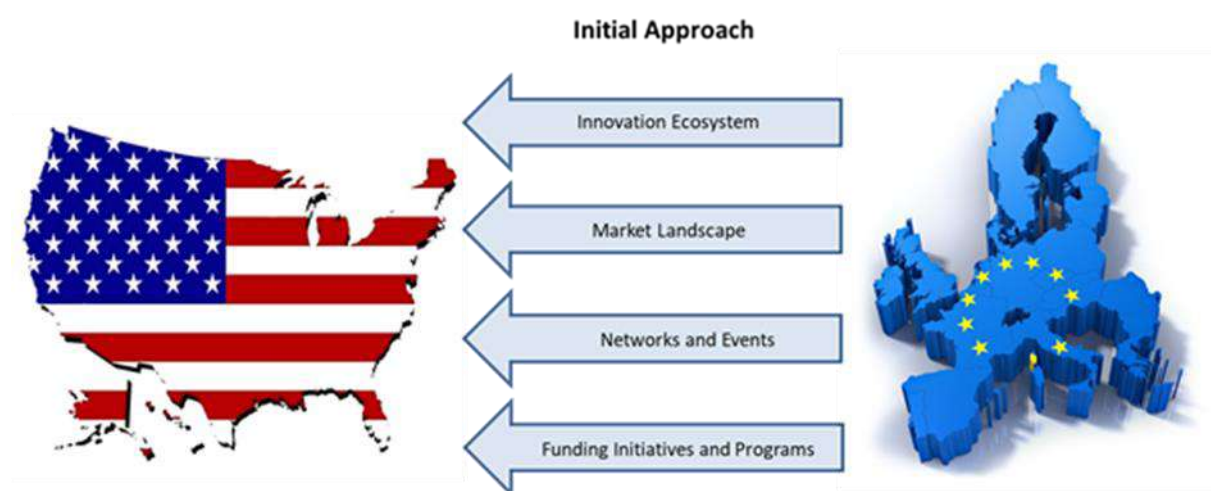


Figure 1 - Initial Approaches for Establishing Collaborative Innovation and Business Activities

Importance of nanotechnology innovation to the EU and the US

Nanotechnology is described by the EC as a key enabling technology with a great potential for addressing societal challenges, such as energy supply and healthcare¹. On the US side, the National Nanotechnology Initiative (NNI) of the US Government defines it as the science, engineering and technology conducted at the nanoscale (around 1 to 100 nanometers)².

The nanotechnology market has had a significant impact in providing new solutions to science and engineering fields. The interdisciplinary characteristic of nanotechnology allows it to have a wide range of applications among different sectors³. Consequently, the importance of nanotechnology applications to the global economy has been growing during the last decades, and it is expected that nanotechnology applications will have a Compound Annual Growth Rate (CAGR) of around 17% between 2018 and 2025⁴. According to the EC, it was estimated that nanotechnologies in 2015 was worth more than \$1 trillion (€900 billion) and is still growing.

The nanotechnologies' market growth is also reflected at the policy level between the EU and the US, which includes nanotechnologies as one of the main thematic collaboration priorities between the regions. Cooperation between the EU and the US in nanotechnology was established at the end of 1999 through an EU-USA Agreement on Scientific and Technological Co-operation, and through an agreement for cooperative activities in the field of materials science. Since then, several agreements have been launched between both regions, including cooperation procedures on nanotechnology⁵.

Innovation ecosystem

In 2018, the US total spending on R&D is expected to reach around \$553 billion (€498 billion), which represents about 2.8% of the US Gross Domestic Product (GDP)⁶. For the NNI, the Fiscal Year of 2018 projected a total budget of \$1.2 billion (€1.08 billion) with a special focus on innovation and promoting competitiveness, economic growth and national security. The main agencies were the ones with the largest investment for 2018, representing around 95% of the total budget: National Science Foundation (NSF) - fundamental research and education across all disciplines of science and engineering; Department of Health and Human Services, National Institutes of Health (HHS/NIH) - nanotechnology-based biomedical research at the intersection of life and physical sciences; Department of Energy (DoE) - fundamental and applied research providing a basis for new and improved energy technologies; Department of Defense (DoD) - science and engineering research advancing defense and dual-use

¹ <https://ec.europa.eu/jrc/en/research-topic/nanotechnology>

² <https://www.nano.gov/>

³ <http://www.nanotechia.org/sectors>

⁴ Global Nanotechnology Market Analysis & Trends - Industry Forecast to 2025, Accuray Research LLP, 2016

⁵ <http://v2.euussciencetechnology.eu/content/nanosciences-nanotechnologies-materials-and-new-production-technologies-nmp>

⁶ http://digital.rdmag.com/researchanddevelopment/2018_global_r_d_funding_forecast?pg=4#pg4



capabilities; and Department of Commerce, National Institute of Standards and Technology (DoC/NIST) - fundamental research and development of measurement and fabrication tools, analytical methodologies, metrology, and standards for nanotechnology. Thus, nanotechnology plays an important role in several areas of the US market, namely within high-tech and manufacturing industries⁷.

When analyzing the US nanotechnology innovation system, European SMEs should first identify the most relevant innovation hubs, facilitators and industry related RDI centers for the particular sector. The innovation ecosystem is the term used to describe the numerous participants and resources that are needed for the innovation process⁸. From the assessment of the US nanotechnology innovation and industry communities' landscape, it is clear there is a particular concentration of innovation hubs/facilitators and industry related RDI centers in the states of California, Illinois, Massachusetts, New York, North Carolina and Texas^{9,10,11}.

Innovation hubs are ecosystems comprised by SMEs, large industries, startups, researchers, accelerators, and investors¹² that aim to foster relationships between these entities and to act as a bridge between research and market needs¹³. Currently, nanotechnology innovation hubs are focused on applications for healthcare, electronics, energy, transportation and aerospace. Another interesting fact is that nanotechnology innovation is strongly dependent on industry-academia cooperation, with leading actors from several areas from both the research and the industry side¹⁴.

Innovation facilitators support, promote and accelerate the innovation process. Thus, organizations such as business accelerators, incubators, science parks and specialized consulting firms are considered innovation facilitators, playing a key role in the nanotechnology innovation process. Within the context of nanotechnology, science parks are very important for the development and deployment of innovative nanotechnology applications in the market¹⁵.

Industry related RDI centers are entities that promote the cooperation between industry, researchers and innovation facilitators, and thus supporting the development of new nanotechnology applications and solution. In the US, most nanotechnology solutions seem to be developed through cooperation

⁷ The National Nanotechnology Initiative - Supplement to the President's 2018 Budget, NNI, 2017

⁸

https://www.researchgate.net/publication/282122544_Innovation_Ecosystems_Implications_for_Innovation_Management

⁹ <http://www.nanotechproject.org/inventories/map/>

¹⁰ <https://www.nano.gov/USnanoresourcemap>

¹¹ Best Practices in State and Regional Innovation Initiatives: Competing in the 21st Century (2013), Chapter: 7 The New York Nanotechnology Initiative, National Research Council, 2013

¹² <https://ec.europa.eu/digital-single-market/en/blog/digital-innovation-hubs-ict-2015>

¹³ <http://americanjobsproject.us/system/innovation-ecosystem/>

¹⁴ Working Texas Style, Chapter 12: Nanotechnology, 2013

¹⁵ Processes of Innovation in the Field of Nanotechnology, Anna Butzin, 2007



between industries and universities or researcher centers¹⁶. Thus, the US has witnessed the emergence of several industry-related centers that promote new entrepreneurial ventures and solutions within the context of nanotechnology.

Market landscape

The US is the world leading country in number of companies of nanotechnology-related firms¹⁷. In 2014, the US invested around \$6 billion (€5.4 billion) in nanotechnology among governments, corporations and private investors. Moreover, the revenue from nano-related products has increased 90% from 2012 to 2014, which shows the great potential of this technology from the business side¹⁸. As the market for nanotechnologies applications is quite spread among sectors and areas, the analysis concentrates on segments within each sector that have a strong focus on nanotechnology applications. Thus, the segments considered for the analysis are as follows: Pharmaceutical and Medicine Manufacturing, Electronic Computer Manufacturing, Storage Battery Manufacturing, Paint and Coating Manufacturing, and Aerospace Product and Parts Manufacturing. Taking into account this analysis, the states of California, Florida, Texas and New York were identified as the main business areas of nanotechnology in the US. Other states such as Massachusetts, New Jersey and Illinois also seem to have a particular high concentration of manufacturers.

Networks and events

Nanotechnology is an area that is constantly advancing and innovating. Thus, it is highly recommended that EU researchers and industry representatives get in contact with key US nanotechnology related networks and attend nanotechnology events and conferences located in the US. The knowledge gained through relevant networks, events and conferences is used to decide the most effective approach to establishing contacts with the US community and developing new cooperation opportunities.

Initiatives and programs

The US nanotechnology innovation system is supported by a set of specific federal, state and private initiatives and programs that prioritize research and innovation areas that can lead to technological breakthroughs. Most nanotechnology-related initiatives and activities are funded under federal programs that are involved in the NNI. In 2018, the Federal Budget for the NNI is \$1.2 billion (€1.08 billion) with the aim to support innovation and to promote competitiveness, economic growth and national security. Within the budget for 2018, the following agencies have the largest investment from the NNI (representing 95% of the total budget): NSF - fundamental research and education across all disciplines of science and engineering; HHS/NIH - nanotechnology-based biomedical research at the

¹⁶ Working Texas Style, Chapter 12: Nanotechnology, 2013

¹⁷ OECD, Key Nanotechnology Indicators, <http://oe.cd/kni>, May 2017

¹⁸ Nanotechnology Update: U.S. Leads in Government Spending Amidst Increased Spending Across Asia, LuxResearch, 2015



intersection of life and physical sciences; DoE - fundamental and applied research providing a basis for new and improved energy technologies; DoD - science and engineering research advancing defense and dual-use capabilities; and DoC/NIST - fundamental research and development of measurement and fabrication tools, analytical methodologies, metrology, and standards for nanotechnology¹⁹. In terms of private level funding, there are different solutions available through different institutions spread around the country. These are normally focused at the state-level and act as a complement of the R&D funding available through the NNI. Although there are several programs and initiatives at both public and private levels, it is important to note that information related to funds and grants for European representatives is difficult to find. In most cases, the European innovators and business representatives interested in US nanotechnology-related initiatives and programs need to contact the program officers to know specific details about international eligibility.

¹⁹ The National Nanotechnology Initiative - Supplement to the President's 2018 Budget, NNI, 2017



ENRICH in the USA Summary

ENRICH is the European Network of Research and Innovation Centers and Hubs. Promoted by the European Commission through Horizon 2020, the ENRICH network currently offers services to connect European research, technology and business organizations with three global frontrunner innovation markets: Brazil, China and the USA.

ENRICH in the USA is powered by NearUS, a H2020 initiative to establish a Network of European Research and Innovation Centers throughout the United States of America. ENRICH in the USA acts as a central contact point for European research and innovation actors seeking to grow and reinforce collaboration across the Atlantic. The mission of the Network is to provide standardized as well as various tailor-made, research & innovation internationalization support services to European researchers and innovators, to accelerate access to the US market, and maximize chances of success.

ENRICH in the USA targets to serve the following actors:

- Accelerators
- Businesses
- Clusters
- Entrepreneurs
- Funding Agencies
- Incubators
- Networks
- R&D institutes and labs
- Research managers and administrators
- Research Parks
- SME's
- Start-ups
- Universities
- University Associations

ENRICH in the USA includes the following entities:

- **One “Coordination Node” in Europe** (at EBN)
- **One “Coordination Node” in the US** (at InBIA)
- **Two physical “Landing Hubs”:**
 - **San Francisco Centre:** ENRICH West Coast Hub at EAEC
 - **Boston Centre:** ENRICH East Coast Hub at CIC
- **Five Associate Hubs across the US**, and plans to expand the ENRICH in the USA Network beyond these first five Hubs, over four years.

The ENRICH in the USA Network is built on local US experience and strong existing ties between the EU and USA, while providing new researcher- and entrepreneur-serving capabilities which address the resource gaps necessary to enable access for all EU Member States and Associated Countries, as well as every state in the US.

A variety of services are proposed for researchers and entrepreneurs engaged by the Network during the pilot phase, then the Centers’ pilot activities will be evaluated to inevitably retain the initiative’s most successful components to ensure a sustainable plan for ENRICH in the USA in the future.

Services will target various, commercially viable technology maturity levels, both research-oriented and market-oriented and will include research connection symposia, business matchmaking opportunities, working visits and innovation tours to US organizations to explore technology/product partnerships and/or business development middle/long term opportunities, pitching to potential investors, entrepreneurial boot camps, workspace access, hands on business acceleration programs,

and more. As the ENRICH in the USA initiative is highly competitive to best serve the strongest researchers and entrepreneurs, all services must be applied for through an open and transparent selective mechanism.

60 associated partners in the EU and USA support NearUS and ENRICH in the USA, with more associated partners expected in the future.

NearUS Consortium:

Coordinator: German Aerospace Center (DLR), Germany

Partners:

- > inno TSD, France
- > European Business and Innovation Centre Network (EBN), Belgium
- > International Business Innovation Association (InBIA), USA
- > European American Enterprise Council (EAEC), USA
- > INTRASOFT International (INTRA), Luxembourg
- > Sociedade Portuguesa de Inovação (SPI), Portugal
- > Regional Centre for Information and Scientific Development (RCISD), Hungary
- > National Council of University Research Administrators (NCURA), USA

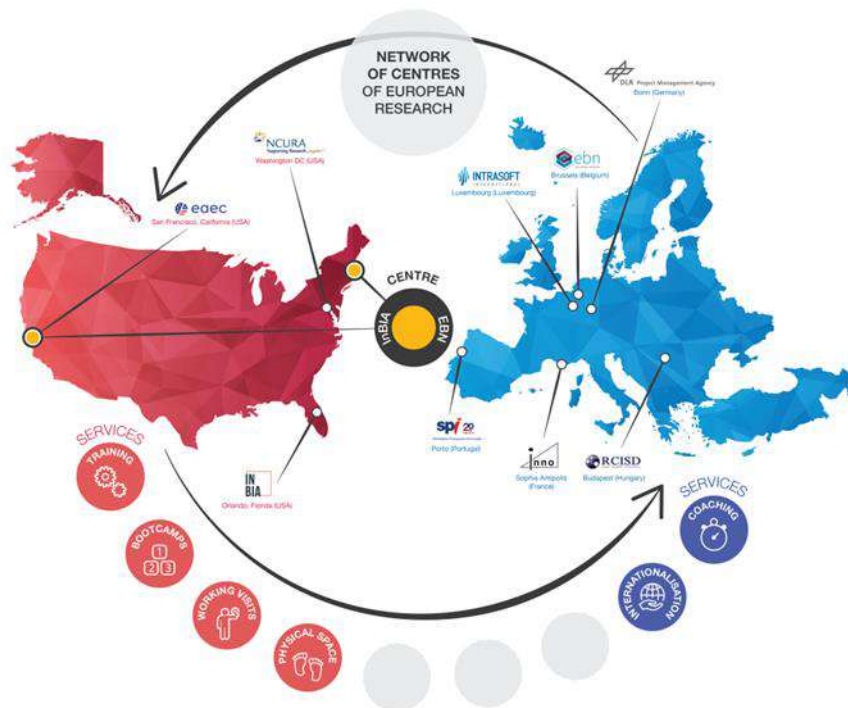


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List of Abbreviations

Table 1 – List of Abbreviations

Abbreviation	Explanation
AMO	Advanced Manufacturing Office
APOMA	American Precision Optics Manufacturers Association
ARPA-E	Advanced Research Projects Agency-Energy
CADMIM	Center for Advanced Design and Manufacturing of Integrated Microfluidics
CAEML	Advanced Electronics through Machine Learning
CAGR	Compound Annual Growth Rate
CARD	Center for Advanced Research in Drying
CDC	Centers for Disease Control and Prevention
CENN	Center of Excellence in Nanoelectronics and Nanotechnology
CiIT	Center for Innovative Instrumentation Technology
CNSE	College of Nanoscale Science and Engineering
CRADA	Cooperative Research and Development Agreement
CTRC	Cooling Technologies Research Center
DEP	Massachusetts Department of Environmental Protection
DoC	US Department of Commerce
DoD	US Department of Defense
DoE	US Department of Energy



EC	European Commission
EDA	Economic Development Agency
EERE	Office of Energy Efficiency and Renewable Energy
EMN	Energy Materials Network
EPO	European Patent Office
ESCA	European Secretariat for Cluster Analysis
ES2	Center for Energy-Smart Electronic Systems
ETIC	Emerging Technologies and Innovation Center
EU	European Union
E2TAC	Energy and Environmental Technology Applications Center
FFRDC	Federally funded research and development centers
FOA	Funding Opportunity Announcement
FY	Fiscal Year
GDP	Gross Domestic Product
GPT	General-Purpose Technology
HHS	Department of Health and Human Services
HPC	High-Performance Computing
HPC4Mfg	High Performance Computing for Manufacturing
IANT	International Association of Nanotechnology
ICBN	Conference on Biotechnology and Nanotechnology
iCLEAN	Incubators for Collaborating & Leveraging Energy and Nanotechnology



ICNMS	International Conference on Nano and Materials Science
IC2NAM	International Conference on Nanoscience, Nanotechnology & Advanced Materials
IEDM	IEEE International Electron Devices Meeting
IIN	International Institute for Nanotechnology
IQT	In-Q-Tel
ISTC	Illinois Science Technology Coalition
IUCRC	Industry–University Cooperative Research Centers
LETN	Lehigh Emerging Technologies Network
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NCN	Network for Computational Nanotechnology
NCNA	NanoAccelerator
NCnano	Northern California Nanotechnology Initiative
nCORE	Nanoelectronic Computing Research
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NNCI	National Nanotechnology Coordinated Infrastructure
NNI	National Nanotechnology Initiative
NNMI	National Network for Manufacturing Innovation
NNN	National Nanomanufacturing Network



NSF	National Science Foundation
NSIs	Nanotechnology Signature Initiatives
NSTI	Nano Science and Technology Institute
NTRC	Nanotechnology Research Center
NWs	Nanowires
NYSERDA	New York State Energy Research Development Authority
NYU-Poly	Polytechnic Institute of New York University
OECD	Organization for Economic Cooperation and Development
OGS	Office of Grants Services
OISE	Office of International Science and Engineering
ONAMI	Oregon Nanoscience and Microtechnologies Institute
ORNL	Oak Ridge National Laboratory
OSTP	Office of Science and Technology Policy
PON	Program Opportunity Notice
RC	Research Coordinator
RFP	Request for Proposals
RFQ	Requests for Quotation or Qualifications
RIF	Rapid Innovation Fun
RTI	Research Triangle Park
RTNN	North Carolina Research Triangle Nanotechnology Network
R&D	Research and Development



R&I	Research and Innovation
SBIR	Small Business Innovation Research
SME	Small and Medium-sized Enterprise
SPRING	Strategic Partnership for Research in Nanotechnology
SRCco	Semiconductor Research Cooperation
STTR	Small Business Technology Transfer
SUNY	State University of New York
TIA	Technology Investment Agreement
UIUC	University of Illinois at Urbana-Champaign
US	United States
USDA	United States Department of Agriculture
UT	University of Texas



1 Introduction

Context

This study, which has been developed in the context of the ENRICH in the USA network²⁰, aims to provide relevant information on the United States (US) landscape concerning the Nanotechnology innovation ecosystem and market. It provides information on the US Nanotechnology innovation ecosystem and market, including: the leading regions from an innovation and market perspective; the key innovation hubs/facilitators; a sample of the main research networks/ professional organizations; as well as important funding programs and initiatives at both federal and state levels.

The Study can be an effective source and tool to gain knowledge on the US related to Nanotechnology fields and:

- To identify the US leading regions from an innovation and market perspectives;
- To identify potential approaches for developing collaborative partnerships with US facilitators of innovation and/or businesses;
- To identify relevant US networks and conferences that can be used as a conduit to meeting potential innovation and market partners; and
- To identify and assess the opportunity to access US funding programs related to nanotechnology in order to propose potential partnerships with US organizations.

