NanoFabNet

international Hub for sustainable industrial-scale Nanofabrication

Initial Database & Map of the Fields of Nanofabrication & Technology Sustainability

NanoFabNet

Cover Picture:

AcumenIST (Top 100 keywords of sustainability publications (generated with VOSviewer 1.6.18))

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Acronyms Listed in Document	
2D	Two-dimensional
3D	Three-dimensional
EC	European Commission
ERC	European Research Council
GDPR	EU' General Data Protection Regulation
H2020	European Union's 8th Framework Programme, called 'Horizon 2020'
MSCA	Marie Skłodowska-Curie Actions
R&I	Research & Innovation
SME	Small & medium-sized company

1. Executive Summary

The NanoFabNet aims to establish an international hub for sustainable nanofabrication, whose structure, business model, detailed strategies and action plans are designed, agreed and carried by its international stakeholders, in order to yield a self-sustaining collaboration platform. To achieve this, however, the barriers between the contributing scientific disciplines must first be overcome and the geopolitical clustering of its expert communities counteracted.

This report initially describes the NanoFabNet's approach to identifying the contributing scientific disciplines, as well as their research foci, the geographical spread of the centres of excellence and their individual experts, as the NanoFabNet's target stakeholder community: the scientific fields of both 'nanofabrication' (by proxy of the predefined category of 'nanoscience & nanotechnology') and 'sustainability' were mapped to delineate them and identify overlaps between them through the use of Big Data text-mining tools and (co-)occurrence analyses combined with modern scientometrics on a body of over 1.6 million scientific publications of the past 40 years. The analysis revealed a (forced) habit for nanotechnology and sustainability experts to publish in entirely different journal categories; this indicates the immense opportunity for the NanoFabNet Hub to establish an unprecedented network, in which experts from both communities can explore mutually beneficial collaborations.

In addition to the keyword mapping in scientific publications, the individual projects of the Horizon 2020 programme were analysed to identify their research activities pertaining to nanofabrication and/or sustainability. The findings highlighted that a large share of projects concerned with both 'nanotechnology' and 'sustainability' were supported by schemes that fostered collaborative research and mobility of researchers, and by schemes reserved for research & innovation (R&I) activities in small- and medium-sized companies (SMEs); this demonstrates that the NanoFabNet Hub provides a niche opportunity for the establishment of new connections and collaborations in both academia and industry.

The mapping exercises ultimately formed the basis of the development of the NanoFabNet Database - the 'digital twin' to the NanoFabNet stakeholder community, whose main goal is to provide structured access to the collected and curated information that has been collected by the NanoFabNet to offer niche services and products to the new expert community of sustainable high-tech innovation.

2. Introduction – the NanoFabNet Approach to 'Sustainable Nanofabrication'

The central objective of the NanoFabNet Project is the establishment of a **strong international hub for sustainable nanofabrication** that stands for (a) a well-implemented, guided approach to high levels of safety and sustainability, (b) trusted technical reliability and quality, and (c) compliance with and drive of harmonisation, standardisation, and regulation requirements, amongst all of its members and along their high-tech fabrication value chains: the **NanoFabNet Hub**.

The Hub aims to be a **one-stop-shop** for all matters and concerns pertaining to sustainable nanofabrication and its successful incorporation into the complex, large-scale high-value industries by bringing together governmental and academic laboratories with large industries and SMEs, and thereby offering a coordination space for past, current and future collaborative nanofabrication projects (incl. both EU-funded projects and initiatives, as well as public-to-public partnerships (P2Ps) and public-private-partnerships (PPPs)).

Two of the main barriers to the creation of a **consolidated, international community of experts and practitioners in sustainable high-tech micro- and nanofabrication**, however, are (a) the current separation of the science and technology fields of sustainability and fabrication, as well as the increasing specialisation within each field, and (b) the geopolitical clustering of specialised

communities and infrastructures: The **NanoFabNet Project specifically addresses and aims to overcome** these hurdles by taking the proposed NanoFabNet Hub beyond **the current state-of-the-art:**

> **(*Sub-)disciplines differ in origin, the challenges they address, the media in which they work, the skills they require, and the value-chains in which they operate:*** *Traditional 'nanofabrication' laboratories tend to be inspired by the engineering discipline of micro-electronics; they focus on 'top-down' fabrication processes and incorporate only those nanoscale building blocks that can be fabricated on site (and often in-situ). By contrast, 'bottom-up' process of synthesising nanoscale building blocks (e.g. in chemical/physical vapour deposition or solution-chemistry approaches) have largely sprung out of the disciplines of inorganic chemistry, chemical engineering, and materials science, where products and intermediaries tend to be produced in bulk quantities for 'ex-situ' integration further down the value chain.*

> ***Geopolitical clustering prevails:*** *Micro- and nanofabrication laboratories tend to cluster on the national or federal level, due to factors connected to their immediate economic, political and geographic infrastructures and those of their client industries; the individual stakeholders and their communities know of each other and tend to meet at international conferences, but aside from investigator-to-investigator collaborations, hardly any formal partnerships exist between the nanofabrication communities around the globe.*

⇒ Both the fragmentation of the field through discipline origins and schools-of-thought and the geopolitical clustering will be overcome through the choice of representative stakeholders from different disciplines and (geopolitical) communities, and the proactive direct invite sent to the identified stakeholders to join the NanoFabNet Hub. Within this context, the NanoFabNet Project will address one specifically ambitious and ground-breaking objective, namely that of developing a bespoke **NanoFabNet concept of 'sustainable micro- and nanofabrication'** by inclusion of world-leading technology sustainability experts.

It is anticipated that the barriers described above will be further lowered, as more stakeholders join the community and engage in defining the NanoFabNet according to their needs and views. By far the most impactful measure to eliminate the barriers to the establishment of a **consolidated, international community of experts and practitioners in sustainable nanofabrication**, however, is the establishment of the **NanoFabNet Database**, which aims to act as a **'digital twin' to the NanoFabNet stakeholder community**; the database catalogues information about the infrastructures and actors that have been initially identified by the mapping exercise described in this report and subsequently elaborated in discipline- and activities-specific profiling exercises (incl. the disciplines of nanofabrication and sustainability, and the activities of validation, harmonisation and standardisation, and infrastructure-, knowledge and skills-assessments, as well as the collaborations and connections between their expertise and capacities. This digitalisation step aims to re-map the fragmented communities according to the **NanoFabNet Database terminologies and ontologies**, and thus render them independent from their previous fragmentation.

2.1 Mapping & Consolidating the Fields of Nanofabrication & Sustainability

The mapping exercise described in this report focussed on generating a comprehensive overview of the landscapes of (a) nanofabrication and (b) technology sustainability across and beyond Europe, involving all relevant stakeholder groups, all stages of the nanofabrication process from particle generation to laboratory scale & industrial scale processing/manufacturing both in an agency, academic and industrial setting. The underlying activities aim at identifying the main disciplines and actors of the two fields (e.g. in nanofabrication: high-tech (clean-room-based), high-value nanofabrication (research) of complex systems of systems in relatively low volume *versus* high-volume manufacturing of functional nanoparticles for additive manufacturing; in technology sustainability:

cradle-to-cradle considerations of all socio-economic and -political elements of a technology innovation process *versus* the detailed safe-by-design (SbD) consideration of human health, workers' health and environmental safety for a specific nanofabrication-based process or product under existing hard regulatory requirements), and sub-disciplines (i.e. schools of practices/thoughts) pertaining to the large diversity of both fields. The mapping exercise **delineates the fields' disciplines** and **sub-disciplines**, and **identifies overlaps** between them.

The underlying mapping activities were guided by the NanoFabNet report entitled 'Methodology for Stakeholders' Identification & Profiling', which made use of state-of-the art social network analyses tools, including advances Big Data text-mining tools and (co-)occurrence analyses combined with modern scientometrics. The resulting 2D maps and longitudinal plots discussed in Section 3 below simultaneously serve the purpose of providing a state-of-the-art visualisation of the inter-connectedness of and within the fields.

2.2 Analysis of EU-funded Projects

In addition to the keyword mapping in scientific publications, the individual projects of the 8th Framework Programme of the European Union (i.e. 'Horizon 2020', 2014 - 2020) were analysed to identify their research foci, as well as possible research and innovation (R&I) activities pertaining to nanofabrication and/or sustainability. The EU Portal data.europe.eu[1] was used as the main data sources; *.xlsx data files was downloaded and further processed using the programmes VantagePoint[2] and Microsoft Office Excel for the cleaning and visualisation of the data.

2.3 Developing the NanoFabNet Database as a 'Digital Twin' of the NanoFabNet Stakeholder Community

The analysis presented in this report helps to identify the stakeholders, that the NanoFabNet aims to cater to in developing a new, community-owned network. The resulting individual publications and projects will be used to both refine range of services, activities and products that the NanoFabNet Hub should offer to its community, and directly notify authors and project partners of the launch of the Hub.