Therefore, it is the hope of the Study authors that the information is useful in assisting the EU research organizations and Small and Medium Enterprises (SMEs) in their efforts to develop stronger ties to the US Nanotechnology innovation ecosystem and market.

Nanotechnology industry

The European Commission (EC) describes nanotechnology as a key enabling technology with a great potential for addressing societal challenges, such as energy supply and healthcare²¹. Moreover, the EC defines nanotechnologies as the “design, characterization, production and application of structures, devices and systems by controlling shape and size at the nanometer scale”²². In parallel, the National Nanotechnology Initiative (NNI) from the US Government defines it as the science, engineering and technology conducted at the nanoscale – which is of around 1 to 100 nanometers. Thus, NNI describes that nanoscience and nanotechnology can be used across a large range of fields such as chemistry,

²⁰ <https://near-us.eu/project-overview>

²¹ <https://ec.europa.eu/jrc/en/research-topic/nanotechnology>

²² NANOTECHNOLOGIES: Principles, Applications, Implications and Hands-on Activities, Directorate-General for Research and Innovation, Industrial technologies (NMP), 2013

biology, physics, materials science and engineering²³. Within this context, nanotechnology applications are defined as the use and development of materials, devices and systems at the nanoscale²⁴.

Nanotechnology has had a significant impact in the global market and in particular in the fields of science and engineering by changing the researchers' mindset and influencing future technologies and solutions²⁵. Furthermore, nanotechnology is considered as a General-Purpose Technology (GPT) (i.e. similar to electricity and computing) that is used in all sectors – being interdisciplinary²⁶. Thus, nanotechnology has a broad impact in nearly every sector of the economy²⁷. According to the EC, it is estimated that nanotechnologies in 2015 were worth more than \$1 trillion (€900 billion) and is still growing. Moreover, there has been a continuous investment in nanotechnology, mostly from China and the US, which is translated into a larger number of manufactured nanomaterials integrated in final consumer products (e.g. clothing, cosmetics, food products, etc.)²⁸. In addition, the global nanotechnology market is expected to have a Compound Annual Growth Rate (CAGR) of around 17% between 2018 and 2025²⁹. This market trend is also reflected at the policy level between the EU and the US, which includes nanotechnology as one of the main thematic collaboration priorities.

Taking into account the recent nanotechnology developments, three areas stand out in terms of global market share by application or product, which account for more than 70%: electronics, energy and healthcare (biomedical). It is also relevant to highlight that the cosmetic industry is one of the most recent adopters of nanotechnology, while the automotive sector has captured around 5% of the global market share^{30,31}. These developments allow the improvement of existing products from different industries as well as the development of new processes and innovative methods. In addition, NNI provides examples of growing applications of nanotechnology and its benefits in several areas, highlighting electronics and IT, medical and healthcare, energy, environmental remediation and future transport³².

As such, the nanotechnology industry is highly complex, encompassing two segments: nanotechnology components and applications. In terms of the nanotechnology market by components, it is relevant to note that the highest market share is captured by the nanomaterials. On the other hand, nanotools account for the second highest share; while nanodevices have the lowest share of the nanotechnology

²³ <https://www.nano.gov/>

²⁴ The Maturing Nanotechnology Market: Products and Applications, Andrew McWilliams, 2016

²⁵ <http://www.gaeu.com/item/this-is-nanotechnology-one-of-the-fastest-growing-markets-in-the-world>

²⁶ <http://www.nanotechia.org/sectors>

²⁷ <https://www.ceramicindustry.com/articles/94506-nano-devices-segment-of-global-nanotechnology-market-expected-to-see-significant-growth>

²⁸ <http://www.gaeu.com/item/this-is-nanotechnology-one-of-the-fastest-growing-markets-in-the-world>

²⁹ Global Nanotechnology Market Analysis & Trends - Industry Forecast to 2025, Accuray Research LLP, 2016

³⁰ <http://www.gaeu.com/item/this-is-nanotechnology-one-of-the-fastest-growing-markets-in-the-world>

³¹ Global Nanotechnology Market 2018-2024: Technological Advancements in Nanotechnology & Increased Government Support and R&D Spending, RNCOS E-Services Private Limited, 2018

³² <https://www.nano.gov/you/nanotechnology-benefits>



market³³. This study will focus on different sector applications of nanotechnology taking into account its three components. Within this context, and taking into account the several studies analyzed, the main nanotechnology market applications can be categorized as the following^{34,35,36}:

- **Nanotechnology for Healthcare:** application of nanotechnology to human healthcare (nanomedicine). Nanotechnology solutions provide new ways of improving medical diagnosis, drug delivery (pharmaceutical), therapy and regeneration^{37,38}.
- **Nanotechnology for Electronics:** use of nanotechnology in electronic components (nanoelectronics), namely in computing³⁹. In particular, semiconducting inorganic nanowires (NWs), carbon nanotubes, nanofibers, nanofibers, quantum dots, graphene and other materials have been extensively explored in the framework of nanoelectronics. Moreover, nanotechnology is essential to advancement of integrated electronics, namely by increasing computational power, reducing device scale, and limiting energy consumption⁴⁰.
- **Nanotechnology for Energy:** applications at several levels, including in the optimization of materials and components, and the development of sources of conversion, storage (batteries), transport and use of energy⁴¹.
- **Nanotechnology for Transportation:** application at several areas of transportation, with a particular focus on the automotive sector: Fuel Cells, Power Systems, Heat Transfer, Lighting and Displays, among others⁴².
- **Nanotechnology for Aerospace:** application of nanotechnology for the areas of space and defense, which hold the majority share of the aerospace nanotechnology market in 2016⁴³.

³³ Global Nanotechnology Market 2018-2024: Technological Advancements in Nanotechnology & Increased Government Support and R&D Spending, RNCOS E-Services Private Limited, 2018

³⁴ <https://nano-engineering.euroscicon.com>

³⁵ <http://www.gaeu.com/item/this-is-nanotechnology-one-of-the-fastest-growing-markets-in-the-world>

³⁶ Global Nanotechnology Market 2018-2024: Technological Advancements in Nanotechnology & Increased Government Support and R&D Spending, RNCOS E-Services Private Limited, 2018

³⁷ http://ec.europa.eu/research/industrial_technologies/nano-in-healthcare_en.html

³⁸ <https://www.cnbc.com/2016/09/27/globe-news-wire-nanotechnology-drug-delivery-market-to-reach-us-119-billion-in-2023-transparency-market-research.html>

³⁹ Global 2017 Market Report for Nanoelectronics (Nanotechnology in Electronics) - Research and Markets, Future Markets, Inc, 2017

⁴⁰ Nanotechnology for Consumer Electronics, Hannah M. Gramling, Michail E. Kiziroglou, Eric M. Yeatman, 2017

⁴¹ Application of Nanotechnologies in the Energy Sector, Volume 9 of the series Aktionslinie Hessen-Nanotech of the Hessian Ministry of Economy, Transport, Urban and Regional Development, 2008

⁴² <https://www.businesswire.com/news/home/20110617005245/en/Research-Markets-Nanotechnology-Automotive-Transportation-Industry-Applications>

⁴³ Aerospace Nanotechnology Market - Global Industry Analysis, Size, Share, Growth, Trends, and Forecast 2017 – 2025, 2018



Importance of nanotechnology market to the EU and US

The nanotechnology application and investment has grown strongly in the past decades, being applied in several new products and materials. According to the Organization for Economic Cooperation and Development (OECD), the US is the country with the highest percentage of nanotechnology R&D in the business enterprise sector between 2008 and 2015, followed by Russia and France⁴⁴. Moreover, high investment funding has been applied to nanotechnology over the last decade, with around \$67.5 billion (€60 billion) being spent. In terms of the funding being applied to nanotechnology in 2015, it is relevant to note that the EU leads at the global level, while the US is in the third position just behind China. It is relevant to note that most of the time nanotechnology funding is hidden within other programs, which include nanotechnology application, being sometimes difficult to precisely estimate the total value invested in the industry.

At the EU level, the amount of funding has increased exponentially between 2001 and 2011, with countries such as France, Germany and Belgium taking the lead in nanotechnology national funding. Moreover, this investment is shifting from nanoscience to applications, leading to an increased impact of the technology at the market level⁴⁵. In the US, NNI has been providing large investments to nanotechnology since 2001, having a cumulative total of \$25 billion (€22.5 billion) since the inception of this initiative. However, the NNI budget for nanotechnology R&D investment has been decreasing since 2016⁴⁶. Nevertheless, nanotechnology has a big importance to both the EU and the US, being considered as a priority for both the market and research sides.

⁴⁴ <http://www.oecd.org/sti/biotech/nanotechnology-indicators.htm>

⁴⁵ Nanotechnology Funding: A Global Perspective, Tim Harper, Cientifica Ltd, 2015

⁴⁶ The National Nanotechnology Initiative - Supplement to the President's 2018 Budget, NNI, 2017



2 US innovation ecosystem

The US is the world leading country in terms of R&D investment, and this is still a fact when the public and private sectors are analyzed separately^{47,48}. In 2018, the country's total spending on R&D is expected to reach around \$553 billion (€498 billion), which represents about 2.8% of its Gross Domestic Product (GDP), and more importantly will account for over a quarter of the global R&D investment⁴⁹. The R&D programs are mainly supported by industry (\$367.7 billion, €330.9 billion), the Federal Government (\$137 billion, €123.3 billion), Academia (\$20.5 billion, €18.5 billion), and non-profits organizations (\$20.8 billion, €18.7 billion)⁵⁰.

In the Fiscal Year of 2018, the Federal Budget for the NNI was \$1.2 billion (€1.08 billion), targeting the support of innovation and promoting competitiveness, economic growth and national security. The budget allocated to the NNI, is divided among several federal organizations. The following organizations have the largest investment from the NNI (95%): NSF (fundamental research and education across all disciplines of science and engineering); HHS/NIH (nanotechnology-based biomedical research at the intersection of life and physical sciences); DOE (fundamental and applied research providing a basis for new and improved energy technologies); DOD (science and engineering research advancing defense and dual-use capabilities); and DoC/NIST (fundamental research and development of measurement and fabrication tools, analytical methodologies, metrology, and standards for nanotechnology). However, and as previously stated, there has been an overall reduction of the NNI investments in 2018 compared with 2016-2017, which reflect the administration's goal in prioritizing federal resources on areas that are not likely to be supported by industry.

Nanotechnology plays an important role in several sectors of the economy, in particular in the "High Tech" or "Knowledge and Technology-Intensive" manufacturing industries⁵¹. These high-tech industries accounted for 15% of the manufacturing sector and added \$511 billion (€460 billion) to the US GDP. Another important fact is that at the end of 2017, the US accounted for more than 650 nanotechnology granted patents in the European Patent Office (EPO), being ranked first at world level⁵².

⁴⁷ <https://www.aip.org/fyi/2016/us-rd-spending-all-time-high-federal-share-reaches-record-low>

⁴⁸ https://www.iriweb.org/sites/default/files/2016GlobalR%26DFundingForecast_2.pdf

⁴⁹ http://digital.rdmag.com/researchanddevelopment/2018_global_r_d_funding_forecast?pg=4#pg4

⁵⁰ http://digital.rdmag.com/researchanddevelopment/2018_global_r_d_funding_forecast?pg=6#pg6

⁵¹ The National Nanotechnology Initiative - Supplement to the President's 2018 Budget, NNI, 2017

⁵² <http://statnano.com/country/USA>



Innovation ecosystems are used to describe several actors and resources which are part of the innovation process⁵³. This includes researchers, universities, venture capitalists, industry companies, SMEs, startups, accelerators, incubators and investors⁵⁴. Considering the multiplicity of actors that the innovation ecosystem encompasses, this study focuses on the leading nanotechnology Innovation Hubs, the facilitators of innovation and the industry related R&D centers in order to identify the US regions that most contribute to the nanotechnology innovation process.

Thus, the analysis on the nanotechnology innovation ecosystem should first describe the innovation hubs and facilitators, as well as the industry related RDI centers that are most relevant for this area. This analysis allows the EU research and innovation community to identify key US nanotechnology organizations that provide support to the advancement of nanotechnology and its application in several sectors.

2.1. Innovation Hubs

Innovation hubs can be described as ecosystems that comprise several actors, including SMEs, large industries, startups, researchers, accelerators, and investors⁵⁵. Thus, a successful innovation hub promotes R&D activities, facilitates the development of new technologies and incubates early stage companies⁵⁶. Moreover, innovation hubs promote cooperation within their ecosystem and act as a bridge between research activities and market needs.

The US is home to some of the world's most recognized innovation hubs. The San Francisco Bay Area is internationally recognized for its world class high-tech companies and numerous highly innovative startups. This innovation hub promotes world leading technological trends as well as important advances in technology⁵⁷. However, in recent years, Boston and New York have also emerged as world leading innovation hubs due to their combination of funding with highly talented professionals, which can lead to important innovation breakthroughs^{58,59}.

Nanotechnology hubs are one of the key drivers of science and engineering related with nano-applications within the US. Several companies and innovation facilitators focused on nanotechnology applications for healthcare, electronics, energy, transportation and aerospace are establishing their

⁵³https://www.researchgate.net/publication/282122544_Innovation_Ecosystems_Implications_for_Innovation_Management

⁵⁴<http://www.know-hub.eu/knowledge-base/videos/innovation-ecosystems-as-drivers-of-regional-innovation-validating-the-ecosystem.html>

⁵⁵<https://ec.europa.eu/digital-single-market/en/blog/digital-innovation-hubs-ict-2015>

⁵⁶<http://americanjobsproject.us/system/innovation-ecosystem/>

⁵⁷<https://medium.com/@RussellMoopa/silicon-valley-innovation-hub-of-the-world-1925278c6289>

⁵⁸<https://www.forbes.com/sites/noahkirsch/2016/10/18/why-boston-is-the-next-hub-for-innovation/#75ab33693d6a>

⁵⁹<https://www.crowdspring.com/blog/startups-entrepreneurs-best-startup-cities-us/>



activities in innovation hubs across the US. Therefore, the nanotechnology innovation hubs support the exchange of knowledge, foster the development of new technologies, facilitate capital attraction and promote research-industry partnerships that can lead to breakthroughs in the area.

As the nanotechnology industry is relatively new, companies are not tied to any region in specific. However, nanotechnology workers are usually people with graduate degrees, which leads companies to located themselves close to the universities and research centers, where they can find highly educated workers and the needed infrastructure to develop their activities⁶⁰. Taking this into account, the nanotechnology innovation process is strongly dependent on market-research cooperation, with leading actors from several areas from both the research and the industry side.

The US major innovation hubs for nanotechnology are primarily concentrated in California, Illinois, Massachusetts, New York, North Carolina and Texas^{61,62,63}. The identified hubs are focused on at least one of the five areas: Healthcare, Electronics & Computers, Energy, Transportation and Aerospace.

Figure 3 presents an overview of the US leading Innovation hubs in the nanotechnology related fields.

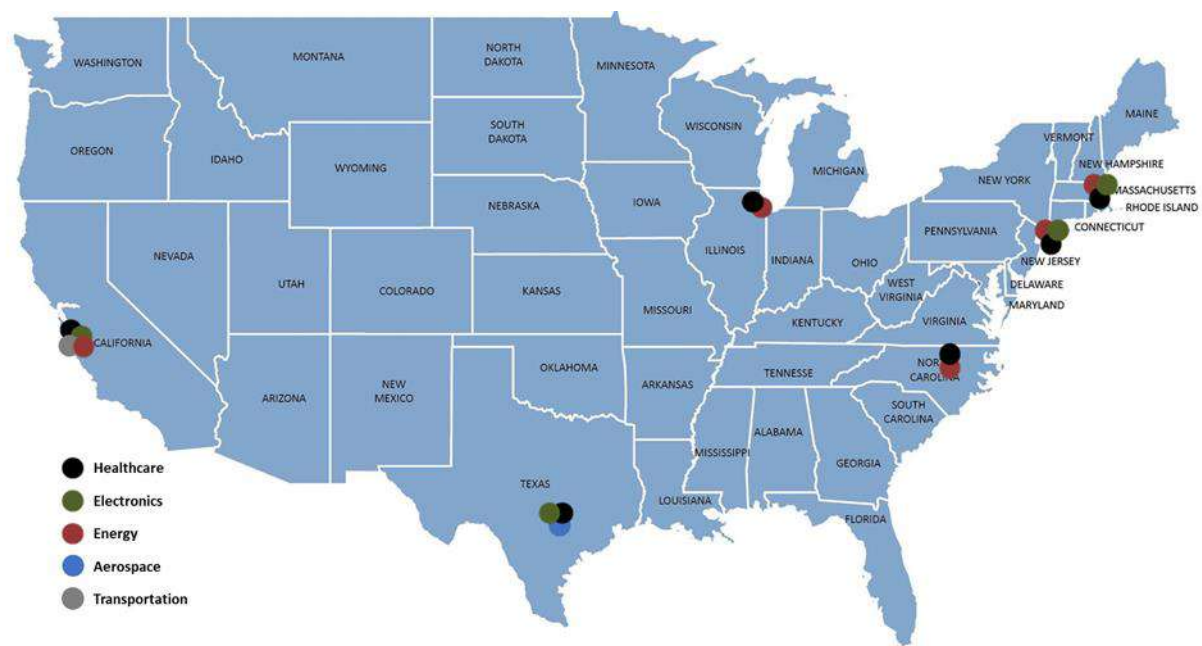


Figure 3 - US Mapping of the leading Innovation Hubs focused on nanotechnology-related products

⁶⁰ Working Texas Style, Chapter 12: Nanotechnology, 2013

⁶¹ <http://www.nanotechproject.org/inventories/map/>

⁶² <https://www.nano.gov/USnanoresourcemap>

⁶³ Best Practices in State and Regional Innovation Initiatives: Competing in the 21st Century (2013), Chapter: 7 The New York Nanotechnology Initiative, National Research Council, 2013

New York City, New York

Applications: Healthcare (biomedicine), Electronics & Computers (in particular microelectronics and semiconductors), Energy

New York has been continuously investing to transform the region into a leading center of nanotechnology R&D⁶⁴. In particular, New York has been developing large-scale investments in university research infrastructure and collaborative agreements with the private sector in nanotechnology. One example is the \$85 million (€76.5 million) investment to create the Center of Excellence in Nanoelectronics and Nanotechnology (CENN) in collaboration with IBM. It is also relevant to highlight the investment in the Tech Valley cluster on nanotechnology, which is based near Albany⁶⁵. New York State is among the leading states in nanotechnology nationwide. Tech Valley is an internationally renowned hub of nanotechnology R&D⁶⁶.

At the same time, New York has a very strong hi-tech industry sector, with a large pool of important players from the industry side. Allied to this, New York features a strong base of academia-industry cooperation, with good access to funding of new projects and high education levels. Within this context, New York encompasses a large set of world-leading organizations that are committed to exploring new opportunities within the application of nanotechnologies⁶⁷. Moreover, the effort developed by the State University of New York (SUNY) at Albany as one of New York's Innovation Hubs led it to become one of the most prominent centers of nanotechnology research at the global and regional levels⁶⁸.

On the other hand, there is a concern at the policy level that New York is still behind in terms of attracting venture capital, compared with other states such as California. Thus, the New York State Innovation Venture Capital Fund was released to attract new and innovative startups to the region⁶⁹. Furthermore, there are several nanotechnology related innovative companies based in the New York State, which contribute strongly to the market development in the region^{70,71}.