One of NanoFabNet's notable characteristics of future-orientation and resilience is its aim to be fully grounded in a digital format: all NanoFabNet services and products will first and foremost be developed and offered through virtual means on the **NanoFabNet Platform**. This allows the network to have thematically and geographically much wider international outreach through the phase of conceptualisation, and development, than would have been possible for physical networks, and to be launched to a truly international stakeholdership. At the heart of the NanoFabNet Platform lies the **NanoFabNet Database** - the **'digital twin' to the NanoFabNet stakeholder community**; this is being developed through incorporating the following steps: (a) requirement analysis for intended content of the database (cf. the NanoFabNet report entitled 'Methodology for Stakeholders' Identification & Profiling', (b) (search) query analysis on the suggested outputs of the database to decide on the most fitting type of database (relational, graph based, etc.), (c) conceptual design of the database (i.e. entities to integrate, relationships between entities, layout of the entities, etc.), (d) mapping of the conceptual design to a scheme of the chosen database system, (e) creation of administrative surface for data entries (i.e. (i) manually (ii) from other sources *via* import filters, APIs, etc.), (f) creation of administrative surface for data entries, (g) creation of interactive query interface and implementation of query language (e.g. SQL etc.), and (h) integration of small workflow to allow for simple curation of entries (e.g. accept/decline etc.). Existing databases, have been (and will continue to be) invited to join

[1] data.europe.eu: https://data.europa.eu/en (last accessed: 29. May 2022).

[2] The VantagePoint: https://www.thevantagepoint.com/ (last accessed: 29. May 2022).

the NanoFabNet development, in order to add value to their structure and/or content, whilst minimising the cost of creating a new database from scratch. A detailed description of the database development can be found in Marquardt *et al.* (Marquardt, Scholz, Nau, & Schmidt, 2022).

The mapping of the scientific disciplines of 'nanofabrication' and 'sustainability', presented in this report, formed the basis of the development of the NanoFabNet Database; a benchmarking analyses was subsequently conducted, in which a number of online information platforms about projects and initiatives were screened, and information deemed relevant for the NanoFabNet was collected. Three main data categories were established as a result of this benchmarking exercise: "organisation", "projects" and "infrastructures"; for each of the categories, a set of relevant fields was collected in accordance with the landscape mapping and data collection described above. These entailed general information, such as the official names, address details, weblinks, digital identifiers, complemented by an in-depth profile describing the activity and industry sectors provided services, available expertise, tools and equipment as well as references such as certifications, publications or project involvements (Marquardt, Scholz, Nau, & Schmidt, 2022).

3. Results & Discussion

3.1 Bibliometric Mapping of the Disciplines of 'Nanoscience & Nanotechnology' and Sustainability'

To characterise and understand developments of the fields of nanofabrication and sustainability, the bibliographic body of primary scientific literature in both fields was analysed to identify the main keywords that each field referred to in the titles of articles over the past 40 years.

Building on the research pertaining to the SCImago Journal Rank (SJR) indicator, introduced by Guerrero-Bote and Moya-Anegón for the bibliographic Elsevier Scopus® database[3] (Guerrero-Bote & Moya-Anegón, 2012), as well as the analysis of convergence between different scientific fields, conducted by Friedrichs (Friedrichs, 2018), the bibliometric mapping used the predefined journal category of 'nanoscience & nanotechnology' as a proxy for the more specialised field of 'nanofabrication' (see ANNEX – A1.a). Journals representing the field of 'sustainability' were defined from first principle (see ANNEX – A1.b). The most often used keywords in the bibliometric discipline categories of **(a) 'nanoscience & nanotechnology'** and **(b) 'sustainability'** were mapped using the VOSviewer programme[4].

3.1.1 Keywords of 'Nanoscience & Nanotechnology'

Figure 1 below shows a map of the **Top 50 keywords** found in the titles of all documents published in the journal category *'nanoscience & nanotechnology'* in the years 1980 – 2019. The overlay colours indicate that attributes of 'Materials Science & Metallurgy'-disciplines were most often used in the early years of nanotechnology research, characterised by keyword, such as ***'alloy'***, ***'steel'***, ***'mechanical property'*** and ***'composite'***, while in recent years, terms, such as ***'graphene'***, ***'graphene oxide'***, ***'lithium ion batteries'*** and ***'drug delivery'*** were introduced, indicating a shift towards research publications on applications and new materials. The full set of results, as well as the corresponding 2D density map can be found in ANNEX – A2.a.

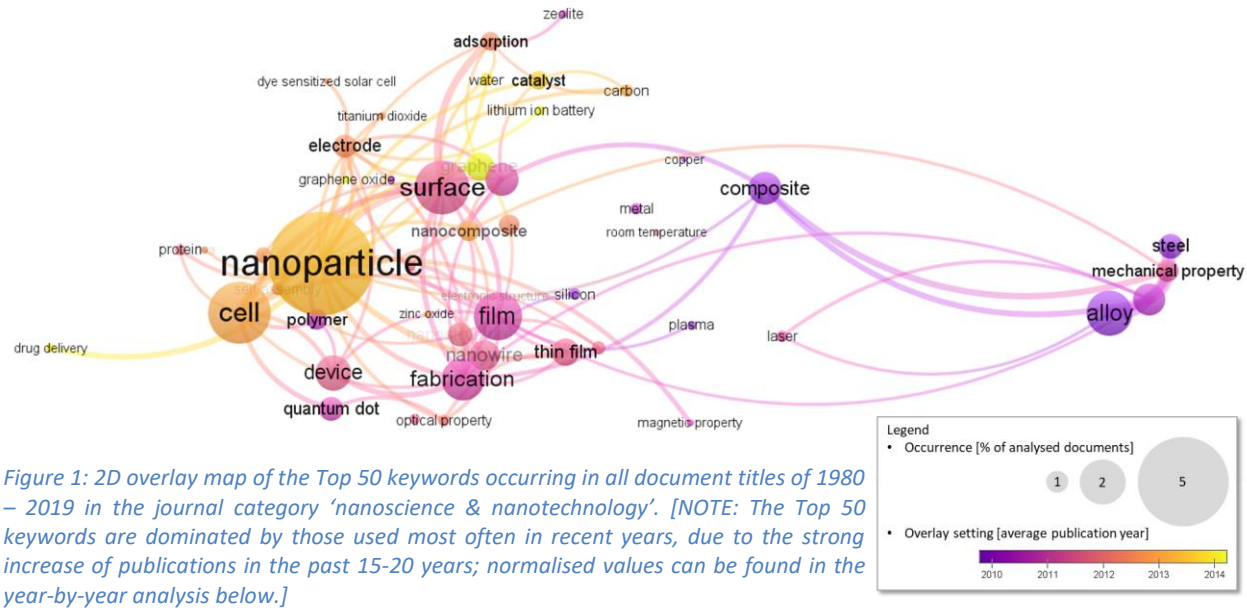


Figure 1: 2D overlay map of the Top 50 keywords occurring in all document titles of 1980 – 2019 in the journal category 'nanoscience & nanotechnology'. [NOTE: The Top 50 keywords are dominated by those used most often in recent years, due to the strong increase of publications in the past 15-20 years; normalised values can be found in the year-by-year analysis below.]

[3] Scopus bibliographic database: https://www.scopus.com/ (last accessed: 29. May 2022)

[4] VOSviewer (version: 1.6.16, executable JAR): https://www.vosviewer.com/ (last accessed: 29. May 2022)

A year-by-year analysis of the Top 50 'nanoscience & nanotechnology' keywords between 1980 and 2019 is illustrated in Figure 2; it shows that the field is characterised by a strong focus on materials; this includes the study of the ***'composition'*** of a ***'material'*** (incl. the composition of an ***'alloy'***), as well as its ***'(micro)structure'*** (incl. ***'surface'*** and ***'film'***), and specific materials, such as ***'steel'*** (most often used in 1988 – 2006), ***'nanoparticle*** (mentioned very often since 1998), and ***'carbon nanotube'*** (amongst the Top 1% of keywords since 2001). The focus on materials also includes the description of research-relevant processes, such as ***'characterisation'*** (a constant concern throughout the series), ***'measurement'*** (used very often until 2009), ***'synthesis'*** (increasingly used since 1982), as well as studies of specific processes at the nanometre scale, such as ***'adsorption'***. The mention of the keyword ***'cell'*** lags the observed focus on materials-research by a few years; since its introduction in the early 2000s, however, the word has become a constant feature in the most often used keywords. It needs to be noted, that the word 'cell' may pertain both to the concept of engineered devices (e.g. '(dye sensitised) solar cell' or 'battery cell'), as well as to the concept of the biological 'cell' (e.g. in toxicological studies); the use of the word in both contexts is illustrated by the 2D overlay map shown in Figure 1: the term 'cell' appears in almost equal distance to both the terms 'drug delivery' (i.e. such as investigated in pharmacokinetic studies), 'electrode' (i.e. such as the electrode of a 'dye sensitised solar cell'), and 'device'.

In the early years of nanoscience and -technology research, keywords describing combined or collective concepts, such as 'system', 'model', and 'device', as well as analyses of properties pertaining to them (e.g. 'reliability', 'failure', and 'cost (benefit) analysis') were often used in the titles of publications in 'nanoscience & nanotechnology' journals. It needs to be noted, that the scarcity of data in the early years of the time series (cf. Section 4.1 below), as well as the curation guarantee provided by the Elsevier Scopus® database itself[5], limits the reliability of data before 1996.