Initial contact point: Tech Valley (SUNY-Albany of the State University of New York)

⁶⁴ Best Practices in State and Regional Innovation Initiatives: Competing in the 21st Century, National Research Council, 2013

⁶⁵ Advances in the Theory and Practice of Smart Specialization, 2017

⁶⁶ Empire State Development Corporation International Division

⁶⁷ <https://www.azonano.com/article.aspx?ArticleID=3120>

⁶⁸ Best Practices in State and Regional Innovation Initiatives: Competing in the 21st Century, National Research Council, 2013

⁶⁹ Best Practices in State and Regional Innovation Initiatives: Competing in the 21st Century, National Research Council, 2013

⁷⁰ <https://www.azonano.com/article.aspx?ArticleID=3120>

⁷¹ New York's Nanotechnology Model: Building the Innovation Economy: Summary of a Symposium, National Research Council, 2013



<https://sunypoly.edu/research/albany-nanotech-complex.html>

San Jose, California

Applications: Healthcare, Electronics & Computers, Energy, Transportation

The California ecosystem is composed of a set of different relevant research and commercial nanotechnology institutions. For example, the University of California has several quality nanotechnology research programs^{72,73}. At the policy level, California has been a national leader in trying to develop policy frameworks for new technologies. Moreover, several companies opt for California when trying to find new opportunities within the technological and scientific areas. Thus, California is growing as an important player in nanotechnology, not only at the US level, but also worldwide^{74,75}. In California, nanotechnology has a significant and important impact on the high-tech economy, with more and more emphasis on the commercialization of nano-related products and services⁷⁶. Back in 2010, California housed around 25% of the total of US nanotechnology companies, receiving a total of 42% of the US venture capital. This is mainly related with the high concentration of academia, research and innovation related entities located in Silicon Valley, indicating strong ties between research and industry⁷⁷.

The California Innovation Hub is composed of a large set of companies which include some big players from different market sectors, namely the IBM facility in San Jose, Intel in Santa Clara and Folsom, and the Alto Research Center, a Xerox company, in Palo Alto⁷⁸.

Initial contact point: Center for Nanotechnology in Society at the University of California

<http://www.cns.ucsb.edu/index.html>

Austin, Texas

Applications: Healthcare, Electronics & Computers (semiconductors), Aerospace

⁷² <https://www.nanowerk.com/news2/newsid=29126.php>

⁷³ <https://californiananoeconomy.org/>

⁷⁴ <https://www.azonano.com/article.aspx?ArticleID=3146>

⁷⁵ <https://californiananoeconomy.org/content/economic-development>

⁷⁶ California Council on Science and Technology, Nanotechnology in California, California Council on Science and Technology, 2010

⁷⁷ Nanotechnology in California, Simone Jackson, Christine Shearer, Barbara Herr Harthorn, 2016

⁷⁸ <https://www.azonano.com/article.aspx?ArticleID=3146>



The research and commercial environment of nanotechnology in Texas is one of the most prominent at the US State level. Besides companies involved in nanotechnology-related businesses, Texas has a large range of universities that include well-respected nanotechnology research programs and initiatives, as well as academic programs⁷⁹. At the research and academia side, the Texas innovation hub is composed of more than 20 universities which include nanotechnology in their research programs and four specific research centers⁸⁰. Texas is positioned to become a key industrial player in the nanotechnology field, namely through the establishment of several companies and a large network of research universities⁸¹. In 2005, through a federal funding investment of \$11 million (€9.9 million), the Strategic Partnership for Research in Nanotechnology (SPRING) was created through a consortium of researchers located at University of Texas (UT)-Arlington, UT-Austin, UT-Brownsville, UT-Dallas, UT-Pan American, the University of Houston and Rice University⁸².

Due to the initial nanotechnology infrastructural developments through science departments of universities, nanotechnology companies, especially the smaller ones, tend to be located near the universities of Rice, UT-Austin, UT-Arlington and UT-Dallas. On the other hand, with the private investment being relatively diminished, federal and state funding become a critical point to support the Texas nanotechnology area⁸³. Moreover, Houston is home to one of the largest semiconductor and computer company hubs worldwide, which fits the nanotechnology innovation sector applications⁸⁴.

Initial contact point: NNCI at the Texas Nanofabrication Facility

<https://www.nnci.net/sites/tnf>

Boston, Massachusetts

Applications: Healthcare, Electronics & Computers, Energy

Massachusetts is in the forefront of nanotechnology research in the US and particularly in nanomanufacturing. Thus, several cooperative projects have been promoted between research institutions and industry organizations, generating technology advancements on bringing new commercial nano-related products to the market. Massachusetts Institute of Technology (MIT) is one good example of an academia institute that has been providing new research and commercial

⁷⁹ <https://www.nanowerk.com/news2/newsid=29029.php>

⁸⁰ <https://www.dcccd.edu/cd/dcc/mech/nanotech/pages/links.aspx>

⁸¹ Working Texas Style, The Texas Workforce Commission, 2013

⁸² Working Texas Style, Chapter 12: Nanotechnology, 2013

⁸³ Working Texas Style, Chapter 12: Nanotechnology, 2013

⁸⁴ <http://www.areadevelopment.com/HighTechNanoElectronics/oct08/nano-tech-centers-clusters.shtml>



opportunities in the nanotechnology field. Moreover, MIT will construct a new facility named “MIT.nano” which aims to be a hub of nanoscience and nanotechnology research and innovation⁸⁵.

At the institutional level, the Massachusetts Department of Environmental Protection (DEP) has been very active in ensuring the safe use of nanotechnology, particularly towards clean air and water treatment, recycling waste, management of toxic materials, among others⁸⁶. Moreover, Harvard University is one of the six NSF-designated nanotechnology centers, leading to several technological breakthroughs and patents for nanotechnology applications⁸⁷. In addition, it is relevant to highlight the progress developed through the University of Massachusetts Lowell, which has been promoting nanotechnology R&D in the region. The university has opened, back in 2012, the Emerging Technologies and Innovation Center (ETIC), which holds programs in the areas of nanotechnology, namely nanomedicine, nanomanufacturing, biomaterials development, among others^{88,89}.

Initial contact point: MassDevelopment

<https://www.massdevelopment.com/>

Chicago, Illinois

Applications: Healthcare, Energy

Illinois is becoming one of the leading states in the US for nanotechnology through its composed infrastructure, diversity and number of research institutions, human capital and a cluster for companies and start-ups. Currently, Illinois is looking to attract more private investment to the state, expanding its resources and available infrastructure for supporting nanotechnology start-ups. Within this context, there has been an increase in research centers from Illinois on developing new nanotechnology-related activities in the state. At the academia level, universities and research facilities are promoting the development of new nanotechnology ideas and trying to enhance the involvement of students in nanotechnology-related activities⁹⁰.

Illinois is well positioned to focus on four sectors with substantial growth potential: energy, clean water, personalized medicine, and advanced manufacturing.

⁸⁵ <https://mitnano.mit.edu/>

⁸⁶ <https://www.azonano.com/article.aspx?ArticleID=3133>

⁸⁷ <http://www.areadevelopment.com/HighTechNanoElectronics/oct08/nano-tech-centers-clusters.shtml>

⁸⁸ <https://web.uml.edu/gallery/index.php/Research/Emerging-Technologies-and-Innovation-Center-ETIC>

⁸⁹ <http://navigate.necce.org/en/custom/startupresources/view/4953>

⁹⁰ <https://www.azonano.com/article.aspx?ArticleID=3210>



Initial contact point: International Institute for Nanotechnology (IIN)

<https://www.iinano.org/>

Raleigh, North Carolina

Applications: Healthcare (nanomedicine), Energy

North Carolina is becoming a leader in nanotechnology at the US level. The constant public investment in the region is promoting the research and innovation development of the industry. Within this context, the North Carolina Department of Commerce has developed a roadmap for investment in nanotechnology during 2006. Thus, there are several universities, research facilities and industry players that compose the nanotechnology innovation ecosystem in North Carolina.

Moreover, North Carolina has a strong focus on private investment in nanotechnology, driven by the new innovations that come from the academia side and feed nanotechnology companies⁹¹. Thus, North Carolina is looking to nanotechnology as a way of obtaining and sustaining reputation in science and technology innovation⁹². With the North Carolina government support, the Research Triangle Park (RTI) was founded. It provides links to universities and business leaders not only within the state but also with other institutions at the international level⁹³. RTI combines scientific and technical knowledge to develop new methods, technologies and programs that support different innovation fields, including nanotechnology.

Initial contact point: Research Triangle Park (RTI)

<https://www.rti.org/>

2.2. Innovation facilitators

Innovation is deeply responsible for the US economic growth⁹⁴. The US entrepreneurial ecosystem is based on flexibility, diversity, creativity and novelty, being supported by a set of public and private

⁹¹ <https://www.azonano.com/article.aspx?ArticleID=3173>

⁹² <https://www.nccommerce.com/sti/nanotechnology>

⁹³ <https://www.rti.org/about-us>

⁹⁴ <https://www.sba.gov/sites/default/files/rs425-Innovation-Accelerators-Report-FINAL.pdf>



programs⁹⁵. Innovation facilitators in the US support, promote and accelerate the innovation process. Within this context, organizations such as business accelerators, incubators, science parks and specialized consulting firms are considered innovation facilitators, playing a very important role in the nanotechnology innovation process.

Accelerators support early-stage innovative companies through programs that offer education, mentorship, access to capital and investment, office space and supply chain resources during a fixed period of time⁹⁶. During the accelerating process, early-stage companies are often grouped with other early stage financing organizations, such as incubators, angel investors and seed-stage venture capitalists in order to attract investment⁹⁷. Incubators support early-stage innovative companies and often provide affordable working spaces, shared offices and services, management training, marketing support and access to finance. Overall, incubators support early-stage innovative companies reducing their costs and growing their businesses faster^{98,99}.

Science parks are areas, often created or supported by a college or university, where companies involved in scientific work and new technology are located¹⁰⁰. Science parks are catalyzers for innovation and promote university-business collaborations, which are likely to lead to important advances in technology. In addition, science parks provide an ecosystem that supports early-stage businesses' incubation and acceleration¹⁰¹.

Nanotechnology is a relatively new technology, which is applied in several sectors and aspects of the industrial ecosystem. Thus, nanotechnology supported manufacturing is rapidly growing, becoming a key aspect in industrial innovation¹⁰². Moreover, considering the close connection of nanotechnology with the development of new innovative products, science parks play an important role in the development and deployment of innovative nanotechnology applications.

Specialized consulting firms can act as important facilitators of innovation. These firms provide services that help startups to promote the creation of strategic partnerships, to promote research and technology transfer, and to foster entrepreneurship. Moreover, specialized consulting firms play a crucial role in applying their entrepreneurial approach, business experience, and fundamental

⁹⁵https://www.researchgate.net/publication/266392166_A_Review_of_the_Entrepreneurial_Ecosystem_and_the_Entrepreneurial_Society_in_the_United_States_An_Exploration_with_Global_Entrepreneurship_Monitor_Dataset

⁹⁶<https://smallbiztrends.com/2016/08/business-accelerator-differ-incubator.html>

⁹⁷<https://hbr.org/2016/03/what-startup-accelerators-really-do>

⁹⁸<http://www.diogenes-incubator.com/incubation/business-incubation-definition>

⁹⁹<http://www.businessdictionary.com/definition/business-incubator.html>

¹⁰⁰<https://dictionary.cambridge.org/dictionary/english/science-park>

¹⁰¹<http://www.unesco.org/new/en/natural-sciences/science-technology/university-industry-partnerships/science-and-technology-park-governance/concept-and-definition/>

¹⁰² Processes of Innovation in the Field of Nanotechnology, Anna Butzin, 2007



scientific knowledge to support technology advances that can benefit nanotechnology-related start-ups.

Thus, based on desk research, this study identifies five leading facilitators of innovation in the nanotechnology industry.

NCnano – The Northern California Nanotechnology, California

The Northern California Nanotechnology Initiative (NCnano) is an initiative focused on promoting a nanotechnology economy of Northern California. California has always been on the forefront of cutting edge technology, entrepreneurial initiatives and hi-tech projects, which position the region as one of the leading nanotechnology hubs at the global level. Thus, NCnano will promote greater access to large equipment, core facilities and research investment to facilitate the development of nanoscale biotechnology, molecular electronics, advanced materials and manufacturing technologies.

<http://www.ncnano.org/aboutus.html>

Magnify, the California NanoSystems Institute Incubator at UCLA, California

Magnify is a business incubator and accelerator held within the California NanoSystems Institute at UCLA that supports the development of technology startups and new ideas through the use of nanotechnology applications. The incubator is located at UCLA's Court of Sciences, promoting entrepreneurial activities in Los Angeles. Magnify includes a co-working laboratory and office space, allowing fast development of startups and facilitating their access to capital and new market opportunities.

<https://cnsi.ucla.edu/incubator/>

NanoAccelerator (NCNA), North Carolina

The NanoAccelerator (NCNA) is a center for startups that have innovative technology in the area of nanotechnology. Thus, NCNA aims to promote business and commercial development for startup companies. The accelerator is technology focused, having a big emphasis on the commercialization aspect of the solutions presented. It provides technical support as well as different resources such as financial advice, lab space, equipment, etc.

<http://www.quartekcorp.com/NanoAccelerator.html>

iCLEAN Incubator at SUNY Polytechnic Institute, New York

The Incubators for Collaborating & Leveraging Energy and Nanotechnology (iCLEAN) is an initiative funded in part through the New York State Energy Research Development Authority (NYSERDA). The incubator is established at the Energy and Environmental Technology Applications Center (E2TAC) at the College of Nanoscale Science and Engineering (CNSE). The main aim of the incubator is to promote



the emerging of new technologies and to create positive energy innovations and solutions that can be replicated on a global scale.

<http://e2tac.org/e2tac/CentersPrograms/NYSPARC.aspx>

Ohio Third Frontier, Ohio

The Ohio Third Frontier is an initiative promoted by several members within the Ohio Development Services Agency, the Governor's advisor and the Ohio Board of Regents', among others. It provides funding to technology-based universities, non-profit organizations and companies within Ohio that promote innovation. Thus, the Ohio Third Frontier promotes the acceleration of different startups and early stage technology companies. Moreover, its portfolio includes high-potential companies from the nanotechnology field.

https://development.ohio.gov/bs_thirdfrontier/

In-Q-Tel (IQT), Washington DC

IQT is a nonprofit investor that focuses on the acceleration and support of cutting-edge technologies to the US Government, supporting start-ups, new ventures and businesses. Within the large range of services provided, IQT supports new ventures in developing strategic needs assessments, solutions and market surveys, due diligence, solution transfers and strategic investments. Thus, IQT provides a large portfolio of investment actions, which includes support on nanotechnology-related entities and innovations¹⁰³.

<https://www.iqt.org/>

2.3. Industry related RDI centers

The cooperation between industry, researchers and innovation facilitators is key for promoting the development of new nanotechnology applications and solutions. As previously mentioned, nanotechnology solutions can be applied in many areas of the innovation ecosystem. Thus, several industry-related centers have emerged in the US in order to promote new entrepreneurial ventures and solutions within the context of nanotechnology.

Most nanotechnology R&D solutions seem to be developed through the cooperation between industries and universities or research centers. Within this context, there is a geographical proximity between universities, research centers and companies in the area to pursue R&D and innovation

¹⁰³ <https://www.iqt.org/>



actions¹⁰⁴. Therefore, most industry related R&D centers typically include as members or partners SMEs and large companies from the nanotechnology industry, which are dependent on the knowledge and technology from research organizations.

Some of nanotechnology related RDI centers are highlighted in Table 2. These centers have been selected through desk research. Even though some of the identified centers are not located in the aforementioned innovation hubs (e.g. Industry/University Cooperative Research Center for Advanced Knowledge Enablement), these represent important contributors to the nanotechnology innovation ecosystem.

¹⁰⁴ Working Texas Style, Chapter 12: Nanotechnology, 2013



Table 2 – A sample of Industry connected RDI Centers in the nanotechnology related fields

Industry Connected RDI Center	Examples of Academic Partners/Members	Examples of Industry Partners/Members	Location	Fields	Internet link
TechLink center at Montana State University's Office of Research and Economic Development	Montana State University's Office of Research and Economic Development	The American Precision Optics Manufacturers Association (APOMA) ¹⁰⁵	Bozeman, Montana	Electronics	https://techlinkcenter.org/
NanoHub.org at Purdue University	Purdue University	General Electric (US) ¹⁰⁶ Gordon and Betty Moore Foundation (US) ¹³² Rock Health (US) ¹³² Salesforce (UK) ¹³² Samsung Strategy and Innovation Center (US) ¹³² Vital Connect (US) ¹³² Voalte (US) ¹³²	San Francisco, California	Electronics, Energy	https://nanohub.org/
Center for Innovative Instrumentation Technology (CiiT) at University of Illinois	University of Illinois at Urbana-Champaign	-	Urbana, Illinois	Electronics (microelectronic sensors)	http://instrumentation.illinois.edu

¹⁰⁵ <http://www.apoma.org/>

¹⁰⁶ <http://centerfordigitalhealthinnovation.org/about-us/>

Industry Connected RDI Center	Examples of Academic Partners/Members	Examples of Industry Partners/Members	Location	Fields	Internet link
nanoMFG at the University of Illinois at Urbana-Champaign (UIUC)	University of Illinois at Urbana-Champaign (UIUC) University of California at Berkeley	-	Champaign, Illinois	Healthcare, Electronics,	http://nano.illinois.edu/
Center for Advanced Research in Drying (CARD) at University of Illinois and Worcester Polytechnic Institute	University of Illinois at Urbana-Champaign Worcester Polytechnic Institute	Hershey's PEPSICO Mondelez Flint Hills resources Ingredion Kimberly-Clark	Worcester, Massachusetts Champaign, Illinois	Energy, Transportation	http://www.dryingresearch.org/
Advanced Electronics through Machine Learning (CAEML) at University of Illinois	University of Illinois at Urbana-Champaign Georgia Tech NC State University	Samsung Intel IBM Hewlett Packard Nvidia Lockheed Martin Global Foundries CISCO Analog Devices Cadence Qualcomm Sandia National Laboratories	Urbana, Illinois	Electronics	https://publish.illinois.edu/advancedelectronics/



Industry Connected RDI Center	Examples of Academic Partners/Members	Examples of Industry Partners/Members	Location	Fields	Internet link
		Synopsys XILINX			
Center for Advanced Design and Manufacturing of Integrated Microfluidics (CADMIM) at University of California, Irvine	University of California, Irvine University of Illinois at Chicago University of Cincinnati	ALine, Inc. Beckman Coulter DuPont Pioneer ESI Group Genentech Genomics Institute of the Novartis Research Foundation GlaxoSmithKline KWS SAAT SE Los Alamos National Lab VTT Technical Research Center of Finland, Ltd.	University of California, Irvine University of Illinois Chicago	Health	http://www.inrf.uci.edu/cadmim/
Center for Energy-Smart Electronic Systems (ES2) at Binghamton University	Binghamton University: The State University of New York The Georgia Institute of Technology University of Texas at Arlington Villanova University	Bloomberg CDAC Comcast Commscope Corning, Inc. Engineered Fluids Evolve Incorporated Facebook Future Facilities Huawei	Binghamton University: The State University of New York The Georgia Institute of Technology University of Texas at Arlington	Electronics, Energy	https://www.binghamton.edu/es2/



Industry Connected RDI Center	Examples of Academic Partners/Members	Examples of Industry Partners/Members	Location	Fields	Internet link
		Innovative Technomics LiquidCool Solutions Logicare Mestex NYSERDA Panduit QuantaCool Verizon Vertiv Xilinx	Villanova University		
Cooling Technologies Research Center (CTRC) at Purdue University	Purdue University	Apple Ford Intel Du Pont Qualcomm Toyota Delphi LG Nokia Sony Samsung Philips Boeing	Purdue University	Electronics, Energy	https://engineering.purdue.edu/CTRC/
Oregon Nanoscience and Microtechnologies Institute (ONAMI)	Oregon Research Universities	ZAPS Technologies NANO3D Systems Northwest UAV Pacific Light Technologies	Corvallis, Oregon	Healthcare, Energy	http://onami.us/



Industry Connected RDI Center	Examples of Academic Partners/Members	Examples of Industry Partners/Members	Location	Fields	Internet link
		Shoei Electronic Materials AbSci Cascade Prodrug DesignMedix Dune Sciences Floragenex			
MATTCENTER	University of Massachusetts	-	Boston, Massachusetts	Healthcare, Energy, Electronics	http://www.mttc.org/



3 US market landscape

In the US, nanotechnology has significantly impacted the country's economy. The US is the world leading country in terms of nanotechnology-related firms, with a considerably number of firms in the area when compared with other countries¹⁰⁷. In 2014, the US invested around \$6 billion (€5.4 billion) in nanotechnology from governments, corporations and private investors, corresponding to 33% of the total amount at the global level. Moreover, the revenue from nano-related products has increased 90% from 2012 to 2014, which shows the great potential of this technology from the business side¹⁰⁸.

The NNI and the Office of Science and Technology Policy (OSTP) have been collaborating in the nanotechnology field in order to promote significant advancements at the national level. Thus, a set of Nanotechnology Signature Initiatives (NSIs) have been agreed, which identify focus areas of national importance and support enhanced coordination and cooperation among actors¹⁰⁹. These NSIs allow the acceleration of nanoscale science and technology from the research and the market point of view. Therefore, the number of manufactured products through the application of nanotechnology has been increasing over the years¹¹⁰.

Due to the US market size and complexity of the nanotechnology industry, namely because of the several applications in a diverse number of sectors and areas, this study identifies the leading US regions for the areas based on the geographical concentration of manufacturers involved within the identified nanotechnology applications, as well as the key considerations to be taken into account by EU businesses interested in accessing the US nanotechnology market.

3.1. Market overview

The US is the world leading nanotechnology market, having the highest investment funding in nanotechnology over the last decade¹¹¹. According to some studies, revenue from nano-enabled products has been exponentially growing at the world level – from \$339 billion (€305 billion) in 2010 to more than \$1 trillion (€900 billion) in 2013. Following this trend, there are now more than 60 countries worldwide that have launched national nanotechnology programs and initiatives, with governments and industry players investing millions in research and innovation¹¹². The US has witnessed a revenue of \$318 billion (€286 billion) alone in 2013¹¹³. Furthermore, the US dominates the world's nanotechnology industry in terms of research and product development¹¹⁴.

¹⁰⁷ OECD, Key Nanotechnology Indicators, <http://oe.cd/kni>, May 2017

¹⁰⁸ Nanotechnology Update: U.S. Leads in Government Spending Amidst Increased Spending Across Asia, LuxResearch, 2015

¹⁰⁹ <https://www.nano.gov/node/1536>

¹¹⁰ <http://www.gaeu.com/item/this-is-nanotechnology-one-of-the-fastest-growing-markets-in-the-world>

¹¹¹ <http://www.oecd.org/sti/biotech/nanotechnology-indicators.htm>

¹¹² <https://www.materialstoday.com/nanomaterials/comment/the-nanotechnology-race-between-china-and-usa/>

¹¹³ https://www.nsf.gov/news/news_summ.jsp?cntn_id=130586

¹¹⁴ Working Texas Style, Chapter 12: Nanotechnology

The US nanotechnology market can be divided by several stages that compose the value chain. Thus, this study focuses on nanotechnology components and applications. The components are related with the nanomaterials that are produced at the nanoscale, while the applications relate with products that incorporate nanoscale materials or have nanostructured features. This includes both final products as well as subassemblies that are included in end-use products. Moreover, an intermediary level exists between these stages that are the nanoscale intermediaries, which incorporate nanoscale materials or have nanostructured features¹¹⁵. Taking this into account, the main key segments identified within the nanotechnology industry are considered within the application perspective. Thus, the application of nanotechnology in the US market is mostly dominated by the healthcare (nanomedicine), electronics & computers, energy, transportation (automotive) and aerospace sectors.

In the healthcare sector application (nanomedicine), the global market accounted for a total of almost \$139 billion (€125 billion) in 2016 and it is expected to grow exponentially until 2023. Nanomedicine is used in the diagnosis, treatment, monitoring and control of biological systems. Moreover, the market is driven by technologies for drug delivery, increase of nanomedicine, more funding and support at the governmental level and cost-effective therapies. Therapeutics accounted for the highest share in revenue in 2016 by products^{116,117}.

In terms of electronics & computers, it is important to highlight the relevant applications that nanotechnology can have in a large range of products, namely the display screens, computers, memory storage and optoelectronic devices, among others¹¹⁸. In the US, the nanoelectronics market has shown a trending growth at the industry level¹¹⁹.

Nanotechnology applications in energy will provide the potential to improve energy efficiency and renewable energy production through different industries and branches. Nanotechnology is applied to five areas of the energy value chain: energy sources, energy conversion, energy distribution, energy storage (including batteries), an energy usage¹²⁰. In terms of market volume from nanotechnology-based products, it is estimated that the market segment with the highest CAGR at the global level between 2009 and 2014 was the micro-energy harvesting for energy autarkic sensors and switches

¹¹⁵ <https://californiananoeconomy.org/value-chain-view>

¹¹⁶ Nanomedicine Market by Modality - Global Opportunity Analysis and Industry Forecast, 2017-2023, Allied Analytics LLP, 2017

¹¹⁷ Nanomedicine Market Analysis By Products, (Therapeutics, Regenerative Medicine, Diagnostics), By Application, (Clinical Oncology, Infectious diseases), By Nanomolecule (Gold, Silver, Iron Oxide, Alumina), & Segment Forecasts, 2018 – 2025, 2017

¹¹⁸ <https://www.nanobay.com/news/blog/172-tips-and-tricks/9299-how-nanotechnology-is-going-to-shape-the-electronics-industry>

¹¹⁹

https://www.sharewise.com/us/news_articles/United_States_Nanoelectronics_Market_Analysis_Report_20172022_anty_naraw_20180201_0936

¹²⁰ <https://www.nanowerk.com/nanotechnology-in-energy.php>



(e.g. electromagnetic induction, thermoelectric, photovoltaics, piezoelectric) and nano-optimized batteries¹²¹.

Concerning nanotechnology applications for transportation (automotive), there has been a high demand from automotive manufacturers to use new technologies that are able to offer cost-effective improvements in the vehicle performance. Thus, there are a number of components in nanotechnology that are being applied to the automotive sector, namely for next-generation battery market, tire production and paintings and coatings^{122,123}. It is estimated that the revenues from nanotechnology in the automotive market have reached around \$6 billion (€5.4 billion) in 2015¹²⁴. Moreover, companies such as Toyota, General Motors, Ford and Rolls Royce are taking a lead in developing innovation in these areas¹²⁵.

In regard to the aerospace sector, the application of nanotechnology solutions represents a big opportunity for one of the most important heavy industries at the global level¹²⁶. In particular, this industry application mainly concerns the lighter construction materials and more efficient engines¹²⁷. Moreover, the global CAGR of aerospace nanotechnology is expected to grow 5.75% from 2017 to 2021¹²⁸.

3.2. Leading regions

Considering the size of the US nanotechnology industry, there are states that can be considered leading regions from a market perspective. As previously stated, nanotechnology applications comprise several areas and sectors, and specifically different products and services. Consequently, to analyze the leading US market regions, it is necessary to describe the main target groups for each nanotechnology application. Within this context, the following target groups are analyzed: pharmaceutical and medicine, electronics and computers, batteries, paints and coatings and aerospace.

¹²¹ Nanotechnology in the sectors of solar energy and energy storage, IEC Project Team, 2014

¹²² <https://www.businesswire.com/news/home/20110617005245/en/Research-Markets-Nanotechnology-Automotive-Transportation-Industry-Applications>

¹²³ Nanotechnology and Tyres – Greening Industry and Transport, OECD Publishing, 2014

¹²⁴ <http://what-when-how.com/nanoscience-and-nanotechnology/nanotechnology-and-automotive-parts-current-status-and-future-prospects/>

¹²⁵ <https://www.businesswire.com/news/home/20110617005245/en/Research-Markets-Nanotechnology-Automotive-Transportation-Industry-Applications>

¹²⁶ <https://nanocongress.nanotechconferences.org/events-list/nanotechnology-in-aerospace>

¹²⁷ <https://www.azonano.com/article.aspx?ArticleID=3103>

¹²⁸ Global Aerospace Nanotechnology Market 2017-2021, Technavio, 2017



Thus, the geographical concentration of the different businesses was identified based on North American Industrial Classification Codes (NAICs) codes. NAICs codes are standardized and used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the US economy¹²⁹. The NAICs codes group businesses into industries based on the similarity of their production processes, covering all economic activities. Thus, it facilitates the collection, tabulation, presentation, and analysis of data related to businesses¹³⁰. Taking into account the US nanotechnology market, this study used five different NAICs codes: NAICS 32541 (Pharmaceutical and Medicine Manufacturing), NAICS 334111 (Electronic Computer Manufacturing), NAICS 335911 (Storage Battery Manufacturing), NAICS 325510 (Paint and Coating Manufacturing) and NAICS 336412/3 (Aerospace Product and Parts Manufacturing).

In this context, manufacturers and suppliers from the identified sectors were considered to be the main target markets for businesses commercializing nano-enabled products. Thus, the regions with a higher concentration of equipment manufacturing and suppliers for each segment seem to represent important market opportunities for businesses providing nano-enabled products. Among those regions, there are four states which particularly stand out: California, Florida, Texas and New York.

Although there are other sectors that may also represent important opportunities for the EU businesses related to nanotechnologies, the scope of this report is based on demonstrating the various avenues that EU businesses can take to approach the US market.

Pharmaceutical and medicine manufacturing

Nanotechnology applications in healthcare allow the development of new equipment and medical solutions. As previously described, solutions concerning therapeutics accounted for the highest share of revenue in the sector for 2016. Within this context and taking into account the influence of nanotechnologies in medical treatments and therapeutics, it is relevant to analyze the pharmaceutical and medicine manufacturing segment^{131,132}. Thus, from a market perspective, the US states and cities with the highest geographical concentrations of pharmaceutical and medicine manufacturers may represent the areas with more nanotechnology applications for pharmaceutical and medicine manufacturing opportunities across the country.

¹²⁹ <https://www.census.gov/eos/www/naics/>

¹³⁰ 2017 North American Industrial Classification Codes Manual, Executive Office of the President, 2017

¹³¹ Nanomedicine Market by Modality - Global Opportunity Analysis and Industry Forecast, 2017-2023, Allied Analytics LLP, 2017

¹³² Nanomedicine Market Analysis By Products, (Therapeutics, Regenerative Medicine, Diagnostics), By Application, (Clinical Oncology, Infectious diseases), By Nanomolecule (Gold, Silver, Iron Oxide, Alumina), & Segment Forecasts, 2018 – 2025, 2017



This study provides an overview of the US states and cities that have a higher geographical concentration of pharmaceutical and medicine manufacturing, as well as the states and cities that have manufacturers which individually invest an average of \$10,000 (€9,000) or more in technology annually. In the US, there are 3,630 pharmaceutical and medicine manufacturers. Figure 4 highlights the areas with higher concentrations of pharmaceutical and medicine manufacturers.

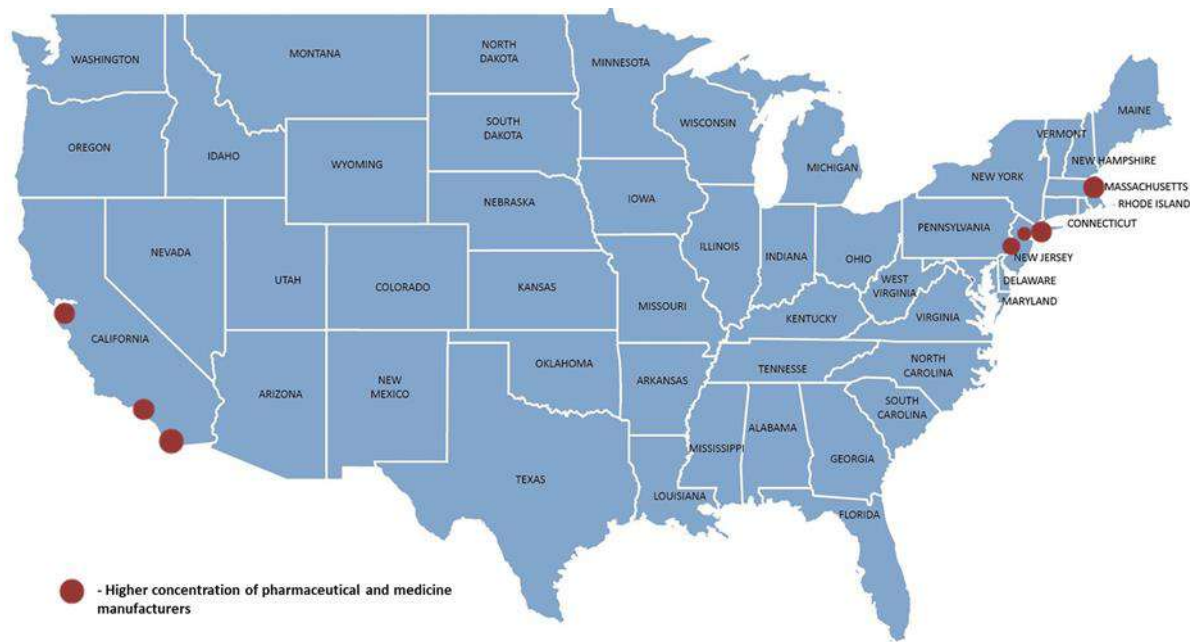


Figure 4 - Location of the US areas with higher concentration of pharmaceutical and medicine manufacturers

Figure 5 shows the US states and cities with the highest concentrations of pharmaceutical and medicine manufacturers. California and New Jersey seem to be the states with the highest geographical concentration of pharmaceutical and medicine manufacturers, with the city of San Diego being the city with the highest concentration of manufacturers at the national level. Moreover, it is relevant to note that both California and Massachusetts have two cities each in the top five cities with the highest concentration of manufacturers at the national level – San Diego, San Francisco, Cambridge and Waltham respectively. Therefore, the states of California and Massachusetts represent important markets for pharmaceutical and medicine manufacturers. In addition, it is relevant to highlight the City of New York, as it is one of the cities with the highest concentration at the national level. In this case, the City of New York might have a high concentration of pharmaceutical and medicine manufacturers due to the fact that it is the area where those companies have their headquarters, e.g. organizations such as Pfizer and Bayer have offices in New York to deal with R&D and administrative aspects.



Figure 5 - US states and cities with the highest concentration of pharmaceutical and medicine manufacturers

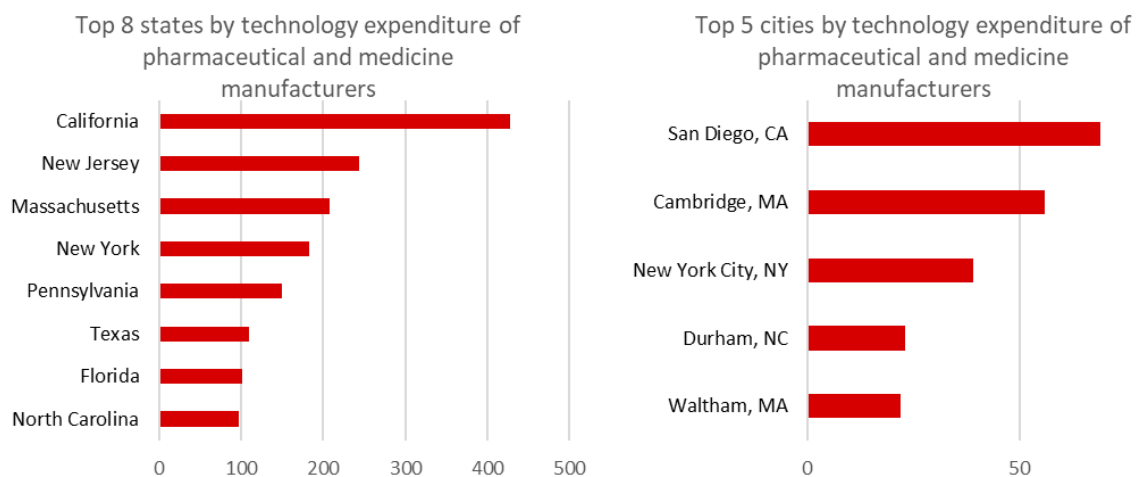


Figure 6 shows the US states and cities with the highest concentration of pharmaceutical and medicine manufacturers that spend on average per manufacturer over \$10,000 (€9,000) in technology per year.

Around one third (33%) of the pharmaceutical and medicine manufacturers spend annually on average between \$10,000 (€9,000) and \$50,000 (€45,000) in technology. Also, around one third (36%) of pharmaceutical and medicine manufacturers spend over \$50,000 per year in technology.

At the national level, the State of California has the highest technology expenditure of pharmaceutical and medicine manufacturers. Thus, the city of San Diego is also the US city with the highest technology expenditure. Moreover, it is relevant to highlight that New Jersey is the second state with the highest technology expenditure in the sector; although it does not have any city represented among the top five cities within the technology expenditure value category.

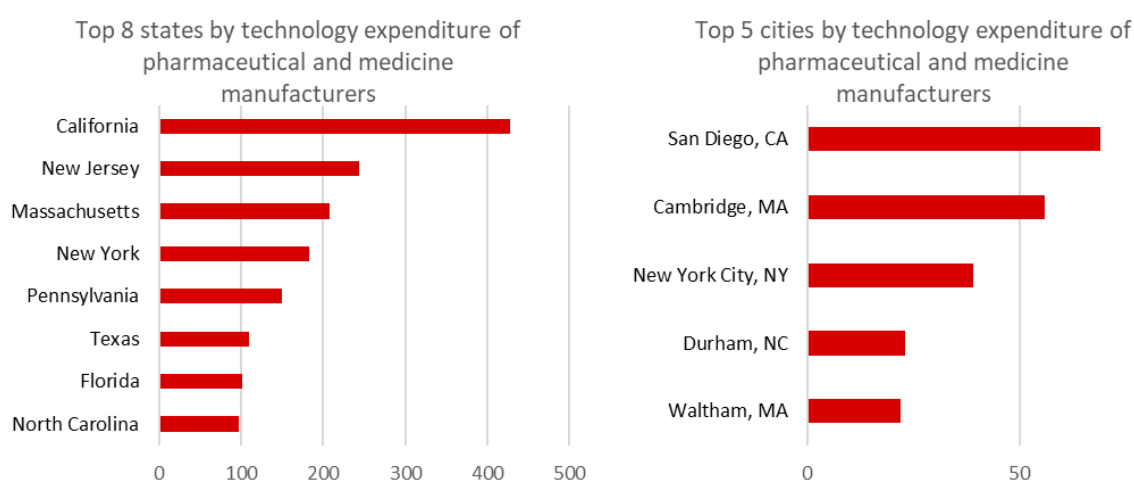


Figure 6 - US states and cities with the highest concentration of pharmaceutical and medicine manufacturers that spend annually on average over \$10,000 in technology

Nanotechnology for electronics & computer products

Nanotechnology applied to electronics and computers products is very much related with electronic computer manufacturing. Therefore, electronics and computer equipment manufacturers correspond to key markets where nanotechnology is applied and innovative products are developed.

This study provides an overview of the US states and cities that have a higher geographical concentration of electronic computer manufacturing, as well as the states and cities that have manufacturers, which individually invest an average of \$10,000 (€9,000) or more in technology annually. In the US, there are 1,912 electronic and computer manufacturers (primary and secondary manufacturers). This includes primary and secondary manufacturers, which means that there might be companies that may not have computer manufacturing as a focus but they are somewhat related

with the area (secondary manufacturers). Figure 7 highlights the areas with higher concentrations of electronic computer manufacturing.