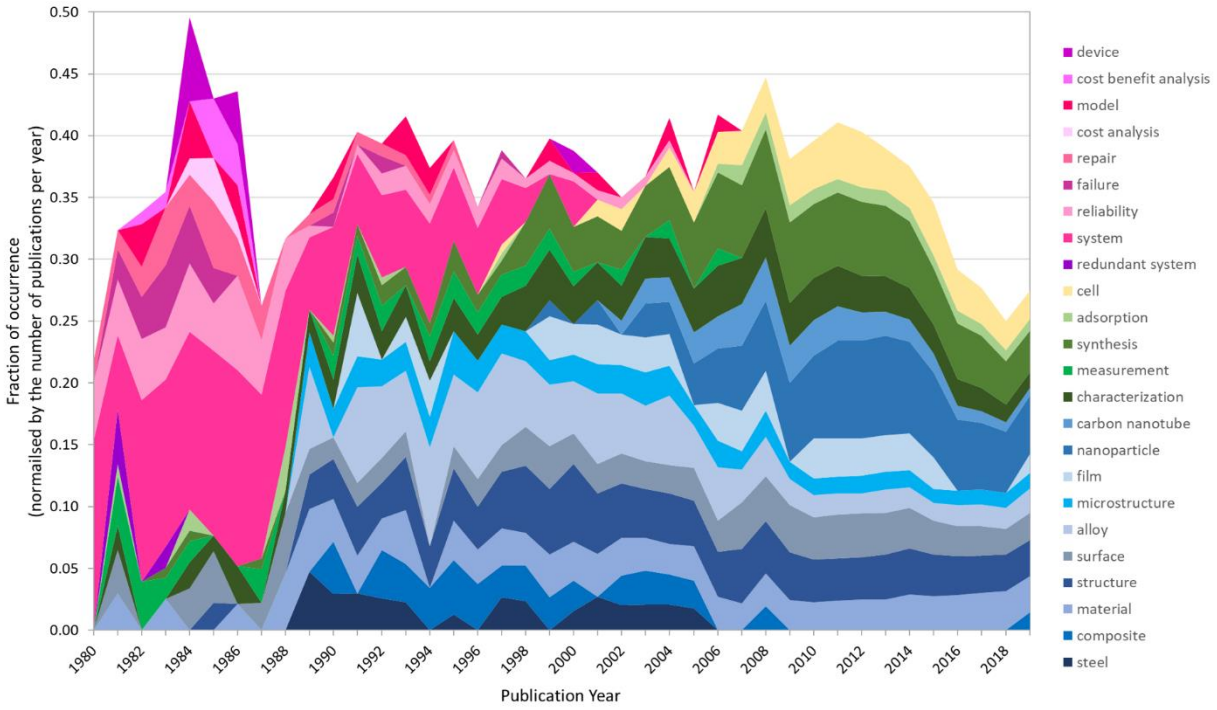


Figure 2: Top 1% of keywords used in the titles of scientific articles published in the journal category of 'nanoscience & nanotechnology' (1980 – 2019). The keywords have featured in at least 1% of articles in at least one year of the timeseries. [NOTE: Keywords have been grouped and colour-coded; the sequence of the groups and the keywords within them is arbitrary.]

[5] The bibliographic Elsevier Scopus® database claims to provide cleaned and curated data for its publication from 1996 onwards, only.

3.1.2 Keywords of 'Sustainability'

The 50 most often occurring keywords in scientific journals concerned with 'sustainability' between 1980 and 2019, as well as their correlation to each other are illustrated in Figure 3. The full set of results, as well as the corresponding 2D density map can be found in ANNEX – A2.b.

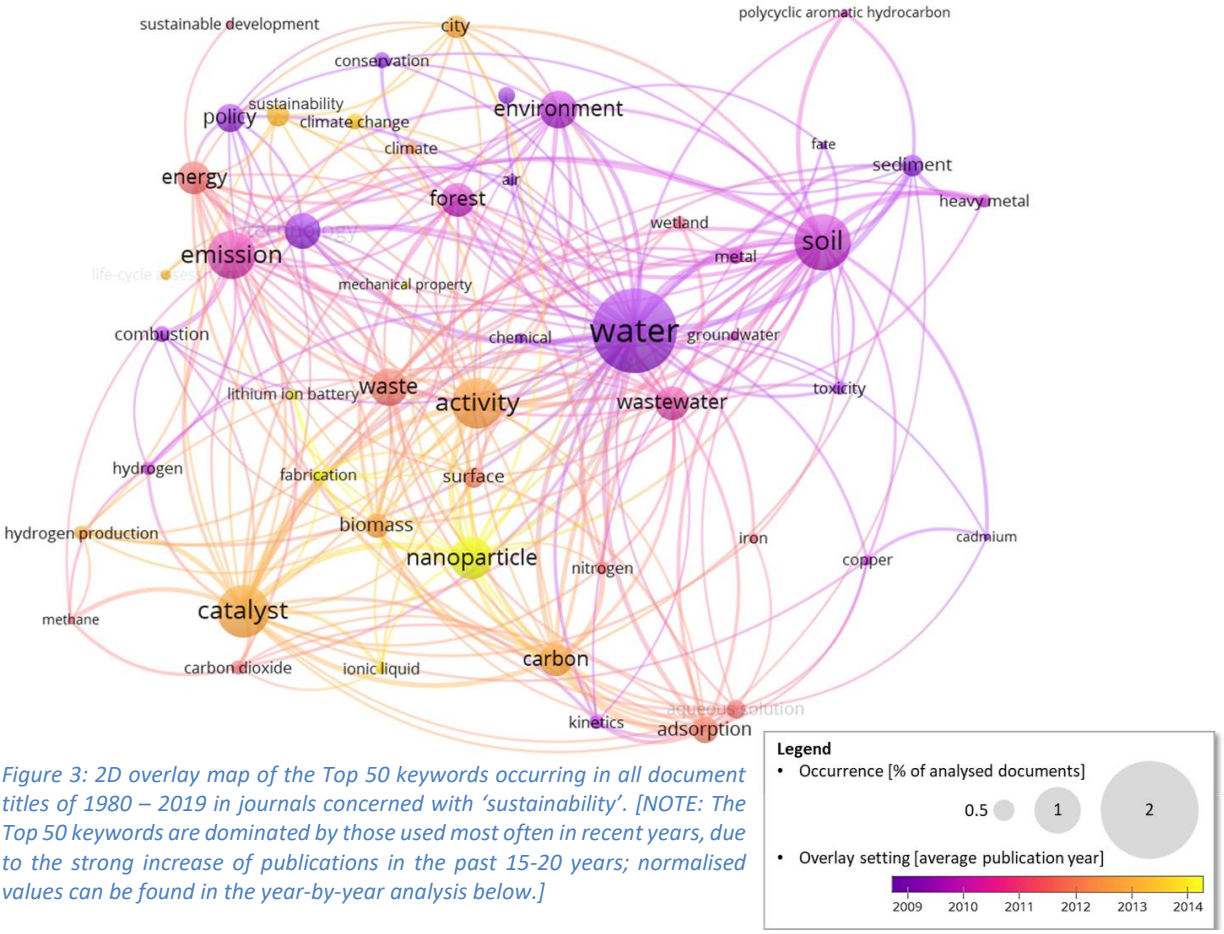


Figure 3: 2D overlay map of the Top 50 keywords occurring in all document titles of 1980 – 2019 in journals concerned with 'sustainability'. [NOTE: The Top 50 keywords are dominated by those used most often in recent years, due to the strong increase of publications in the past 15-20 years; normalised values can be found in the year-by-year analysis below.]

The map reveals an initial broad focus of the field of 'sustainability' on topics, such as ***'policy'***, ***'conservation'***, ***'technology'***, ***'chemical'***, as well as very strong concern with ***'water'***. Just a short time later, the underlying factors and their impacts, such as ***'emissions'***, ***'wastewater'***, ***'(heavy) metal'*** and ***'polycyclic aromatic hydrocarbons'*** moved into the centre of sustainability research. Most recently, a shift in the focus introduced keywords, such as ***'climate change'***, ***'nanoparticle'***, ***'fabrication'*** and ***'lithium ion battery'***, indicating the research on sustainability is increasingly looking at emerging technologies to evaluate their impact on sustainability both in a beneficial and detrimental sense. It is interesting to note that the term ***'sustainability'*** is a more recent addition to the list of Top 50 keywords (i.e. as recent as 'climate change'), and that the keyword ***'hydrogen'*** was once an important keyword around 2010, and re-entered the research focus three years later in the form of ***'hydrogen production'***.

Figure 4 illustrates the findings of the year-on-year analysis of the Top 2% of keywords used in research publications concerned with 'sustainability' between 1980 and 2019.[6] The plot supports the above mentioned findings that the term ***'technology'*** has played an important role throughout the

[6] The percentile of relevant keywords was increased from 1% (in the case of 'nanoscience & nanotechnology') to 2% (in the case of 'sustainability'), in order to obtain a sufficiently large number of keywords; a cut-off of 1%, as was used for 'nanoscience & nanotechnology' would have yielded 11 keywords only.

timeseries, and that the role of specific materials and technologies, such as ***'catalyst'***, ***'membrane'***, ***'aqueous solution'*** and ***'nanoparticle'*** have become increasingly important to the research of sustainability.

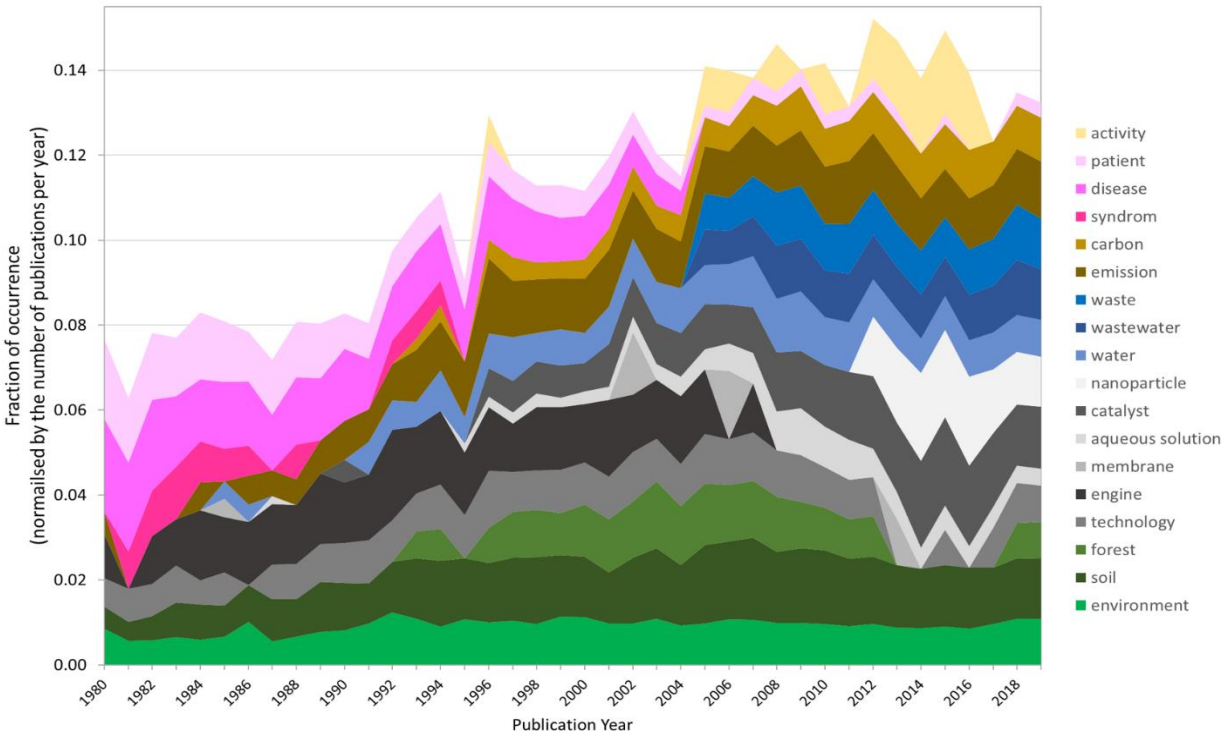


Figure 4: Top 2% of keywords used in the titles of scientific articles published in journals concerned with the topic of 'sustainability' (1980 – 2019). The keywords have featured in at least 2% of articles in at least one year of the timeseries. [NOTE: Keywords have been grouped and colour-coded; the sequence of the groups and the keywords within them is arbitrary.]

3.1.3 General Discussion of longitudinal Keyword Analyses

A comparison of the vertical axes of the graphs shown in Figure 2 and Figure 4 illustrates the general differences between the investigated scientific fields of (a) 'nanoscience & nanotechnology' and (b) 'sustainability':

a) The field of 'nanoscience & nanotechnology' is quite narrow in its focus; it amounts to a total of 421.814 individual publications between 1980 and 2019, and its Top 1% most often used keywords collectively appear in up to 40% of all individual publication titles (counting the more reliable part of the timeseries only).
b) The field of 'sustainability', as defined through the articles in journals concerned with the topic, is very diverse; it amounts to 1.231.844 publications between 1980 and 2019. Its Top 2% of most often used keywords collectively appear in up to 13% of all publication titles in the field only.[6]

3.1.4 Identifying Overlaps between 'Nanofabrication' and 'Sustainability'

No single journal was listed in both the category of (a) 'nanoscience & nanotechnology' and (b) 'sustainability', indicating that there was currently no journal that offered a specific focus on both sustainability and nanotechnology; **experts working in these fields have to choose to publish their results either in designated science- and technology-focussed journals or in those offering topics of 'sustainability'**, as identified in the journal's title. The reason for this strict separation could be caused by the notion that journals focussing on 'nanoscience & nanotechnology' could be perceived as those featuring papers concerned with a technology-push of nanoscience and -technology-based solutions,

while journals aiming to illustrate a sustainability-focus are predominantly concerned with the impact (and thus technology-pull); the latter would serve a much more diverse, technology-independent readership and thus be less attractive to experts of nanoscience and -technology to share their latest results. By comparison, the journal category of 'biotechnology' was found to have a large overlap with that of 'nanoscience & nanotechnology' (Friedrichs, 2018).

The thus identified **(forced) habit for nanotechnology and sustainability experts to publish in entirely different journal categories** indicates the immense opportunity for the NanoFabNet Hub to establish an unprecedented network, in which experts from both communities can explore mutually beneficial collaborations. As a consequence, the overlap between the fields of 'nanoscience & nanotechnology' and 'sustainability' was determined by overlaying the keyword maps of the two fields.

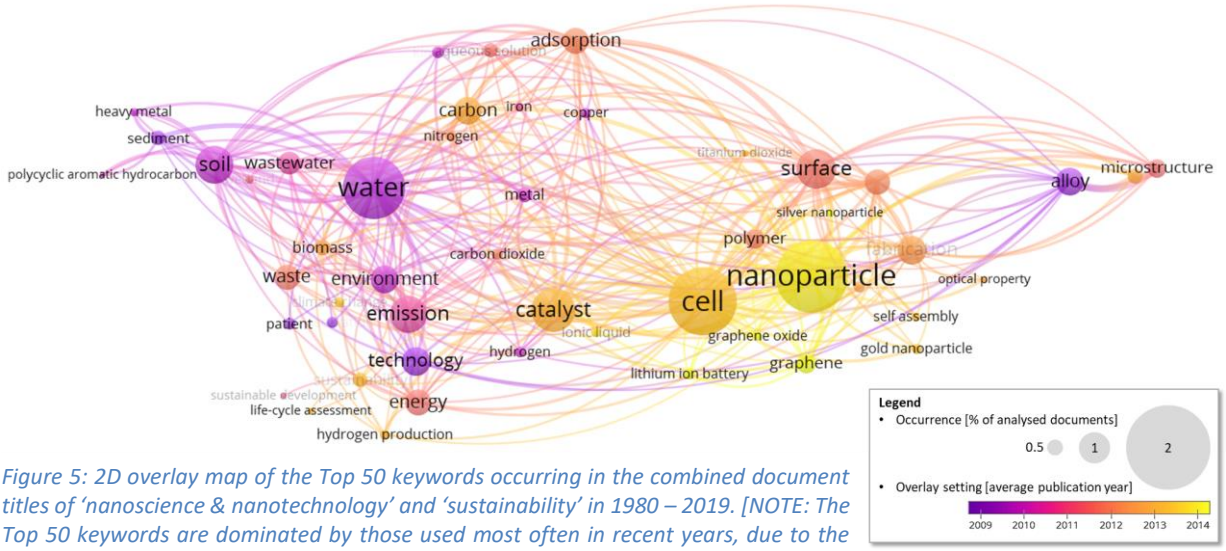


Figure 5: 2D overlay map of the Top 50 keywords occurring in the combined document titles of 'nanoscience & nanotechnology' and 'sustainability' in 1980 – 2019. [NOTE: The Top 50 keywords are dominated by those used most often in recent years, due to the strong increase of publications in the past 15-20 years.]

Figure 5 provides a 2D overlay map of Top 50 keywords generated through the combination of all scientific articles published in the fields of (a) 'nanoscience & nanotechnology' and (b) 'sustainability' between 1980 and 2019 (i.e. 1.653.658 publications). The journal group of origin, as well as the significant overlap in research between the fields of (a) 'nanoscience & nanotechnology' and (b) 'sustainability' are illustrated in the annotated illustration of Figure 6.

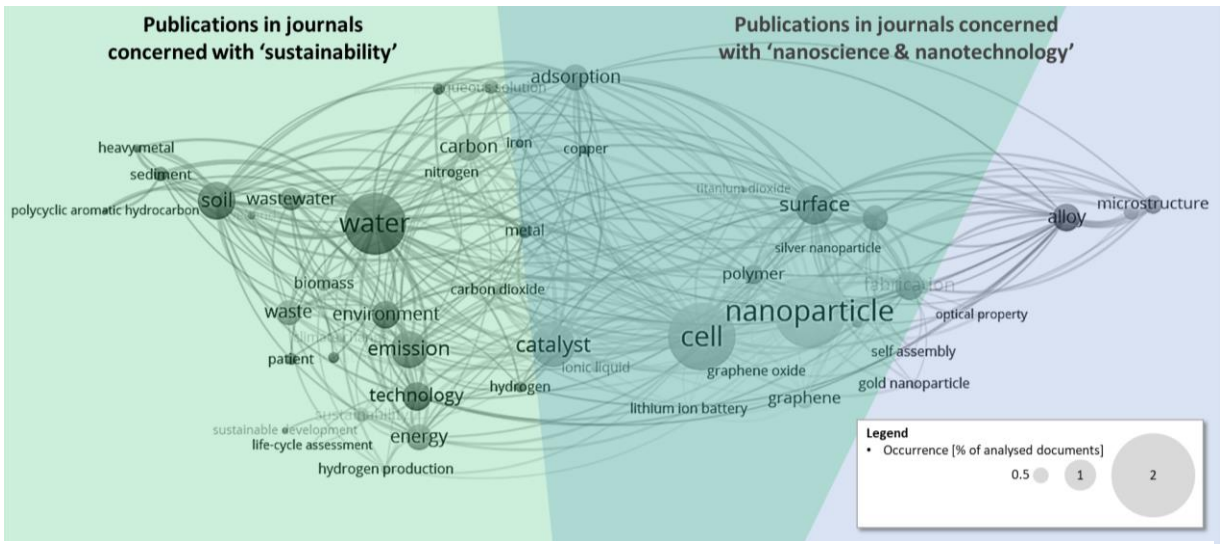


Figure 6: Annotated 2D network map of the Top 50 keywords occurring in the combined document titles of 'nanoscience & nanotechnology' and 'sustainability' in 1980 – 2019; the coloured overlays illustrate the journals, from which the keywords predominantly originate.