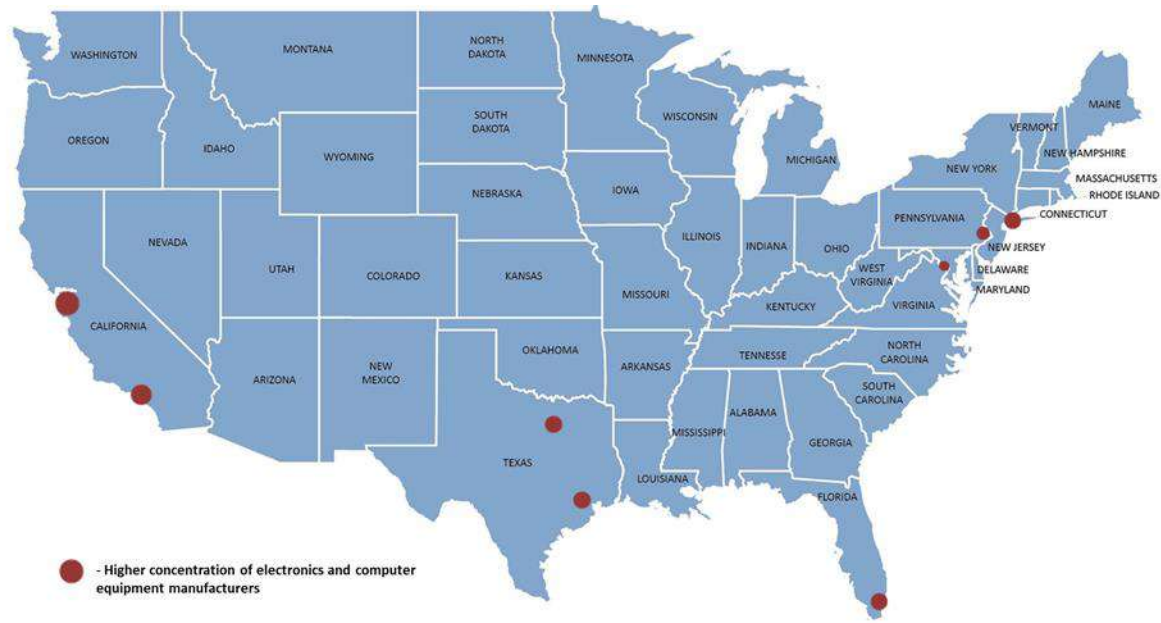


Figure 7 - Location of the US areas with higher concentration of electronics and computer equipment manufacturers

Figure 8 indicates US states and cities with the highest concentration of electronics and computer equipment manufacturers. US electronics and computer equipment manufacturers are primarily located in the high population regions of the country and, therefore, concentrated in the states of California, Florida, New York and Texas. This indicates that these four states are important areas to find market opportunities related to nanotechnology for electronics and computers.

California is the state with the highest concentration of electronics and computer equipment manufacturers, with two cities (Fremont and San Jose) occupying the top two positions. On the contrary, it is relevant to note that although Phoenix is ranked among the top 10 cities in terms of geographical concentration, its state (Arizona) is not among the US states with the highest concentrations of electronics and computer equipment manufacturers.

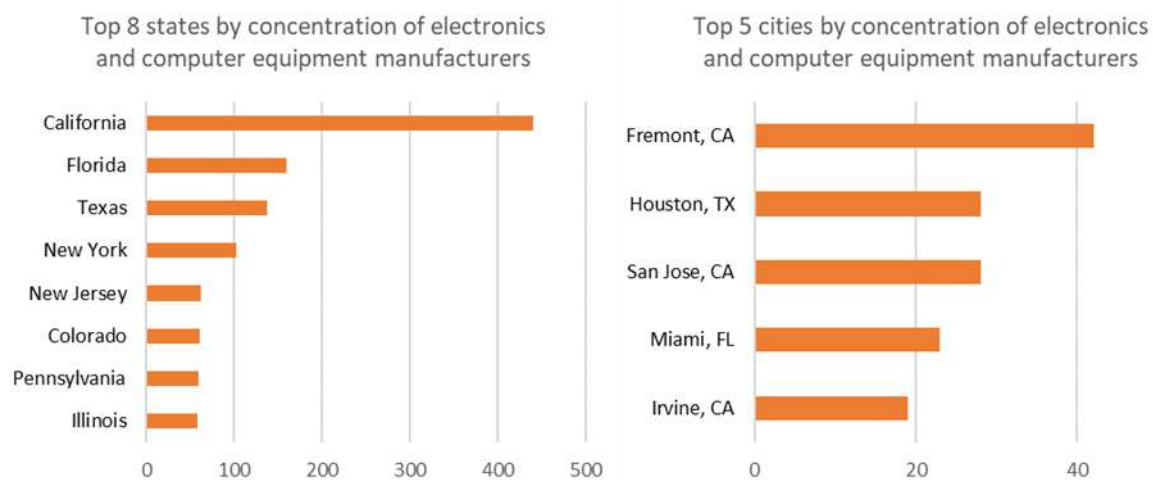


Figure 8 - US states and cities with the highest concentration of electronics and computer equipment manufacturers

The technology expenditure of electronics and computer equipment manufacturers is a key indicator in terms of measuring the advancements in new solutions that perceive the utilization of nanotechnology. Thus, it allows to measure the predisposition of the market to invest in nano-enabled electronic products, such as computers. From a market perspective, the states and cities with the highest concentration of electronics and computer equipment manufacturers that spend on average per manufacturer over \$10,000 (€9,000) in technology per year represent important areas in terms of business opportunities.

Within this context, Figure 9 shows the US states and cities with the highest concentration of electronic and computer equipment manufacturers that spend on average per manufacturer over \$10,000 (€9,000) in technology per year. Around one third (34%) of the electronic and computer equipment manufacturers spend annually on average between \$10,000 (€9,000) and \$50,000 (€45,000) in technology. On the other hand, around one quarter (22%) electronic and computer equipment spend over \$50,000 per year in technology. From these, 93 of the electronic and computer equipment manufacturers that spend over \$50,000 in technology per year are located in California, while 35 are located in Texas. The other 287 are located across the country.

California is the state with the highest technology expenditure of electronic and computer equipment manufacturers. Moreover, three cities located in California (Fremont, San Jose and Irvine) are the top three cities with the highest technology expenditures. On the other hand, although the state of Arizona

is not among the top eight states, Phoenix is among the top 10 cities with the highest technology expenditure of electronic and computer equipment manufacturers.

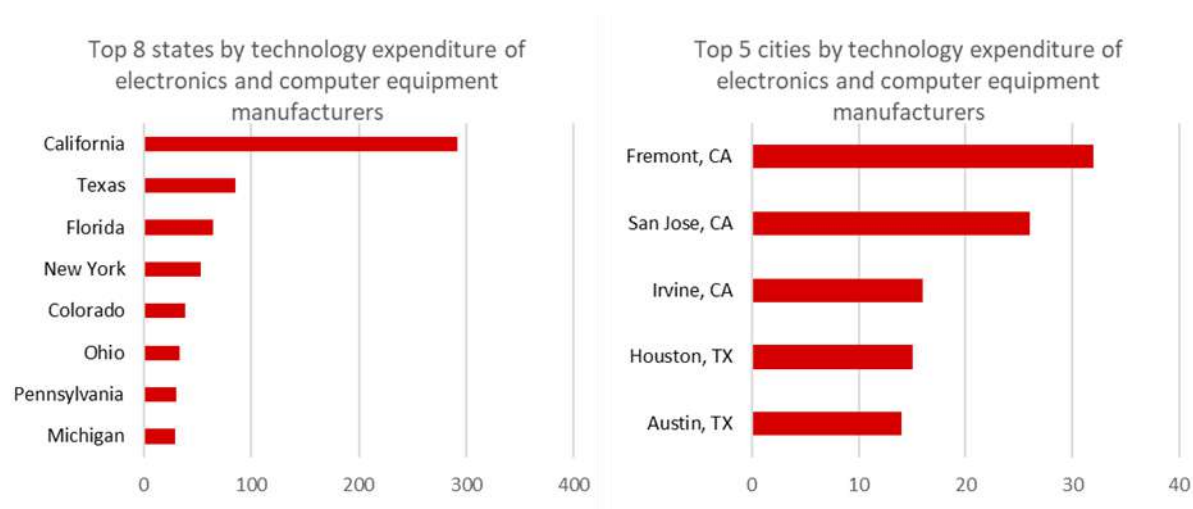


Figure 9 - US states and cities with the highest concentration of electronics and computer equipment manufacturers that spend annually on average over \$10,000 in technology

Nanotechnology for energy products (batteries)

Nanotechnology applications for batteries allow new energy efficiency and renewable energy solutions in different industries and branches. Among the distinct set of solutions, the application of nanotechnology in energy storage systems, namely for storage batteries, has been one of the main focuses. From a market perspective, the US states and cities with the highest geographical concentrations of storage batteries' manufacturers may represent the areas with more nanotechnology applications for energy-related market opportunities across the country.

Within this context, this document provides an overview of the US states and cities that have a higher geographical concentration of storage batteries manufacturing, as well as the states and cities that have manufacturers, which individually invest an average of \$10,000 (€9,000) or more in technology annually. In the US, there are 727 storage batteries manufacturers. Figure 10 highlights the areas with higher concentrations of storage batteries manufacturers.

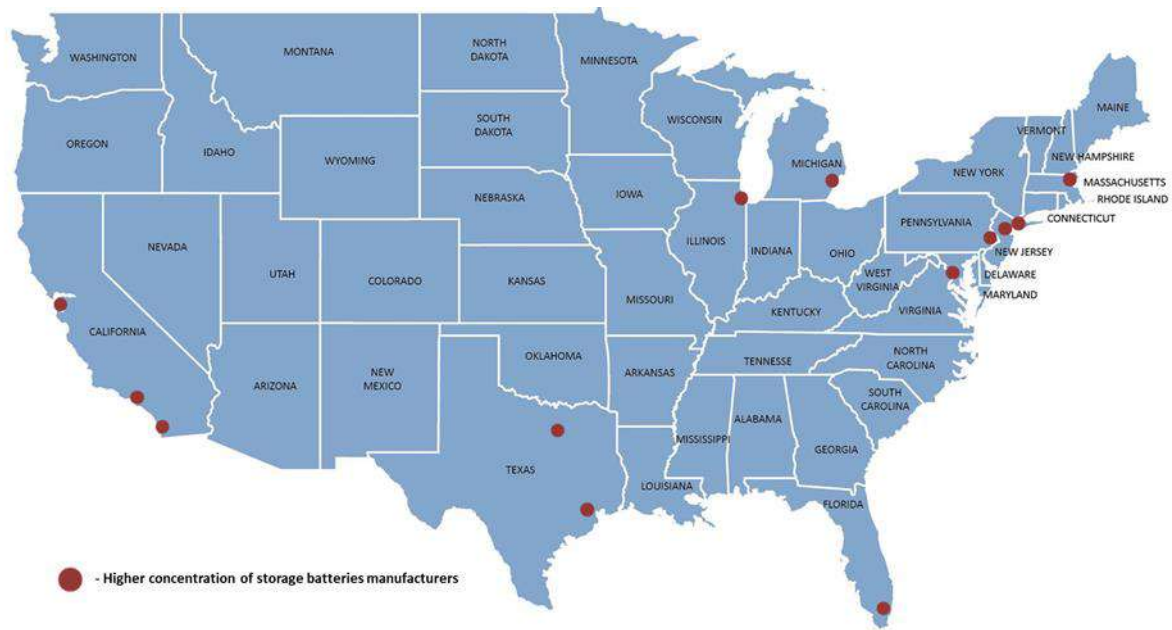


Figure 10 - Location of the US areas with higher of concentration of storage batteries manufacturers

Figure 11 indicates US states and cities with the highest concentrations of storage batteries manufacturers. Illinois and Texas seem to be the states with the highest geographical concentration of storage battery providers, with the cities of Chicago and Houston being the top two cities in terms of concentration of storage battery manufacturers. Therefore, the states of Illinois and Texas represent an important market for storage battery manufacturers. Moreover, it is relevant to highlight the city of Milwaukee, which has one of the highest concentration of storage battery manufacturers, showing its importance to the market. However, the state of Wisconsin is not ranked within the top ten states in terms of geographical concentration.

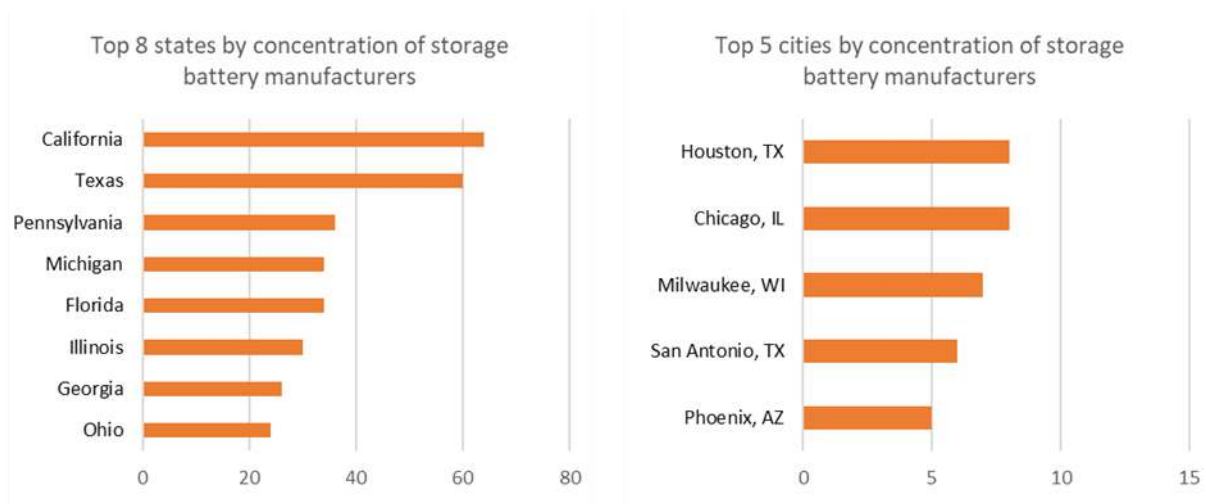


Figure 11 - US states and cities with the highest concentration of storage batteries manufacturers

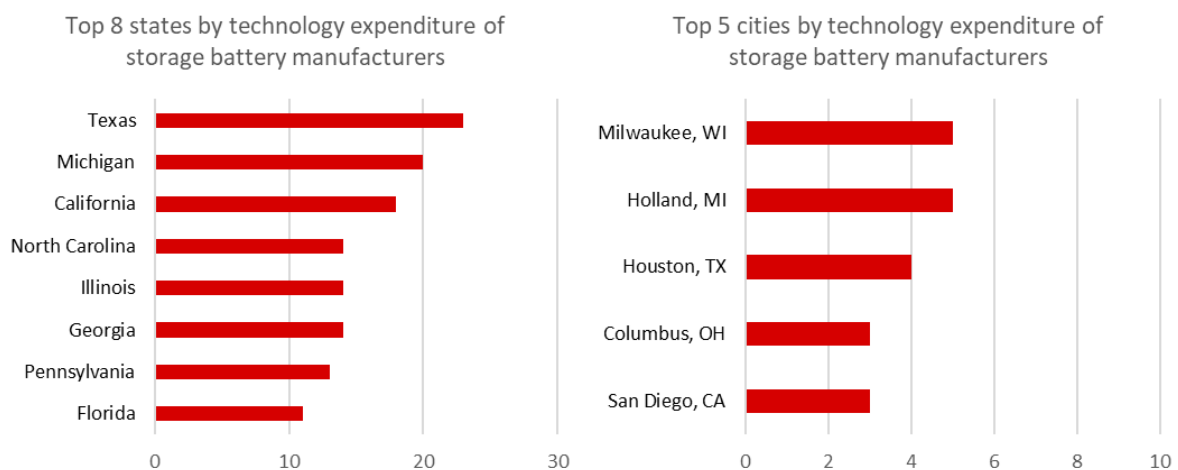


Figure 12 shows the US states and cities with the highest concentration of storage battery manufacturers that spend on average per manufacturer over \$10,000 (€9,000) in technology per year. Around one third (29%) of the storage battery manufacturers spend annually on average between \$10,000 (€9,000) and \$50,000 (€45,000) in technology. On the other hand, only around 11% of storage battery manufacturers spend over \$50,000 per year in technology.

Texas is the state with the highest technology expenditure of storage battery manufacturers. However, the top two cities with the highest technology expenditure are not located within the state of Texas. Moreover, it is relevant to note that Wisconsin is not among the top states in terms of technology expenditure, although the city of Milwaukee is within the top five cities with the highest technology expenditure. It is also relevant to highlight the considerably lower number of US businesses in the battery manufacturing sector when compared with the area of electronics and computers products.

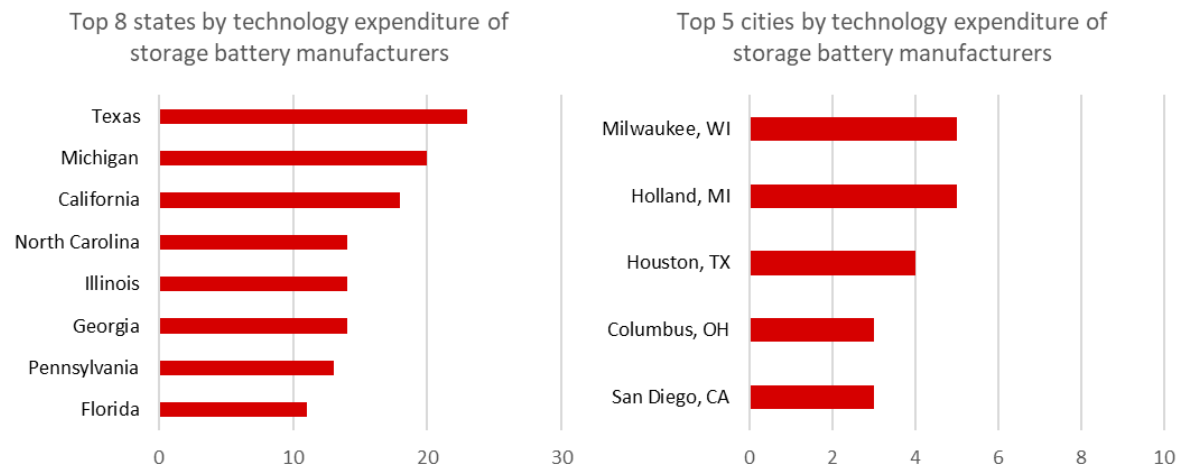


Figure 12 - US states and cities with the highest concentration of storage batteries manufacturers that spend annually on average over \$10,000 in technology

Nanotechnology for painting and coating

Nanotechnology applications for developing paintings and coatings in the automotive sector has been a focus of many manufacturers¹³³. From a market perspective, the US states and cities with the highest geographical concentrations of painting and coating manufacturers may represent the areas with more nanotechnology applications for automotive market opportunities across the country.

This study provides an overview of the US states and cities that have a higher geographical concentration of painting and coating manufacturers, as well as the states and cities that have manufacturers which individually invest an average of \$10,000 (€9,000) or more in technology annually. In the US, there are 3,000 paint and coating manufacturers. Figure 13 highlights the areas with higher concentrations of paint and coating manufacturers.