3.1.5 Geopolitical Spread of Excellence in 'Nanoscience & Nanotechnology' and 'Sustainability'

Figure 7 and Figure 8 illustrate the origin of all individual authors (by country/territory) of the analysed publications in the field of (a) nanoscience & nanotechnology' (Figure 7) and (b) 'sustainability' (Figure 8). Both maps indicate the strong international research participation that is driving both fields.

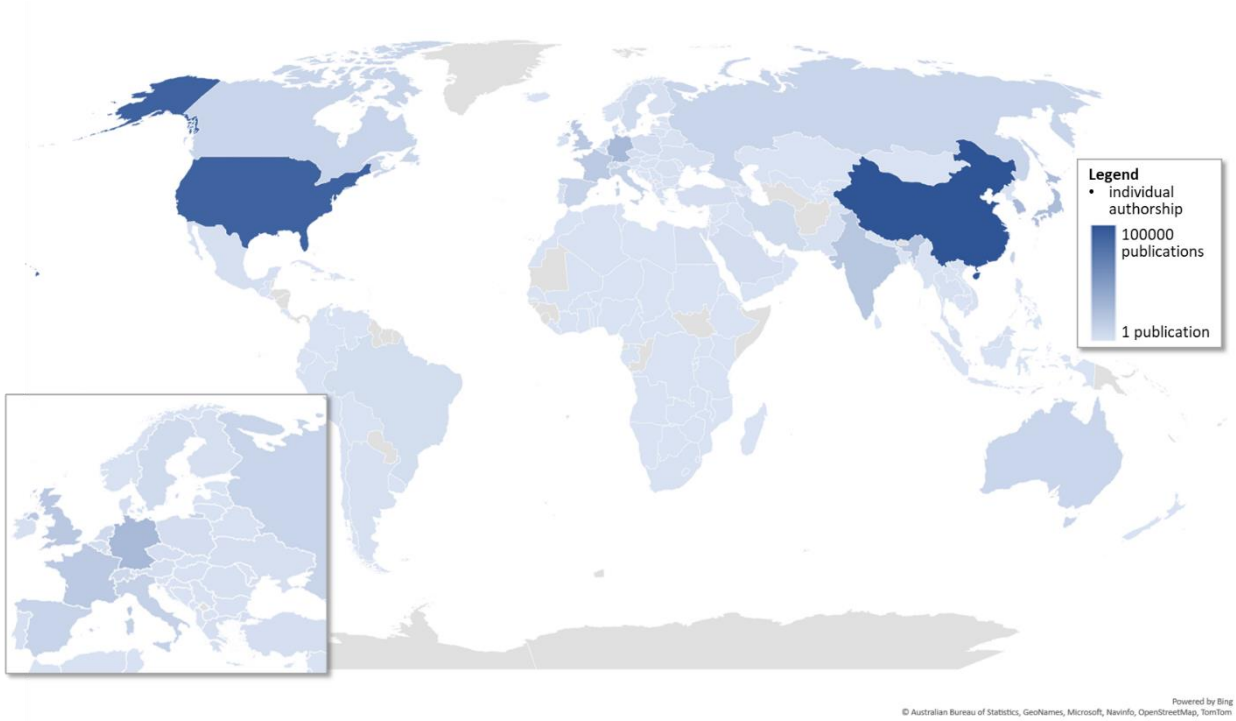


Figure 7: World map overlay illustrating the individual authorship of scientific publications on 'nanoscience & nanotechnology' (1980 - 2019).

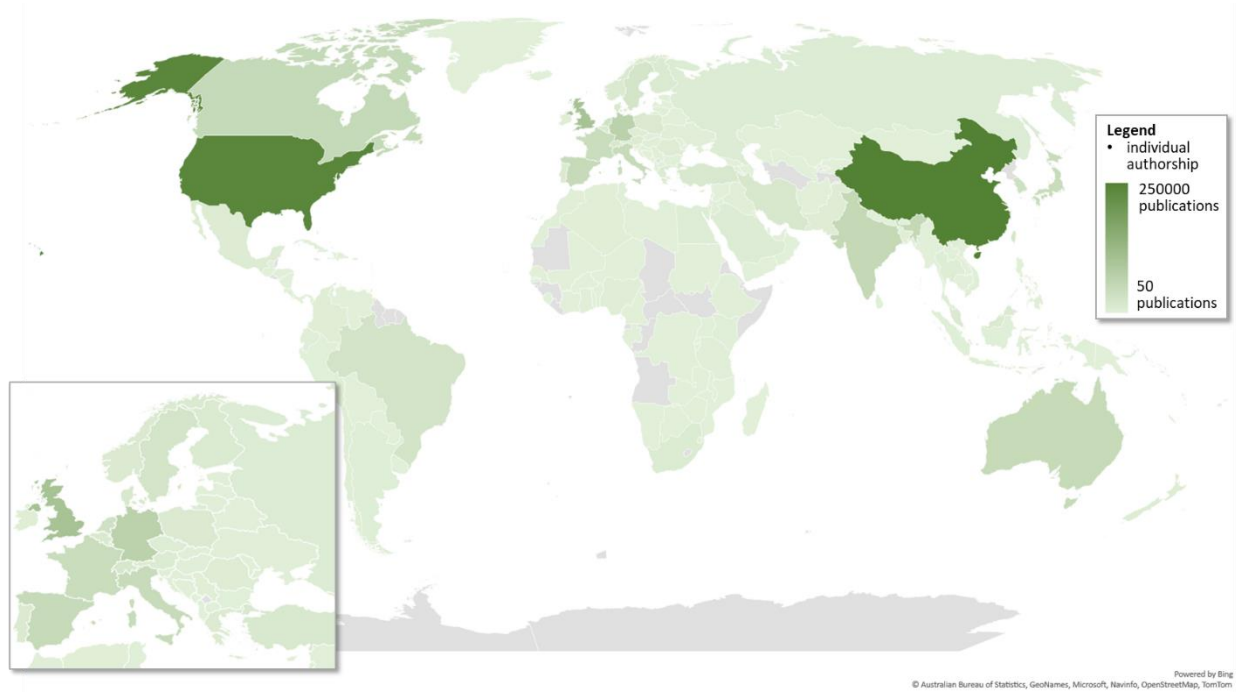


Figure 8: World map overlay illustrating the individual authorship of scientific publications on 'sustainability' (1980 - 2019).

3.2 EU-funded R&I Projects in 'Nanotechnology' and 'Sustainability' – the *Horizon 2020* Framework Programme

3.2.1 Identification of Horizon 2020 Projects concerned with 'Nanofabrication' and/or 'Sustainability'

The European Union's 8th Framework Programme, called 'Horizon 2020' (H2020), was analysed to identify and delineate R&I activities in both (a) 'nanotechnology' and (b) 'sustainability'. At the time of the data retrieval, a total number of 35.372 projects were listed within the CORDIS database and further used for analysis (see Section 4.2); an analysis of the project's 'objective'-description for the stemmed terms "nano*" and "sustainab*" yielded in **(a) 3.040 projects concerned with 'nanotechnology'**, and **(b) 4.788 projects concerned with 'sustainability'**.[7]

Table 1: Summary of results obtained from the analyses of EU H2020 research projects.

	Number of Projects	Fraction of Projects
All Projects	35372	
… of these: containing the single keyword "nano*"	3040	9%
… of these: containing the single keyword "sustainab*"	4788	14%
… of these: containing both "nano*" AND "sustainab*"	**316**	1%

A cross-correlation of both terms identified 319 projects that referred to both 'nanotechnology' and 'sustainability in their objective formulation. Box 1 provides some selected text-excerpts from the 316 cross-correlated projects.

Box 1: Selected text-excerpts from the 'objective'-descriptions of the 316 cross-corelated projects concerned with both 'nanotechnology' and 'sustainability'

[…] tweaking the current nanoelectronics roadmap will be neither enough nor sustainable, but requires to completely rethink transistor devices and circuits. (GA-ID 899141)

Our 3D model catalysts will be assembled from ordered mesoporous silica and carbon support materials and Cu-based promoted and bimetallic nanoparticles. […] for a future more sustainable production of chemicals and fuels from renewable resources. (GA-ID 648991)

Nanophotonic methods for light-trapping, spectral and spatial control of solar radiation will be developed to further enhance the absorption. […] This would enable to generate renewable/ecological/sustainable energy at a levelized production cost below ~7 ¢/kWh. (GA-ID 695116)

The full control over the nanoscale behavior of light holds incredible potential for the realization of various next-generation technologies with dramatic impact on society […], and a more sustainable future (UNESCO's Sustainable Development Goals number 7 and 9). (GA-ID 894847)

[… one-stop-shop for all matters and concerns pertaining to sustainable nanofabrication and its successful incorporation into the complex, large-scale high-value industries […]. (GA-ID 886171)

[7] The "*" was used as truncation mark to encompass all related forms of the keywords (e.g. adjectives, nouns).

Figure 9 displays a 2D overlay map of the Top 50 most often co-occurring keywords found in the 'objective'-description of H2020 projects that are concerned with both 'nanotechnology and 'sustainability'. While no significant time-variation of the individual terms can be discerned, the strong focus on applied innovation (i.e. ***'device'***), as well as the targeted proximity to ***'industry'*** and the ***'market'*** are remarkable.