¹³³ <https://www.azonano.com/article.aspx?ArticleID=3031>

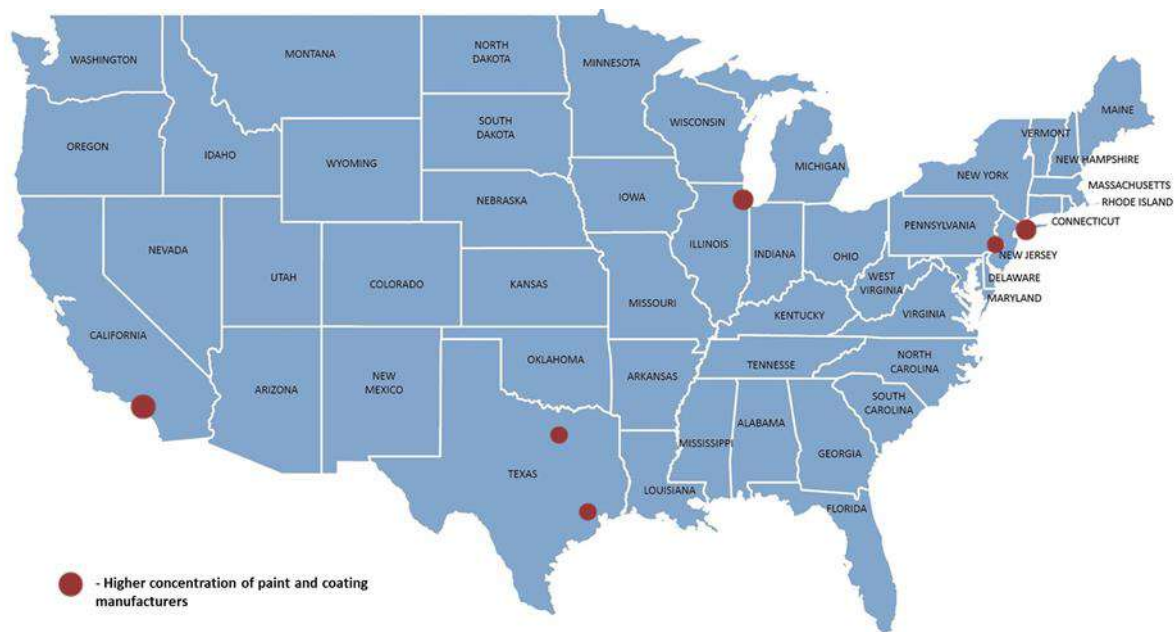


Figure 13 - Location of the US areas with higher of concentration of paint and coating manufacturers

Figure 14 indicates US states and cities with the highest concentrations of paint and coating manufacturers. US paint and coating manufacturers are primarily located in the high population regions of the country and, therefore, concentrated in the states of California, Florida and Texas. This indicates that these three states are important areas to find market opportunities related to nanotechnology for paint and coating. California seems to be the state with the highest geographical concentration of paint and coating manufacturers. However, in terms of city concentration, Houston is the city which includes the highest number of US businesses in the paint and coating manufacturing sector. Therefore, the state of Texas represents an important market for paint and coating providers. Moreover, it is relevant to note that although Missouri is not within the top states in terms of business concentration, it currently includes two cities (Kansas City and St. Louis) in the city ranking, showing the strong focus of these cities in the paint and coating sector.

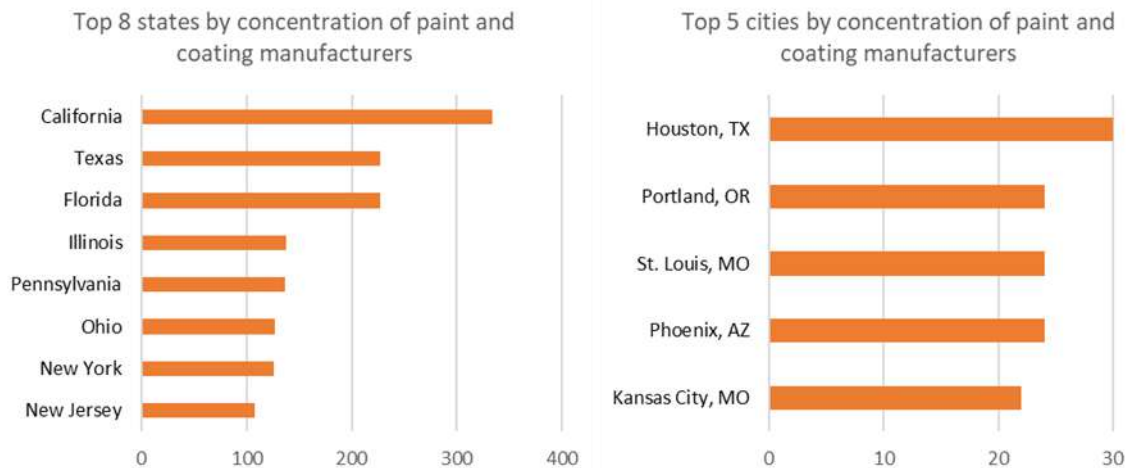


Figure 14 - US states and cities with the highest concentration of paint and coating manufacturers

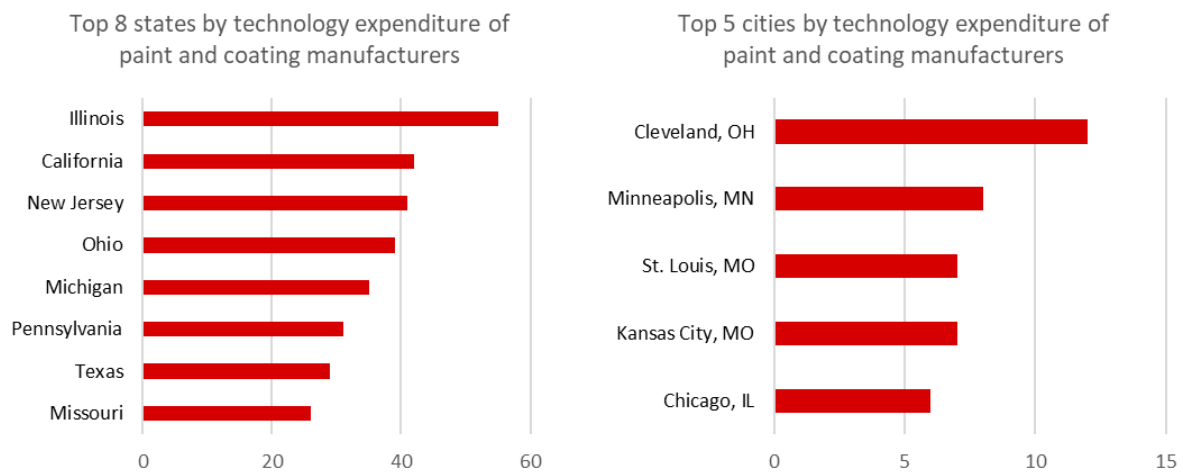


Figure 15 shows the US states and cities with the highest concentration of paint and coating manufacturers that spend on average per manufacturer over \$10,000 (€9,000) in technology per year. Around 15% of the paint and coating manufacturers spend annually on average between \$10,000 (€9,000) and \$50,000 (€45,000) in technology. On the other hand, around 5% of paint and coating manufacturers spend over \$50,000 per year in technology.

Illinois is the state with the highest technology expenditure of paint and coating manufacturers. However, the top four cities with the highest technology expenditure are not located within the state of Illinois. Chicago holds the fifth position in terms of highest technology expenditure. Moreover, it is relevant to note that Missouri is not among the top five states in terms of technology expenditure, although the cities of Kansas City and St. Louis are both within the top five cities with the highest technology expenditure.

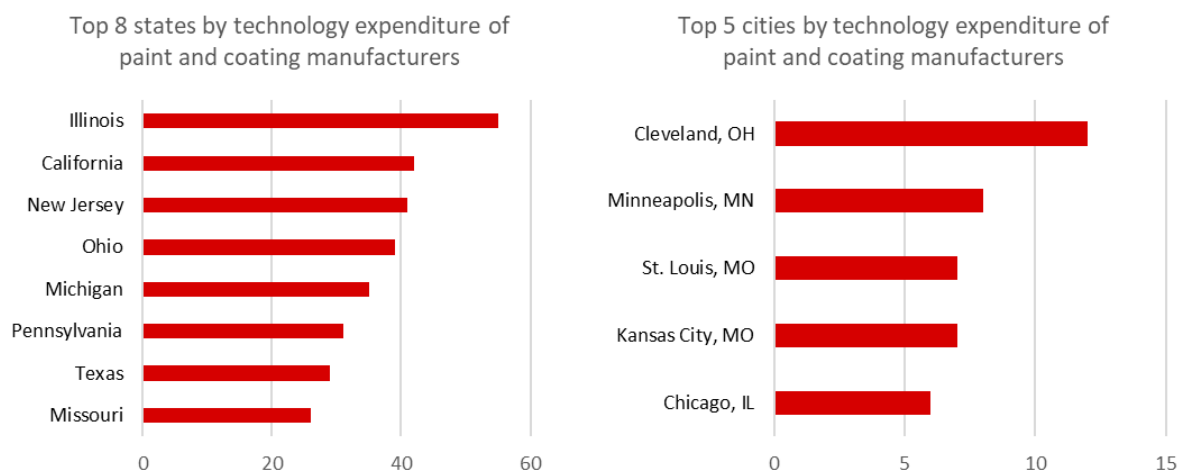


Figure 15 - US states and cities with the highest concentration of paint and coating manufacturers that spend annually on average over \$10,000 in technology

Nanotechnology for aerospace manufacturing

Nanotechnology applications for the aerospace industry focuses on the creation of new products that are able to reduce costs and increase safety and comfort. Thus, nanotechnology solutions have been applied to the aerospace industry, improving properties that improve the mechanical and electrical performance or that can deliver additional functionalities¹³⁴. From a market perspective, the US states and cities with the highest geographical concentrations of aerospace product and parts manufacturing may represent the areas with more nanotechnology applications for aerospace market opportunities across the country.

This study provides an overview of the US states and cities that have a higher geographical concentration of aerospace engine, engine and auxiliary parts manufacturers, as well as the states and cities that have manufacturers which individually invest an average of \$10,000 (€9,000) or more in technology annually. In the US, there are 1,983 aerospace products and parts manufacturers. Figure 16 highlights the areas with higher concentrations of manufacturers.

¹³⁴ <https://www.businesswire.com/news/home/20170118005690/en/Global-Market-Nanotechnology-Aerospace-2017---Research>



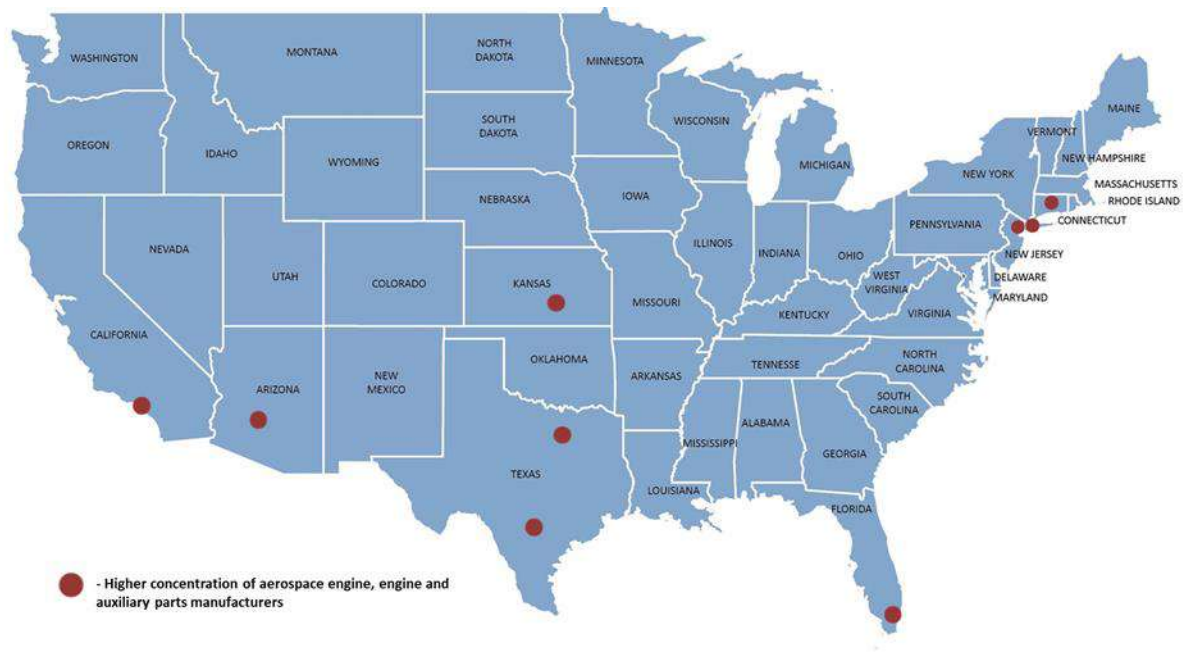


Figure 16 - Location of the US areas with higher of concentration of aerospace engine, engine and auxiliary parts manufacturers

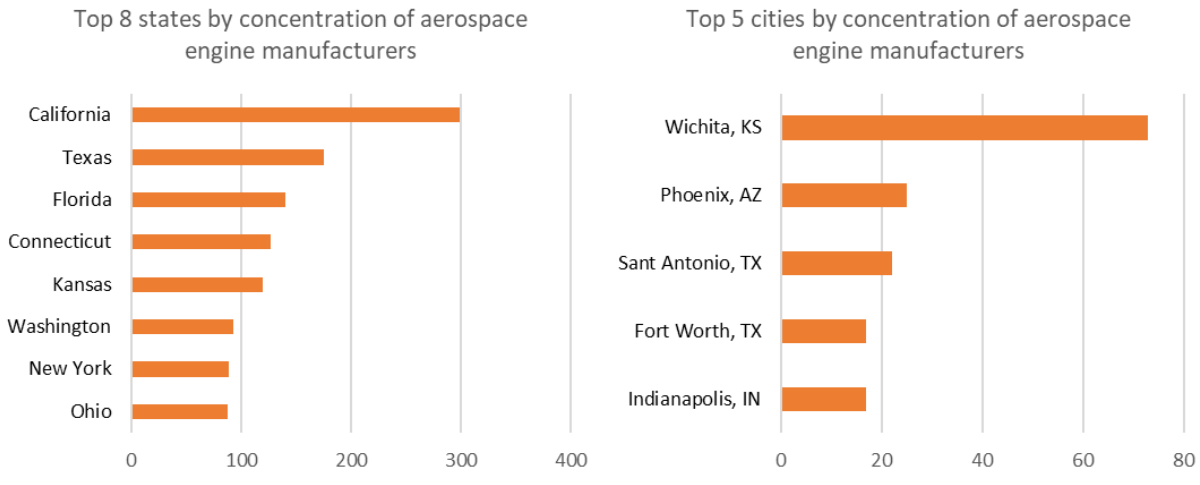


Figure 17 indicates US states and cities with the highest concentrations of aerospace engine, engine and auxiliary parts manufacturers. US aerospace manufacturers are primarily located in the high population regions of the country and, therefore, concentrated in the states of California, Texas and Florida. This indicates that these three states are important areas to find market opportunities related to nanotechnology for aerospace solutions. California seems to be the state with the highest geographical concentration of aerospace engine, engine and auxiliary parts manufacturers. However, in terms of city concentration, Wichita is the city which includes the highest number of US businesses



in the aerospace engine, engine and auxiliary parts sector. Therefore, the state of Kansas represents an important market for aerospace engine, engine and auxiliary parts providers. Moreover, it is relevant to note that although Arizona is not within the top states in terms of business concentration, the city of Phoenix is in the second position in terms of city ranking, showing its strong focus in the aerospace engine, engine and auxiliary parts sector.

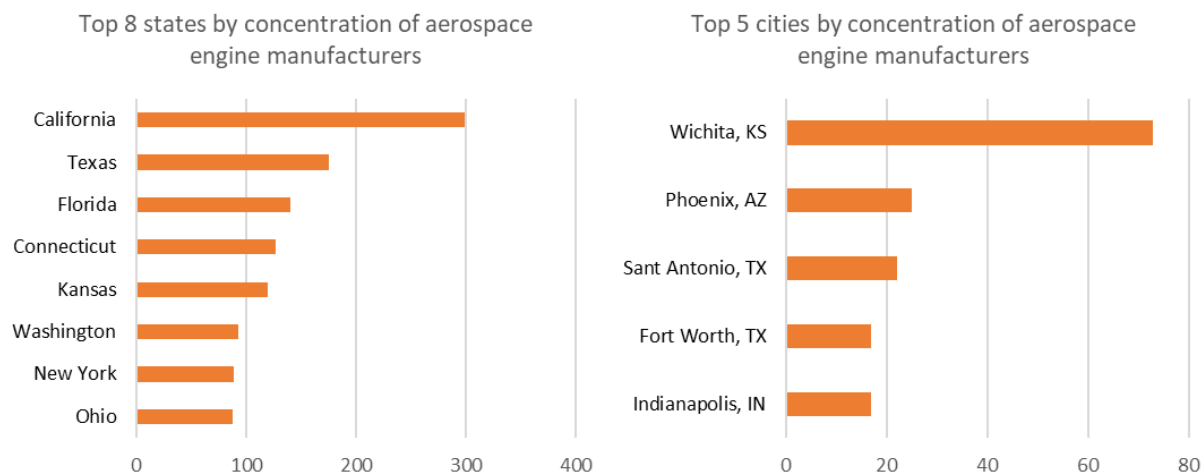


Figure 17 - US states and cities with the highest concentration of aerospace engine, engine and auxiliary parts manufacturers

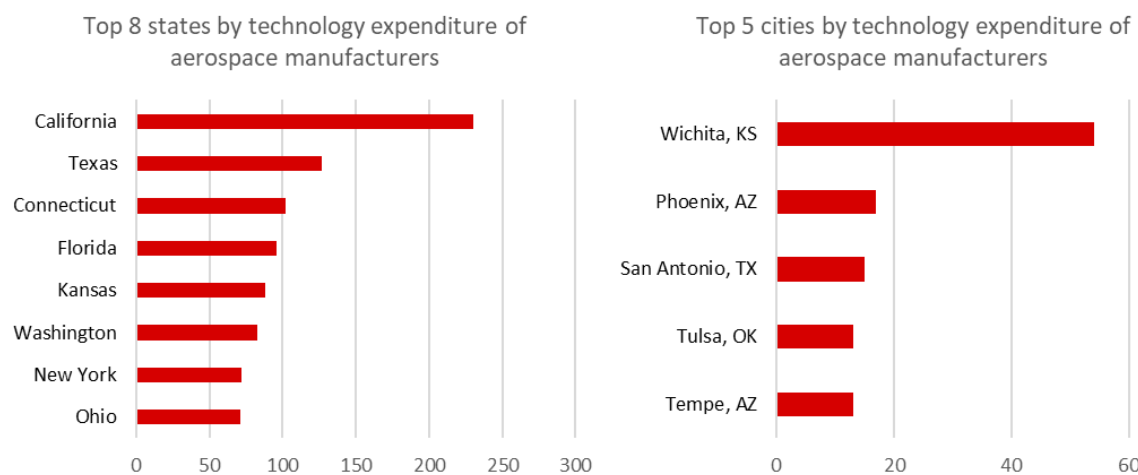


Figure 18 shows the US states and cities with the highest concentration of aerospace engine, engine and auxiliary parts manufacturers that spend on average per manufacturer over \$10,000 (€9,000) in technology per year. Around one quarter (25%) of the aerospace engine, engine and auxiliary parts manufacturers spend annually on average between \$10,000 (€9,000) and \$50,000 (€45,000) in technology. On the other hand, around 51% of aerospace engine, engine and auxiliary parts



manufacturers spend over \$50,000 per year in technology. Thus, it is important to highlight the high share (more than half) of US businesses in the aerospace engine, engine and auxiliary parts manufacturing that spend more than \$50,000 per year in technology, showing a high concentration of innovation actions in the sector.

California is the state with the highest technology expenditure of aerospace engine, engine and auxiliary parts manufacturers. However, the top ten cities with the highest technology expenditure are not located within California. Wichita holds the first position in terms of highest technology expenditure, followed by Phoenix and San Antonio. Moreover, it is relevant to note that Arizona is not among the top five states in terms of technology expenditure, although the cities of Phoenix and Tempe are both within the top five cities with the highest technology expenditure.