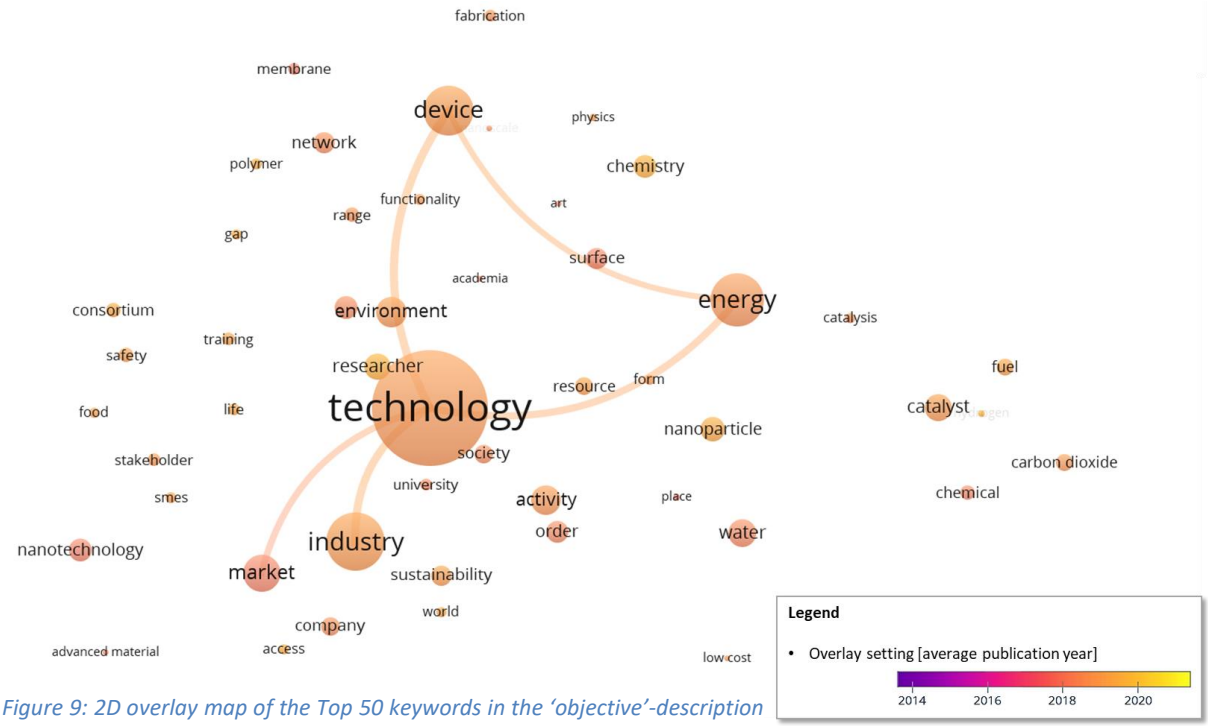


Figure 9: 2D overlay map of the Top 50 keywords in the 'objective'-description of H2020 projects that are concerned with both 'nanotechnology and 'sustainability'.

3.2.2 Hot-Spots of Excellence in Horizon 2020 Projects concerned with 'Nanofabrication' and/or 'Sustainability'

A geographical analysis was conducted on the countries that provide partners to the 316 mostly collaborative projects that are concerned with both 'nanotechnology' and 'sustainability'. Figure 10 shows a word map that illustrates the country of origin of the individual institutes that participate(d) in those 316 H2020 projects that are concerned with both 'nanotechnology' and 'sustainability'. Table 2 lists the countries with the 20 highest participation counts shown in the world map. Germany and Spain lead the table with highest participation count (i.e. 248 and 232, respectively), followed by Italy, France, and the Netherlands. In the coordination of the 316 projects, however, Spain leads before Germany, Italy, France and Switzerland, as illustrated in Figure 11.

Table 2: List of Top 20 countries with the most participation of individual institutes participating in H2020 projects concerned with both 'nanotechnology' and 'sustainability'.

Country	Project participations	Country	Project participations
Spain	248	Denmark	45
Germany	232	Finland	44
Italy	184	Poland	32
France	179	Norway	31
Netherlands	83	Czechia	29
Switzerland	81	Ireland	29
Belgium	77	Slovenia	28
Portugal	67	United States	22
Austria	56	Israel	18
Sweden	51	Cyprus	13

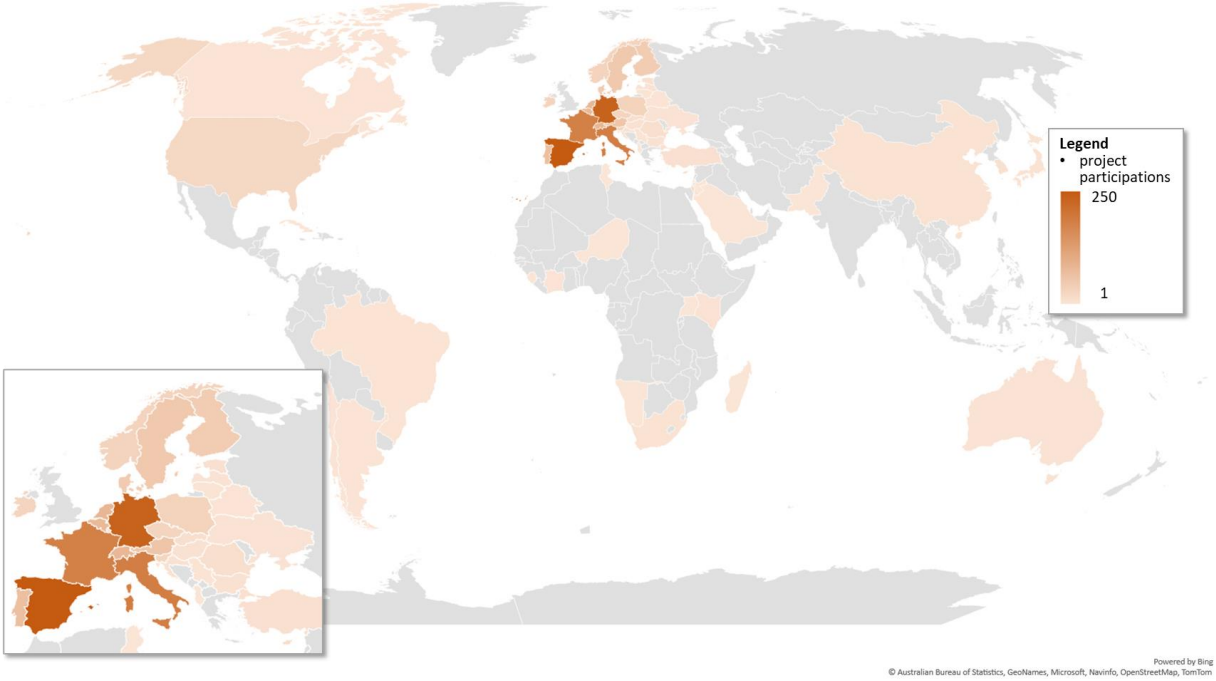


Figure 10: World map overlay illustrating the partnership of individual institutes in H2020 projects concerned with both 'nanotechnology' and 'sustainability'.

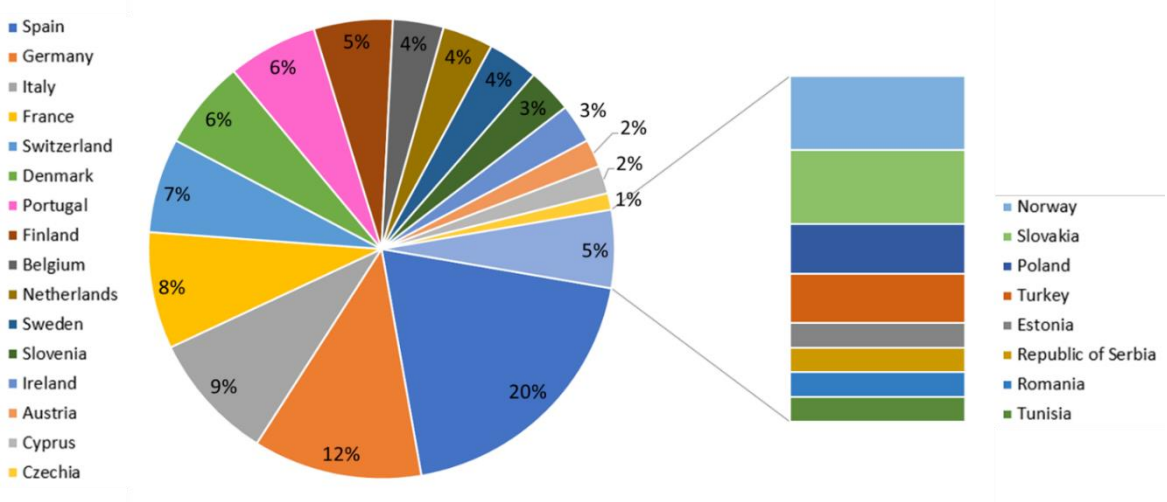


Figure 11: Illustrated statistics of the coordination of the 316 H2020 projects concerned with both 'nanotechnology' and 'sustainability'.

3.2.3 *Funding programmes supporting Horizon 2020 Projects concerned with 'Nanofabrication' and 'Sustainability'*

An analysis of the funding schemes supporting the 316 projects concerned with both 'nanotechnology' and 'sustainability' reveals a remarkable focus on Marie Skłodowska-Curie Actions (MSCA) (i.e. over 1/3 of projects are MSCA-funded). Since MSCA projects are focussed on the provision of opportunities for both collaborative research and mobility of researchers, the finding demonstrates that the NanoFabNet provides a niche opportunity for the establishment of new connections and collaborations in both nanotechnology and sustainability. The finding furthermore indicates the pronounced need for careers and personnel development services and training, because the field of 'sustainable high-tech innovation' is not only nascent in its own right, but also attracts researchers at early stages of their career.