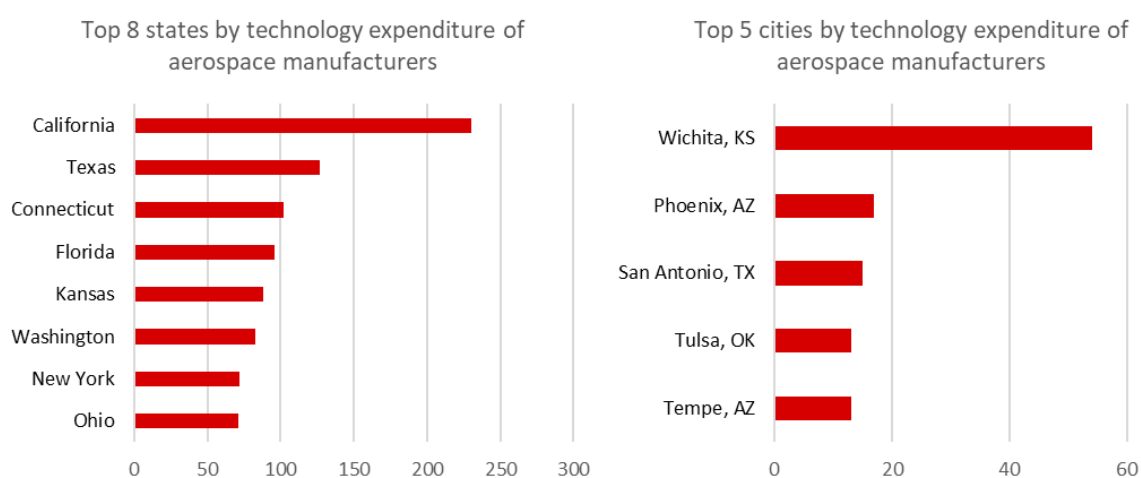


Figure 18 - US states and cities with the highest concentration of aerospace engine, engine and auxiliary parts manufacturers that spend annually on average over \$10,000 in technology

3.3. Market considerations

3.3.1. Opportunities

Large and growing market

As previously stated, the US is the world leading market in nanotechnology. Over the last decade, the US has been the country with the highest investment at the global level¹³⁵. Moreover, there has been a large focus on both the commercial and the research and product development sides¹³⁶. Thus, and taking into account the budget allocated to NNI, it is expected this trend will be kept throughout the next years. The interdisciplinary aspect of nanotechnology, its broad impact and innovative solutions that bring to products and applications (e.g. nanomedicine, computers, batteries, among others) can explain the rapid growth of the industry.

New applications and nanotechnology “mainstreaming”

The impact of nanotechnology at the market level can be seen in several user-products and new applications (e.g. coatings, anti-bacterial clothing, cosmetics, and food products)¹³⁷. Moreover, it has influenced future technologies and solutions at the research and commercial levels. Thus, it is expected that new applications arise through further R&D investment in nanotechnology and that the current innovations are scaled to more products and services at the global level. Taking into account the continued federal investment at the US level through the NNI, it is expected that new discoveries and applications are achieved in order to maintain the US as the forefront market for nanotechnology research and innovation¹³⁸.

Opportunities at several stages of the value chain

As previously described, the application of nanotechnology is done at an interdisciplinary basis, being applied in several sectors and stages of the value chain. Thus, this interdisciplinary aspect of nanotechnology provides an opportunity for a large range of companies and businesses that are able to include nanotechnology solutions into their product development processes. Particularly in the US, the corporate spending for nanotechnology R&D was the highest at the global level and covering a different set of applications¹³⁹. Thus, opportunities at several levels of the value chain should be explored within the US market, where the investment in different areas is higher than in other regions at the global level.

¹³⁵ <http://www.oecd.org/sti/biotech/nanotechnology-indicators.htm>

¹³⁶ Working Texas Style, Chapter 12: Nanotechnology

¹³⁷ <https://www.ceramicindustry.com/articles/94506-nano-devices-segment-of-global-nanotechnology-market-expected-to-see-significant-growth>

¹³⁸ The National Nanotechnology Initiative - Supplement to the President's 2018 Budget, NNI, 2017

¹³⁹ Economic Research Working Paper No. 29 – Economic growth and breakthrough innovations: A case study of nanotechnology, WIPO, Lisa Larrimore Ouellette, 2015



3.3.2. Barriers

Nanotechnology development costs

The nanotechnology industry represents a relatively new market for both consumers and producers. Thus, development costs related with products and processes that are enabled by nanotechnology solutions might require relatively high investments to SMEs and start-ups¹⁴⁰. Taking this into account, the commercialization of nanotechnology products might require large investments and funding from start-ups and SMEs.

Regulatory requirements

Nano-enabled products or services may contain different attributes than those of the conventionally-manufactured products. Consequently, several regulatory actions have been taken by US agencies and entities in order to regulate nanotechnology applications. Currently, the main authorities involved in regulating nano-enabled products are the US Environmental Protection Agency (EPA) and US Food and Drug Administration (FDA)¹⁴¹. For example, the US Environmental Protection Agency has a Significant New Use Rule (SNUR) which states that nanoscale materials have a proper regulatory review, including stakeholders who will manufacture, import or process nanoscale materials¹⁴². On the other hand, the FDA has been implementing several actions that support innovation and safe use of nanotechnology in FDA-regulated products¹⁴³. Taking this into account, the manufacturing and processing of nanoscale materials need to be compliant with the regulatory requirements from the different agencies, depending on the specific sector (e.g. food, energy, health, etc.). Thus, the potential restrictions due to regulatory requirements might be seen as a barrier when entering the US nanotechnology market.

4 Recognized networks and events

Networks and events are crucial to enhance the connection between researchers and between academia and industry at both national and international levels. They provide a great opportunity for

¹⁴⁰ <https://globenewswire.com/news-release/2017/01/19/909415/0/en/Nanotechnology-Market-to-Cross-USD-12-Billion-in-Revenue-by-2021-as-Commercialization-of-Technologies-Across-Industry-Verticals-Increases-IndustryARC-Analysis.html>

¹⁴¹ http://www.chemsafetypro.com/Topics/USA/Regulations_of_Nanomaterials_in_USA.html

¹⁴² <https://www.dummies.com/education/science/nanotechnology/organizations-involved-in-nanotechnology-regulation/>

¹⁴³ <https://www.fda.gov/scienceresearch/specialtopics/nanotechnology/ucm301114.htm>



researchers and industry representatives from nanotechnology related fields to share knowledge and experience.

Networks and events are often used as sources of information and knowledge towards a specific area or sector. Thus, as nanotechnology advancements are a constant and rapidly changing and it is considered to have a broad and fundamental impact on every sector¹⁴⁴, EU researchers and industry representatives are particularly recommended to contact the key US nanotechnology related networks and attend events located in the US.

The knowledge gained through relevant networks and events provides support on deciding the most effective approach to establish contacts with the US community to develop innovation and industry collaborative opportunities.

4.1. Innovation and market networks/associations

The concept of innovation/market networks has been developed by considering innovation as a collaborative phenomenon¹⁴⁵. Innovation/market networks are collaborative platforms composed of individuals, small and large corporations, startups, academic and government institutions that aim to create new ideas, products, services or business models¹⁴⁶. Within this context, innovation/market networks can promote linkages between different types of organizations related with nanotechnology, in order to promote new applications to the market¹⁴⁷.

Moreover, innovation/market networks can support the development of innovation in SMEs and startups, promoting flexibility, lowering the expenditures from single expenses for innovation purposes and offering more opportunities for collaborative innovation processes. Thus, innovation/market networks can help SMEs and startups to reach innovation targets, access to complementary resources, attract investment and advance technologies^{148,149}.

On the other hand, a professional association is a body of individuals engaged in the same profession, formed usually to control entry into the profession, maintain standards, and represent the profession

¹⁴⁴ Global Nanotechnology Market 2018-2024: Technological Advancements in Nanotechnology & Increased Government Support and R&D Spending, RNCOS E-Services Private Limited, 2018

¹⁴⁵ <http://www.emeraldinsight.com/doi/full/10.1108/JBIM-03-2015-0042>

¹⁴⁶ <http://www.helixinnovation.com/what-is-an-innovation-network/>

¹⁴⁷ <http://www.emeraldinsight.com/doi/full/10.1108/JBIM-03-2015-0042>

¹⁴⁸ <http://www.innosupport.net/index.php?id=2331>

¹⁴⁹ <http://www.innosupport.net/index.php?id=2331>



in discussions with other bodies^{150,151}. Professional associations are a crucial segment of the US Industry. In 2013, membership organizations alone employed over 1.3 million people in the US¹⁵².

Table 3 provides a brief description of some of the main research networks/professional associations in the nanotechnology related applications.

¹⁵⁰<https://www.vocabulary.com/dictionary/professional%20association>

¹⁵¹<http://www.dictionary.com/browse/professional-association>

¹⁵²<http://www.thepowerofa.org/wp-content/uploads/2012/03/PowerofAssociations-2015.pdf>



Table 3 – Examples of key US nanotechnology related networks and associations

Network	Main goal	Internet link
<u>International networks and associations</u>		
International Association of Nanotechnology (IANT)	The International Association of Nanotechnology (IANT), is a non-profit organization with the goal to foster scientific research and business development in the areas of Nanoscience and Nanotechnology for the benefit of society.	http://www.ianano.org/aboutus.htm
IEEE Nanotechnology Council	IEEE Nanotechnology Council aims to support the theory, design and development of nanotechnology and its scientific, engineering and industrial applications. The Council is responsible for sponsoring recognized international conferences and relevant publications.	http://sites.ieee.org/nanotech/
<u>Federal networks and associations</u>		
National Nanomanufacturing Network (NNN)	The National Nanomanufacturing Network (NNN) is an alliance of academic, government and industry partners which aim to cooperate in strengthening nanomanufacturing in the US. NNN works as an open network of centers, leaders, experts and stakeholders from the nanomanufacturing community.	http://nnn.internano.org/
National Network for Manufacturing Innovation (NNMI)	The National Network for Manufacturing Innovation (NNMI) is an US initiative in advanced manufacturing. NNMI is composed of public-private partnerships focused on manufacturing. The main aim is to bring together innovative manufacturers, university engineering schools, community colleges, federal agencies, non-profits, and regional and state organizations to invest in manufacturing technologies with broad applications, namely nanotechnology.	https://www.manufacturing.gov/
Nano Science and Technology Institute (NSTI)	The Nano Science and Technology Institute (NSTI) advances and integrates nanotechnologies through training, conventions, publishing and research services. NSTI produces the annual Nanotech conference and expo, being the largest gathering of the nanotechnology industry in the US. NSTI was founded in 1997	https://www.nsti.org/

Network	Main goal	Internet link
	as a merge between different scientific societies. It is currently headquartered in Austin, Texas and it has offices in Cambridge, Massachusetts, and Danville, California.	
National Nanotechnology Coordinated Infrastructure (NNCI)	The National Nanotechnology Coordinated Infrastructure (NNCI) was established in 2015 as the latest version of an initiative from the NSF to provide nanotechnology resources to researchers in the US.	https://www.nci.net/
The American Precision Optics Manufacturers Association (APOMA)	The American Precision Optics Manufacturers Association (APOMA) aims to promote new opportunities for the precision optics industry. APOMA represents different manufacturers within the industry, as well as with academic associates.	http://www.apoma.org/
<u>State networks and associations</u>		
North Carolina Research Triangle Nanotechnology Network (RTNN)	The North Carolina Research Triangle Nanotechnology Network (RTNN) is an innovation hub focused on transformative nanotechnology research, education and commercialization. The RTNN offers access to its nanotechnology facilities within the research triangle area for researchers across the US.	https://www.rtnn.ncsu.edu/
NCN@Illinois - Network for	The Network for Computational Nanotechnology (NCN) at the University of Illinois is based at Purdue University. The project aims to connect theory, experiments and computation to support innovation in nanotechnology solutions.	http://ncn.illinois.edu/



Network	Main goal	Internet link
Computational Nanotechnology		
Lehigh Emerging Technologies Network (LETN)	The Lehigh Emerging Technologies Network (LETN) is composed by a diverse group of businesses, education actors, government and economic development and services members. The main aim is to discover new applications of technology, develop research and educational activities, promoting the commercialization of new materials' technologies.	https://www.lehigh.edu/letn/
Rhode Island Consortium for Nanoscience and Nanotechnology	Rhode Island Consortium for Nanoscience and Nanotechnology was established in 2010 as a joint entity between the University of Rhode Island and Brown University. The consortium aims to develop the state of Rhode Island's competitiveness in nanoscience and nanotechnology, promoting industry-university cooperation. Its main focus areas are nanomaterials, nanohealth, nanotools and nanoenergy.	https://web.uri.edu/nano/



4.2. Innovation and market events

Conferences and other networking events provide an important platform where nanotechnology innovators and researchers can present and discuss high-quality research and technology advances. Nanotechnology conferences are also an excellent opportunity to foster collaboration between researchers, professionals and industry members, share knowledge and discuss the development and deployment of technologies.

Due to the importance of nanotechnology, there are several conferences and other networking events focused on this field in the US. The conferences and other networking events identified show an emphasis on the healthcare area, with several events focusing on this topic. Moreover, it can be concluded that most of nanotechnology-related conferences and other networking events are not specified in a particular area or topic, but more on the nanotechnology industry as a whole. In terms of timeline distribution, the conferences and events focused on nanotechnology seem very well distributed throughout the year.

Regarding the geographical distribution of the US nanotechnology related conferences and other networking events, there is a high degree of concentration in the northeast region, more particularly in New York and Massachusetts, as well as in the state of California.

Table 4 – Nanotechnology related innovation and market events

Date	Conference/ Event title	Interval	Location	Areas	Internet link
21-24 August 2018	ASME: NanoEngineering for Medicine and Biology Conference	-	Los Angeles, California	Healthcare, Energy	https://www.asme.org/events/nemb
11-12 October 2018	2018 U.S.-EU Workshop	Annual	Washington DC	Healthcare, Electronics, Energy	https://us-eu.org/2018-u-s-eu-workshop/
29 October - 1 November 2018	NANOSMAT USA	Annual	South Padre Island, Texas	Not specified	http://www.nanosmat-usa.com/
22-24 April 2019	NANO Boston Conference	From two to two years	Boston, Massachusetts	Healthcare, Energy	http://nanoworldconference.com/
05-06 October 2018	20 th World Summit on Nanotechnology and expo	-	Los Angeles, California	Healthcare, Electronics, Energy, Automotive, Aerospace	https://nanotechnologyexpo.conferenceseries.com/
05-07 December 2018	2018 “End2cancer: Emerging Nanotechnology and Drug Delivery Applications for Cancer” Conference	-	Oklahoma City, Oklahoma	Healthcare	http://end2cancer.com/

Date	Conference/ Event title	Interval	Location	Areas	Internet link
01-05 December 2018	IEEE International Electron Devices Meeting (IEDM)	Annual	San Francisco, California	Automotive, Electronics, Energy, Aerospace	https://ieee-iedm.org/
15-17 October 2018	13TH IEEE Nano Materials & Devices Conference (NMDC 2018)	Annual	Portland, Oregon	Healthcare, Electronics, Energy, Automotive, Aerospace	http://www.ieeenmdc.org/2018/
19-23 August 2018	ACS National Meeting & Expo: Nanoscience, Nanotechnology & Beyond	Bi-Annual	Boston, Massachusetts	Not specified	https://www.acs.org/content/acs/en/meetings/national-meeting.html?sc=meetings_170416_mtg_BO18_od
19-23 August 2018	PIE Nanoscience + Engineering 2018	-	San Diego, California	Healthcare, Electronics, Energy	http://spie.org/conferences-and-exhibitions/optics-and-photonics/nanoscience-and-engineering?SSO=1
4-6 January 2019	7 th International Conference on Nano and Materials Science (ICNMS 2019)	Annual	San Francisco, California	Not specified	http://www.icnms.org/



Date	Conference/ Event title	Interval	Location	Areas	Internet link
20-21 March 2019	Pharmaceutical Nanotechnology and Nanomedicine	Annual	New York City, New York	Healthcare	https://nanomedicine.pharmaceuticalconferences.com/usa/
16-17 August 2018	ISER-418 th International Conference on Nanoscience, Nanotechnology & Advanced Materials (IC2NAM)	-	Boston, Massachusetts	Not specified	http://iser.co/Conference2018/USA/12/IC2NAM/
02-03 November 2018	2nd International Conference on Nanostructured Materials & Nanotechnology	Annual	San Francisco, California	Not specified	https://nanochemistry.conferenceseries.com/
26 September 2018	Nano Manufacturing 2018 - Conference	Annual	Greensboro, North Carolina	Not specified	http://www.nanomanufacturingconference.org/home.php
08-09 October 2018	20th International Conference on Biotechnology and	-	New York City, New York	Not specified	https://waset.org/conference/2018/10/new-york/ICBN



Date	Conference/ Event title	Interval	Location	Areas	Internet link
	Nanotechnology (ICBN 2018)				
21-22 March 2019	24th Annual Meeting on Nanomaterials Science	Annual	New York City, New York	Not specified	https://nanotech.conferenceseries.com/
06-07 December 2018	American Conference on Materials Research and Technology	-	Las Vegas, Nevada	Not specified	https://pagesconferences.com/materials-research-technology-conference/
23-24 November 2018	NanoTechnology and NanoMaterials Conference 2018	-	Las Vegas, Nevada	Not specified	https://www.meetingsint.com/nanotechnology-conferences/nanomaterials



5 US innovation initiatives and programs

The US governmental funding system is highly decentralized and comprises several actors, such as agencies of federal and state governments, universities, the private sector and non-profit organizations¹⁵³. The US government has identified the importance of nanotechnology for innovation at the multidisciplinary level. Funding nanotechnology related initiatives and programs is currently a priority for both public and private entities, which are focused on fostering the commercialization of nanotechnology.

The NNI is an initiative from the US Government established in 2001 responsible for the development of nanotechnology innovation and R&D. NNI targets the promotion of world-class nanotechnology R&D, fosters technology transfer, develops educational resources and a skilled workforce, and supports the responsible development of nanotechnology. The budget for the Fiscal Year of 2018 for the NNI was of \$1.2 billion (€1.08 billion), allocated among different federal organizations¹⁵⁴. Thus, the initiatives funded within the NNI are considered in the analysis of US innovation initiatives and programs for nanotechnology.

A review of the US funding initiatives and programs at both public and private levels was conducted to identify some examples of relevant innovation initiatives and programs in the nanotechnology related fields. There are several initiatives at the federal level that provide support to nanotechnology innovation. Thus, some of the main programs and agencies at the federal level that focus on nanotechnology are described within this section. It is relevant to highlight that additional public and private initiatives and programs exist, which are not described within this report. The following subsections provide descriptions of the initiatives and programs. Annex 1 provides a summary table of the initiatives and programs detailed in this chapter.

5.1. Public initiatives/programs

In the US, nanotechnology research and innovation development is supported by a set of public initiatives and programs. At the federal level, the US Department of Health and Human Services, the NSF, the US Department of Energy and the US Department of Defense are the entities primarily responsible for initiatives and programs that promote innovation in the nanotechnology related fields¹⁵⁵ (Figure 19).

¹⁵³ <http://www.eusscienceandtechnology.eu/assets/content/documents/InnovationSystemInnovationPolicyUS.pdf>

¹⁵⁴ The National Nanotechnology Initiative - Supplement to the President's 2018 Budget, NNI, 2017

¹⁵⁵ The National Nanotechnology Initiative - Supplement to the President's 2018 Budget, NNI, 2017

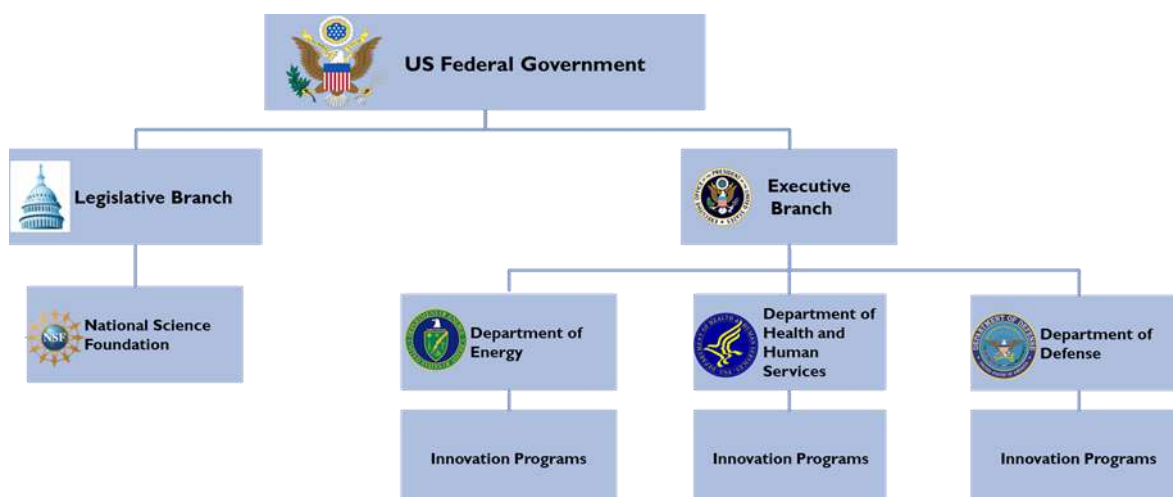


Figure 19 - US Government Organizational Chart highlighting the main sponsors of innovation programs in nanotechnology related fields

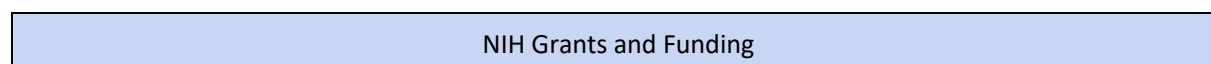
A review of the US Federal Government innovation initiatives and programs was conducted to identify some of the most relevant ones in fields related to nanotechnology. Although this study only provides federal initiatives and programs established by its main sponsors, it is important to highlight that there are several initiatives and programs in fields related to nanotechnology promoted by several other US departments and entities. These include the US Department of Commerce, the US Department of Agriculture and the National Aeronautics and Space Agency¹⁵⁶.

5.1.1. Department of Health and Human Services (HHS)

The US HHS is comprised of several agencies that provide funding for initiatives and programs to promote nanotechnology development. Among those, there are two that can be highlighted: National Institutes of Health (NIH) and Centers for Disease Control and Prevention (CDC).

National Institutes of Health (NIH)

The NIH is the largest public funder of biomedical research in the world, investing more than \$32 billion (€28.8 billion) a year in R&D activities¹⁵⁷.



¹⁵⁶ The National Nanotechnology Initiative - Supplement to the President's 2018 Budget, NNI, 2017

¹⁵⁷ https://grants.nih.gov/grants/about_grants.htm

<p>International Collaboration</p>	<p>In general, foreign institutions and international organizations, including public and private non-profit or for-profit organizations, are eligible to apply for NIH research project grants. Foreign institutions and international organizations are not eligible to apply for Kirschstein-NRSA institutional research training grants, program project grants, center grants, resource grants, SBIR/STTR grants, or construction grants.</p> <p>European researchers could review the Eligibility section of the Funding Opportunity Announcement (FOA) to determine whether their non-US entity is eligible to apply to that particular FOA¹⁵⁸.</p>
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Centers for Disease Control and Prevention (CDC)

The CDC is one of the major initiatives within the HHS. This national initiative aims to conduct and support research intended to support health, safety and security within the community¹⁵⁹. In this context, the CDC provides grants and cooperative agreements to support research and non-research public health programs that are aligned with the CDC’s public health mission both domestically and globally. In 2017, the Office of Grants Services (OGS) supported 4,519 grant awards to 1,345 recipients¹⁶⁰.

National Institute for Occupational Safety and Health (NIOSH) - Nanotechnology Research Center (NTRC): NIOSH is the federal agency focused on worker safety and health. NIOSH is responsible for managing the federal government health and safety initiative for nanotechnology: Nanotechnology Research Center (NTRC), which was established in 2004. NIOSH includes a set of research programs, training and funding through the NIH grants and contracts¹⁶¹.

First Approach	
<p>Information about Funding Opportunities</p>	<p>European researchers interested in the NIOSH funding opportunities could contact the representative identified in the Funding Opportunities Announcements (FOAs).</p>

¹⁵⁸ <https://grants.nih.gov/grants/who-is-eligible.htm>

¹⁵⁹ <https://www.cdc.gov/about/organization/cio.htm>

¹⁶⁰ <https://www.cdc.gov/grants/index.html>

¹⁶¹ <https://www.cdc.gov/niosh/topics/nanotech/>



International Collaboration	The eligibility criteria for NIOSH’s funding opportunities and support can be found in the FOAs listed on Grants.gov . Each opportunity details all eligibility requirements and definitions.
Internet link	https://www.cdc.gov/niosh/oep/funding.html

5.1.2. National Science Foundation (NSF)

The NSF provides support through grants and cooperative agreements to universities, businesses, informal science organizations and other research organizations focused on areas that are most likely to result in considerable technological progress¹⁶². The NSF funds initiatives that aim to advance research that contributes to the scientific community's better understanding. The NSF supports cooperative research between universities and industry, as well as the US researchers’ participation in international scientific and engineering research activities. Collaboration between US researchers and European researchers can be funded in almost all new proposals to NSF or in supplements to existing NSF awards. Thus, European researchers interested in collaborating with US researchers could ask their US counterparts to contact the NSF disciplinary program officer or use the Office of International Science and Engineering (OISE) Regional and Country Contacts to inquire about funding possibilities¹⁶³.

First Approach	
European Union OISE Regional Contact	eeinfo@nsf.gov
International Collaboration	OISE fosters institutional partnerships throughout the global science and engineering research and education community, and it supports international collaborations in NSF's priority research areas. OISE encourages funding applicants to include an international component in proposals submitted to the appropriate research directorate ¹⁶⁴ .
Internet links	www.nsf.gov/od/oise/country-list.jsp ; www.nsf.gov/od/oise/europe/

¹⁶²<https://www.nsf.gov/about/how.jsp>

¹⁶³<https://www.nsf.gov/od/oise/europe/>

¹⁶⁴<https://www.nsf.gov/od/oise/about.jsp>



5.1.3. Department of Energy (DoE)

The DoE aims to guarantee the country’s security and prosperity by addressing its energy, environmental and nuclear challenges through highly innovative science and technology solutions¹⁶⁵. Among the DoE Offices, it is relevant to highlight the following in the field of nanotechnology: Advanced Research Projects Agency-Energy (ARPA-E) and the Office of Energy Efficiency and Renewable Energy (EERE)¹⁶⁶.

Advanced Research Projects Agency-Energy (ARPA-E)

The ARPA-E aims to promote the advancement of high-potential and high-impact energy technologies, which are in a stage that is too early for private investment. The ARPA-E is focused on supporting projects that promote prosperity, national security, and environmental well-being¹⁶⁷. In this context, the ARPA-E funds technology-focused and applied R&D projects that can generate real and concrete solutions to important problems in energy creation, distribution, and use. Thus, the ARPA-E promotes periodic FOAs dedicated to solving specific technical barriers of a specific energy area. The ARPA-E also issues periodic OPEN FOAs to identify high-potential projects that address a wide range of energy-related technologies, including a focus on nanotechnology-related areas and applications^{168,169}.

First Approach	
Information about Funding Opportunities	European researchers interested in ARPA-E’s funding opportunities could contact the representative identified in the FOAs.
International Collaboration	The eligibility criteria for ARPA-E’s funding opportunities can be found in the FOAs listed on https://arpa-e-foa.energy.gov/ . Each FOA details all eligibility requirements and definitions.
Internet link	https://arpa-e-foa.energy.gov/

Office of Energy Efficiency and Renewable Energy (EERE)

The EERE aims to promote and sustain the US leadership in the transition to a clean energy economy. Most of EERE’s funding is provided by grants or cooperative agreements. However, the EERE’s funding portfolio also includes other forms of funding such as Cooperative Research and Development

¹⁶⁵ <https://www.energy.gov/about-us>

¹⁶⁶ <https://www.energy.gov/science-innovation/clean-energy>

¹⁶⁷ <https://www.arpa-e.energy.gov/?q=arpa-e-site-page/about>

¹⁶⁸ <https://www.arpa-e.energy.gov/?q=programs/apply-for-funding>

¹⁶⁹ <https://www.nano.gov/initiatives/funding-opportunities>



Agreements (CRADAs), Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) Awards, Technology Investment Agreements (TIAs) and Unsolicited Proposals¹⁷⁰.

First Approach	
Information about Funding Opportunities	European researchers interested in the EERE funding opportunities could contact the representative identified in the Funding Opportunities Announcements (FOAs).
International Collaboration	The eligibility criteria for EERE’s funding opportunities can be found in the FOAs listed on Grants.gov and EERE Exchange . Each FOA details all eligibility requirements and definitions.
Internet link	www.energy.gov/eere/funding/find-funding-opportunity-announcements-0

DoE Office of Energy Materials Network (EMN): The Energy Materials Network (EMN) aims to integrate all stages of R&D and facilitate industry access to the EMN national laboratories’ capacity tools. Thus, it accelerates the development cycle of materials and new products within the energy sector. Funding Opportunity Announcements (FOAs) related with the EMN are listed within the EERE Funding Opportunity Information site.

First Approach	
Information about Funding Opportunities	European researchers interested in the EMN funding opportunities could contact the representative identified in the Funding Opportunities Announcements (FOAs).
International Collaboration	The eligibility criteria for EMN’s funding opportunities can be found in the FOAs listed on Grants.gov and the EERE Funding Opportunity site . Each FOA details all eligibility requirements and definitions.
Internet link	https://www.energy.gov/eere/energy-materials-network/energy-materials-network

High Performance Computing for Manufacturing (HPC4Mfg): The HPC4Mfg program aims to support US manufacturing companies that are related with the field of high-performance computing (HPC) technology in the area of clean energy and energy efficiency. The program is promoted under the US DoE and led by Lawrence Livermore National Laboratory. The HPC4Mfg is sponsored by the Advanced

¹⁷⁰ <https://www.energy.gov/eere/funding/find-funding-office-eere>



Manufacturing Office (AMO) of the DoE. The DoE provides up to \$3 million (€2.7 million) funding support to manufacturers in modeling, simulation and data analysis actions to promote innovation and enhanced performance in HPCs. The program includes several rounds, which seek proposals in different primary areas¹⁷¹.

First Approach	
Information about Funding Opportunities	European researchers interested in the HPC4Mfg solicitations could contact the representative identified in the HPC4Mfg Solicitation page.
International Collaboration	The eligibility HPC4Mfg funding opportunities are targeted to entities that manufacture products in the US for commercial applications. Technical questions should be directed to the HPC4Mfg Director at hpc4mfg-submissions@llnl.gov .
Internet link	https://hpc4mfg.llnl.gov/

5.1.4. Department of Defense (DoD)

The US Army, on behalf of the DoD, administers several federally funded programs focused on nanotechnology R&D. The DoD includes several science and technology programs, as well as different departments and agencies (components). Within the component programs, there are several that focus on projects associated with research and technology at the broad level, including nanotechnology. Nanotechnology plays an important role in the DoD strategy in terms of military applications. Thus, DoD views nanotechnology as a broad enabling technology¹⁷².

DoD Grants and Funding	
International Collaboration	The DoD foreign eligibility criteria depend on the level of sensitivity of the researchers and the specific policy of each agency. The authorizing legislation and agency policies will determine whether a foreign individual or organization may apply for a specific grant ¹⁷³ .

¹⁷¹ <https://hpc4mfg.llnl.gov/index.php>

¹⁷² <https://www.nano.gov/node/144>

¹⁷³ <https://www.grants.gov/web/grants/learn-grants/grant-eligibility.html>



DoD ManTech Program: The DoD Manufacturing Technology (ManTech) program is the DoD investment mechanism for promoting its defense manufacturing capability. The program promotes the development of new technologies and processes for the sustainability of defense systems. Thus, nanotechnology solutions are closely connected with opportunities within this program to develop innovative defense systems¹⁷⁴.

First Approach	
Information about Funding Opportunities	European researchers interested in DoD ManTech Program could contact the point of contact identified in the Service and Agency ManTech Programs ¹⁷⁵ .
Email	Help@DoDManTech.com
Internet link	https://www.dodmantech.com/ContactUs/

Rapid Innovation Fund (RIF): The RIF was originally established as the Rapid Innovation Program back in the year of 2011. It aimed to accelerate the development of innovative technologies into military systems. Thus, RIF supports small businesses in developing innovative technologies that meet the defense needs. In 2016, it was re-designated as the RIF. Until 2016, RIF has provided 553 contract awards (486 of those to small businesses) with a value of over \$1.4 billion (€1.26 billion) invested.

First Approach	
Information about Funding Opportunities	European researchers interested in Rapid Innovation Fund could contact the Key Points of Contact identified in the Program page .
International Collaboration	The eligibility RIF funding opportunities are targeted to entities that develop innovative technologies for the US defense system. Technical questions should be directed to the Key Points of Contact identified in the Program page .
Internet link	https://dodrif.com/

¹⁷⁴ <https://www.dodmantech.com/About/>

¹⁷⁵ <https://www.dodmantech.com/ManTechPrograms/>



5.2. Private initiatives/programs

There are several private funding initiatives and programs that are being implemented at the US state level. Thus, it is expected that during the next years there will be an increase of the private sector funding for R&D in nanotechnology¹⁷⁶. The investment in the nanotechnology industry thus complements the R&D funding that is provided mainly through the NNI investments in nanotechnology¹⁷⁷. Within this context, there are several non-federal organizations that provide funds to support nanotechnology R&D initiatives and programs.

5.2.1. Nanoelectronic Computing Research (nCORE) Program

The Semiconductor Research Cooperation (SRCco) is a technology research consortium that manages the Nanoelectronic Computing Research (nCORE) program. The nCORE program provides funding within its research areas of interest, which includes “Advanced manufacturing and nanofabrication to enable the fabrication of emerging devices and systems”¹⁷⁸. The program targets US universities in the specified research areas. However, specific collaborations might be pursued in order to allow participation of other organizations.

First Approach	
Information about Funding Opportunities	European researchers interested in the Nanoelectronic Computing Research (nCORE) program could contact the administrator at proposal.admin@src.org .
International Collaboration	The eligibility criteria for the Nanoelectronic Computing Research (nCORE) program can be found in the Requests for Proposals .
Internet link	https://www.src.org/compete/ncore/rfp/

5.2.2. The Corridor’s Matching Grants Research Program

The Corridor’s Matching Grants Research Program is a state funded initiative managed by the Florida High Tech Corridor Council, which is composed of the University of South Florida, University of Florida,

¹⁷⁶ Global Nanotechnology Market (by Component and Applications), Funding & Investment, Patent Analysis and 27 Companies Profile & Recent Developments - Forecast to 2024, iGATE Research, 2018

¹⁷⁷ The National Nanotechnology Initiative - Supplement to the President's 2018 Budget, NNI, 2017

¹⁷⁸ <https://www.src.org/compete/ncore/rfp/>



and University of Central Florida. The program promotes the development of commercially applicable emerging technologies in the region. The program can provide up to \$150,000 (€135,000) of grant funds for collaborative research projects. In terms of eligibility, the projects must involve a local industry partner and a University of South Florida Principal Investigator and support the economic development of the region. Thus, it is recommended that European applicants establish collaboration agreements with local organizations. Nanotechnology is one of the areas encouraged within the program¹⁷⁹.

First Approach	
Information about Funding Opportunities	European researchers interested in the Corridor’s Matching Grants Research Program could contact the representative at matchinggrants@research.usf.edu .
International Collaboration	The eligibility criteria for the Corridor’s Matching Grants Research Program can be found in the Program Guidelines .
Internet link	http://www.usf.edu/research-innovation/rf/usf-connect/funding-available/index-old.aspx

¹⁷⁹ <http://www.usf.edu/research-innovation/rf/usf-connect/funding-available/index-old.aspx>



6 Observations

The Study on nanotechnologies shows that the US is the global leader in the nanotechnology industry in terms of R&D investments, as well as in terms of revenues towards nano-enabled products. As explained, nanotechnology can be described within several stages of the industrial value chain. Thus, the Study focuses on the applications of nanotechnologies into products and services. Through this targeted analysis, the Study identifies a set of specific sectors within nanotechnology application: healthcare, electronics & computers, energy, transportation and aerospace. The application of nanotechnology within these sectors has been growing and leading to higher revenue shares within the US market.

Through the analysis on the US innovation ecosystem, it was found there is a particularly high concentration of innovation hubs, facilitators and industry related RDI centers in the states of California, Massachusetts, New York, North Carolina, Illinois and Texas. Due to the large number of sector applications in nanotechnologies, the analysis on the US nanotechnology market is not obvious. Thus, there is a need to analyze specific segments within the identified sectors that are most likely to use nanotechnology for developing their products or services. The segments considered for the analysis are as follows: Pharmaceutical and Medicine Manufacturing, Electronic Computer Manufacturing, Storage Battery Manufacturing, Painting and Coating Manufacturing and Aerospace Product and Parts Manufacturing. Within this context, the analysis of manufacturers within the different sectors identified California, Florida, Texas and New York as the main states of nanotechnology business development in the US. Other states such as Massachusetts, New Jersey and Illinois also seem to have a particular high concentration of manufacturers from the different segments.

In addition, as nanotechnology is an area that is constantly advancing and innovating, it is highly recommend that EU researchers and industry representatives get in contact with key US nanotechnology related networks and attend nanotechnology events and conferences located in the US. Thus, this study provides a short summary of some potential relevant networks and events that could be of support for EU researchers and industry representatives.

Regarding the US innovation initiatives and programs, the nanotechnology area has been highly supported by public and private initiatives and programs. At the US federal level, the nanotechnology innovation and R&D actions are managed under the NNI, which involves 20 departments and independent agencies at the US national level. At the private level, there is funding available through different institutions spread around the country, and normally with a state-level focus. This private funding acts as a complement to the R&D funding available through the NNI. Although there are several programs and initiatives at both federal and private levels, it is important to note that information related to funds and grants for European representatives is difficult to find. In most cases, the European innovators and business representatives interested in US nanotechnology-related



initiatives and programs need to contact the program officers to know specific details about international eligibility.

In summary, the assessment carried out demonstrates there are several and relevant EU-US innovation and business cooperation opportunities in the nanotechnology area. Both regions consider nanotechnology as a priority and are highly committed to promote innovation and invest in this area with the aim of improving the application of nanotechnology in consumer-products and processes.





Annex 1: Summary of the US Public and Private Funding Initiatives and Programs

Table A1 - Summary of the US Public and Private Funding Initiatives and Programs

Agencies	Programs/ Initiatives	Responsible entities	Contact Info	Internet link
<u>Federal Initiatives and Programs</u>				
Department of Health and Human Services (HHS)	NIH Grants	NIH	Contact the point of contact identified in the FOAs	https://grants.nih.gov/grants/about_grants.htm
	National Institute for Occupational Safety and Health (NIOSH) - Nanotechnology Research Center (NTRC)	Centers for Disease Control and Prevention (CDC)	Contact the point of contact identified in the FOAs	https://www.cdc.gov/niosh/oep/funding.html
National Science Foundation (NSF)	NSF Grants	NSF	eeinfo@nsf.gov	www.nsf.gov/od/oise/country-list.jsp ; www.nsf.gov/od/oise/europe/



Agencies	Programs/ Initiatives	Responsible entities	Contact Info	Internet link
Department of Energy (DOE)	EERE funding opportunities	EERE	Contact the point of contact identified in the FOAs	www.energy.gov/eere/funding/find-funding-opportunity-announcements-0
	Energy Materials Network (EMN)	Advanced Research Projects Agency-Energy (ARPA-E)	Contact the point of contact identified in the FOAs.	https://arpa-e-foa.energy.gov/
	High Performance Computing for Manufacturing (HPC4Mfg)	EERE	hpc4mfg-submissions@llnl.gov .	https://hpc4mfg.llnl.gov/
Department of Defense (DOD)	DoD ManTech Program	DoD	Help@DoDManTech.com	https://www.dodmantech.com/ContactUs/
	Rapid Innovation Fund (RIF)	DoD	Contact the point of contact identified in the FOAs.	https://dodrif.com/
<u>State Initiatives and Programs</u>				



Agencies	Programs/ Initiatives	Responsible entities	Contact Info	Internet link
Semiconductor Research Cooperation (SRCco)	nanoelectronic COmputing REsearch (nCORE)	Semiconductor Research Cooperation (SRCco)	proposal.admin@src.org	https://www.src.org/competen/core/rfp/
Florida High Tech Corridor Council	Corridor's Matching Grants Research Program	Florida High Tech Corridor Council	matchinggrants@research.usf.edu	http://www.usf.edu/research-innovation/rf/usf-connect/funding-available/index-old.aspx