The relatively high proportion of projects supported by the 'SME-Instrument' (i.e. over 10%) matches the finding of the projects' proximity to *'industry'* and the *'market'*, described in Section 3.2.1 above. This finding, too, provides valuable information about opportunities and needs of the members that the NanoFabNet Hub aims to attract.

Table 3: Summary table, illustrating the H2020 funding scheme that are supporting the 316 projects concerned with both nanotechnology and sustainability.

Funding Schemes	Projects	Funding Schemes	Projects
Bio-Based Industries (BBI JU)	7	Leadership in enabling and industrial technologies (LEIT)	2
SME-Instrument (SMEInst)	36	Low Carbon, Green Deal (LC-GD)	2
European Research Council (ERC)	53	Sustainable Food Security (SFS)	2
Energy efficient Buildings (EeB) PPP	2	Blue Growth (BG)	1
Future & Emerging technologies (FET)	18	Spreading Excellence and Widening Participation (WIDESPREAD)	8
Marie Skłodowska-Curie Actions (MSCA)	115	FETProactive	6
Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing (NMBP)	40	EIC Fats-Track to Innovation (FTI) PILOT	2
Nanotechnologies, Advanced Materials and Production (NMP) PILOTS	5	Green Vehicles (GV)	1
Twinning Network (TWINN)	1	Electronic Components and Systems for European Leadership (ECSEL) JU	1
Secure, clean and efficient energy (LC-SC3)	4	Innovation in SMEs (INNOSUP)	1
European Innovation Council Fast-Track to Innovation (EIC-FTI)	1	Factories of the Future (FOF)	1
Food & Natural Resources (FNR)	1	Connecting economic and environmental gains - the circular economy (SC5)	1
European research infrastructures (including eInfrastructures) (INFRA)	6	Governance for the Advancement of Responsible Research and Innovation (GARRI)	1

4. Methodology

4.1 Source Identification – the bibliographic Discipline Categories of 'Nanoscience & Nanotechnology' and 'Sustainability'

Term co-occurrence networks maps were created using text data downloaded from the bibliographic Elsevier Scopus® database[4]. In the case of the grouped disciplines of 'nanoscience & nanotechnology', the relevant journal ISSN numbers were identified using the same journal categorisation (i.e. 'nanoscience & nanotechnology') defined by SCImago for the Elsevier Scopus® database, based on the SCImago Journal Rank (SJR) indicator, accumulated over the years 1999-2019 (Guerrero-Bote & Moya-Anegón, 2012) (see ANNEX – A1.a).

The category of 'sustainability' journals was defined through iterative refinement of keyword search results and informed reviews conducted by the NanoFabNet team. The subsequent mapping exercise was conducted within the thus identified subset of 'sustainability' journals (see ANNEX – A1.b).

Box 2 summarises the number of cleaned articles per publication year for both the dataset of (a) 'nanoscience & nanotechnology' and the dataset of (b) 'sustainability'.

Box 2: Summary of the cleaned, unique documents used for the bibliographic analysis of keywords for the discipline categories of (a) 'Nanoscience & Nanotechnology' and (b) 'Sustainability' per year.

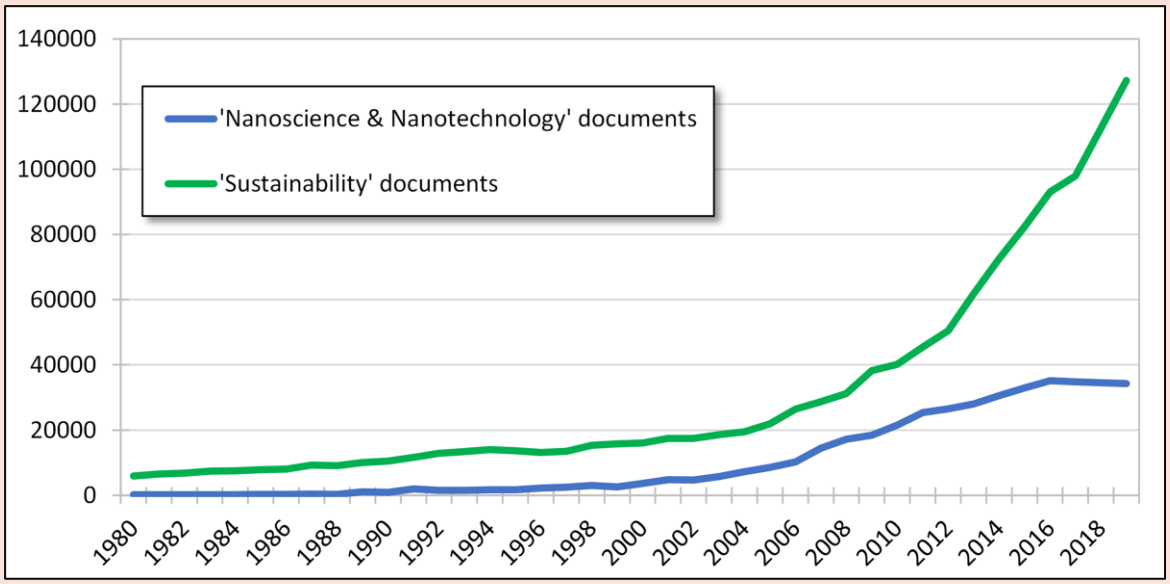


Figure 12: Summarising illustration of the number of documents used for the bibliographic analysis of keywords for the discipline categories of (a) 'nanoscience & nanotechnology' and (b) 'sustainability' per year.

Table 4: Number of documents used for the bibliographic analysis of keywords for the discipline categories of (a) 'nanoscience & nanotechnology' and (b) 'sustainability' per year.

Year	'Nanoscience & Nanotechnology'	'Sustainability'	Year	'Nanoscience & Nanotechnology'	'Sustainability'
1980	234	5969	2000	3657	16094
1981	201	6517	2001	4794	17461
1982	204	6781	2002	4683	17487
1983	237	7401	2003	5783	18635
1984	236	7553	2004	7216	19485
1985	314	7895	2005	8547	21952
1986	328	8060	2006	10242	26474
1987	362	9247	2007	14469	28770
1988	284	9074	2008	17170	31206
1989	1079	10040	2009	18437	38220
1990	923	10498	2010	21544	40154
1991	1935	11611	2011	25399	45491
1992	1527	12843	2012	26514	50441
1993	1491	13369	2013	28004	61824
1994	1691	14048	2014	30581	72616
1995	1713	13672	2015	32949	82434
1996	2252	13154	2016	35146	93066
1997	2461	13457	2017	34784	97887
1998	2996	15312	2018	34575	112582
1999	2599	15795	2019	34253	127269
			Total	**421814**	**1231844**

4.1.1 Data Cleaning

Since no single journal utilised in the analysis was listed in both the category of (a) 'nanoscience & nanotechnology' and (b) 'sustainability', the cleaning of datasets focussed on the removal of duplicates (e.g. those cause by the inclusion of a commentary, retraction or 'erratum report' of an article in the same journal; these often reproduce the full title of the article) and/or irrelevant tiles (e.g. such as articles entitled *'Editorial'*, or *'Preface'*).

4.1.2 Network Mapping for Keywords of 'Nanoscience & Nanotechnology' and 'Sustainability'

Bibliometric 2D keyword maps were created and visualised using the VOSviewer Programme[4] (see Box 3 below). All maps were created using a combined thesaurus file that had been created from a detailed analysis of all annual maps of both 'nanoscience & nanotechnology' and 'sustainability'; the thesaurus contained 634 entries that either replaced terms (e.g. *'zno'* -> *'zinc oxide'*) or eliminated irrelevant terms (e.g. *'Argentina'*, *'challenge'*):

- The creation of network maps was conducted using the programme's default settings on the 'title'-fields of the underlying publication datasets only.
- The visualisations of the resulting 2D maps utilised the settings provided in Box 3 below.

Box 3: Summary of VOSviewer settings utilised throughout all analyses.

VOSviewer Settings - Creation

- Default settings:
  - Normalisation Method: Association
  - Layout: default
  - Clustering: DO NOT merge small clusters

VOSviewer Setting – Visualisation

<table>
<tr><th>Network Visualisation</th><th>Overlay Visualisation</th><th>Density Visualisation</th></tr>
<tr><td colspan="3">Visualisation:
- Scale: 1.51
Weights: Occurrence</td></tr>
<tr><td colspan="3">Labels:
- Size variation: 1.00
- Circles
- Max. length: no limitation
Font: Open Sans</td></tr>
<tr><td colspan="2">Lines:
- Size variation: 0.5
- Min. strength: set to 10% of the total number of links
- Max. strength: no limitation
- Coloured lines
- Curved lines</td><td>Density:
- Kernel width: 1.20
- Item density</td></tr>
<tr><td>Colours:
- Cluster colours</td><td>Colours:
- Plasma colours
- No normalisation</td><td>Colours:
- Viridis</td></tr>
</table>

The settings described above were utilised to create the Maps of the Top 50 keywords, shown and discussed in Section 3.1 (see also ANNEX – A2.a and ANNEX – A2.b).

4.1.3 Analyses of Authors and geographic Spread of Excellence

Geographical authorship analyses of publications were conducted using the information provided on the Elsevier Scopus® database[4], and visualised using the map charts of the Microsoft Excel programme (Microsoft 365; Excel Version 2204).

4.2 Analyses of Horizon 2020 Projects

To identify projects concerned with nanotechnology and sustainability funded by the European Union, the EU Portal data.europe.eu[8] was used as the main data sources; a set of *.xlsx data files was downloaded and further processed using the programmes VantagePoint[2] and Microsoft Office Excel for data cleaning and visualisation.

At the time of the data retrieval, a total number of 35.372 projects were listed within the CORDIS database and further used for analysis. The listed projects' 'objective'-descriptions were processed for keyword analysis using the natural language processing (NLP) tool of the VantagePoint software[2]. The generated multi-word phrases were subsequently subjected to keyword searches (see Section 3.2):

- Single keyword searches (binary counting) resulted in **(a) "nano*" 3040 projects**, and **(b) "sustainab*" 4788 projects**, respectively.[9]
- A cross-correlation between the two datasets (a) and (b) to identify projects whose contained **both** the keywords **"nano*" and "sustainab*"** yielded **316 projects**.

4.2.1 Geographical Analyses

Geographical analyses of project partner organisations and their countries of origin were conducted and results visualised using the programmes VantagePoint and Microsoft Office Excel.

4.3 Stakeholder Identification

Individual stakeholders will be identified by searching for the most relevant keywords of 'nanoscience& nanotechnology' in the publications of the 'sustainability' field, and extracting the contact details of authors. These will be contacted once (*via* email) to be notified of the establishment of the NanoFabNet Hub, and invited to engage with the Hub's activities. All identifications and approaches will be done under full consideration of GDPR and other relevant privacy policies.

[8] data.europe.eu: https://data.europa.eu/en; H2020 project dataset downloaded from: https://data.europa.eu/data/datasets/cordish2020projects?locale=en (last accessed: 30. May 2022)

[9] The "*" was used as truncation mark to encompass all related forms of the keywords (e.g. adjectives, nouns).

5. Conclusions

The core aim of the analyses presented and discussed in this report was to gain an understanding of the delineations of the R&I fields of (a) 'nanofabrication' (by proxy of 'nanoscience & nanotechnology') and (b) 'sustainability', both in terms of the research topics and objectives addressed by the two fields, and the individual players involved in the R&I conducted, in order to better define both the target stakeholders and niche services and activities of the NanoFabNet Hub.

5.1 Delineation of the Fields of 'Nanofabrication' and 'Sustainability'

The bibliographic analysis of over 1.6 million scientific publications in nanotechnology and sustainability revealed that the two fields are acting largely separately from each other; scientific journals, for instance, which offer a pre-defined overlap between the fields of biotechnology and nanotechnology (Friedrichs, 2018), keep publications pertaining to the wide topic of 'sustainability' separate from those concerned with nanotechnology.

These findings strongly support the need for a community space, such as the planned NanoFabNet Hub, which encourages the **establishment of new individual connections and collaborative research in** the area of **'sustainable high-tech innovation'**.

A strongly international authorship of the publications in both fields of research support the need to provide a network for a truly international membership, and to engage this geographically and thematically diverse membership at an early stage of the network's development.

5.2 Stakeholders & Excellence in the Field of 'Nanofabrication' and 'Sustainability'

An investigation of the projects funded by the European Union's 8th Framework Programme, Horizon 2020, showed that 10% of all analysed projects are concerned with both 'nanotechnology' and 'sustainability'; a high proportion of these projects (i.e. over 30%) focusses on the establishment of new research collaborations and the development of individual researchers' skills and mobility, while over 10% of the projects are conducted by SMEs, with pronounced industry- and market-oriented goals. These findings strongly impact the development of services and products of the NanoFabNet Hub, as well as its structural and organisational provisions.

5.3 Development of the NanoFabNet Database as the 'digital Twin' of the Community

The landscape mapping and data collection approaches described in this report were used to create the underlying structure of the NanoFabNet Database, whose main goal is to provide structured access to the collected and curated information that is relevant to an interdisciplinary expert community of sustainable high-tech innovation. In doing so, the database is providing a major contribution to the implementation of the 2030 strategic roadmap for sustainable nanofabrication, to be published by the NanoFabNet Project in due course.

5.4 Outlook

The identified publications and projects pertaining to research in both the field of 'nanotechnology' and 'sustainability' provide a wide range of knowledge about both (a) the opportunities and challenges for a new network that is to be established in the strongly interdisciplinary field of 'sustainable high-tech, (b) the countries and individual researchers engaged in the two fields, and (c) the services and products that the NanoFabNet Hub should develop with its members and offer to the nascent community it aims to address.

The obtained results leave room for more in-depth analyses, such as identification of centres of excellence in each one of the fields, as well as longitudinal trend analyses of both the R&I topics/objectives addressed and the individual research institutions involved in the work.

6. Bibliography

Friedrichs, S. (2018). *Report on statistics and indicators of biotechnology and nanotechnology, OECD Science, Technology and Industry Working Papers, No. 2018/06.* Paris: OECD Publishing. Retrieved from http://dx.doi.org/10.1787/3c70afa7-en

Guerrero-Bote, V., & Moya-Anegón, F. (2012, 10 1). A further step forward in measuring journals' scientific prestige: The SJR2 indicator. *Journal of Informetrics, 6*(4), 674-688. doi:10.1016/j.joi.2012.07.001

Marquardt, C., Scholz, S. G., Nau, K., & Schmidt, A. (2022). Development of a Database for the Management and Use of available Resources in the Field of Susatinable Nanomanufacturing. *Conference Series: SDM-2022 - 9th International Conference on Sustainable Design and Manufacturing*, (submitted; to be published in a volume of the KES Smart Innovation Systems and Technologies series, submitted for indexing in Scopus and Thomson-Reuters Conference Proceedings Citation Index (CPCI) and the Web of Science).

ANNEX – A1.a: Meta-Data: Documents in the Field of 'Nanoscience & Nanotechnology'

In the case of 'nanofabrication', the bibliographic mapping analysis was conducted as described in the NanoFabNet report entitled 'Methodology for Stakeholders' Identification & Profiling' (D1.1, PU, published 24.06.2020); the mapping was conducted within the 'nanoscience and nanotechnology' category of journals, defined by SCImago for the Elsevier Scopus® database, based on the SCImago Journal Rank (SJR) indicator, accumulated over the years 1999-2019 [Guerrero-Bote et al. 2012]; Box 4 below shows the resulting query string, and Table 5 lists the corresponding journal titles.

Box 5 describes the statistics of (a) number count and (b) subject area of the individual 'nanoscience & nanotechnology' documents, retrieved from the corresponding journals; Box 6 shows statistics of the origins of the document's authors.

Box 4: Query String for the Advanced Search for 'Nanoscience & Nanotechnology' Journals (1980-2019).

SCOPUS 'Advanced Search' query string for all journals on 'Nanoscience & Nanotechnology', 1980-2019

ISSN ("09359648" OR "15214095" OR "13596462" OR "09215093" OR "01429612" OR "18785905" OR "18734235" OR "09565663" OR "09574484" OR "13616528" OR "13616439" OR "09601317" OR "13869477" OR "01679317" OR "13871811" OR "1536383X" OR "15364046" OR "01416359" OR "1616301X" OR "09467076" OR "15728781" OR "13872176" OR "09598324" OR "00262714" OR "19342608" OR "19327447" OR "19327455" OR "10274510" OR "18197094" OR "13880764" OR "1572896X" OR "15334899" OR "15334880" OR "14730197" OR "14730189" OR "15306992" OR "15306984" OR "15361241" OR "15582639" OR "1536125X" OR "19325134" OR "19325150" OR "17518741" OR "14773155" OR "15694429" OR "15694410" OR "16058127" OR "16065131" OR "17935350" OR "0219581X" OR "14757435" OR "15461955" OR "15461963" OR "16134982" OR "16134990" OR "19475756" OR "19475748" OR "17403499" OR "20413092" OR "15504832" OR "15504840" OR "13480391" OR "17904439" OR "15499634" OR "15499642" OR "1546203X" OR "15462080" OR "16136829" OR "16136810" OR "15734137" OR "17469406" OR "17469392" OR "11782013" OR "11769114" OR "17458080" OR "17458099" OR "1936086X" OR "19360851" OR "19321058" OR "19427808" OR "19324510" OR "17528941" OR "17528933" OR "15507041" OR "15507033" OR "17532515" OR "17532507" OR "15577929" OR "15577910" OR "19448252" OR "19448244" OR "18423582" OR "1943085X" OR "19430906" OR "19430833" OR "19430841" OR "19430884" OR "19430876" OR "18800688" OR "15551318" OR "1555130X" OR "16874129" OR "16874110" OR "16726030" OR "17486963" OR "17435889" OR "1556276X" OR "19317573" OR "17480132" OR "17483387" OR "17483395" OR "15571955" OR "17500443" OR "18714765" OR "18714757" OR "17435390" OR "17435404" OR "22124020" OR "18722105" OR "18653936" OR "18653928" OR "16619897" OR "16625250" OR "17932920" OR "16606795" OR "22352074" OR "21505578" OR "23116706" OR "21505551" OR "19980124" OR "19980000" OR "20403372" OR "20403364" OR "19950780" OR "19950799" OR "19472943" OR "19472935" OR "19395116" OR "19390041" OR "21904286" OR "19492944" OR "19492952" OR "19487185" OR "18764037" OR "18764029" OR "19414900" OR "19414919" OR "11778903" OR "17880718" OR "21583226" OR "21585857" OR "21585849" OR "22106812" OR "22106820") AND (LIMIT-TO (SRCTYPE , "j")) AND (EXCLUDE (EXACTSRCTITLE , "Undefined"))

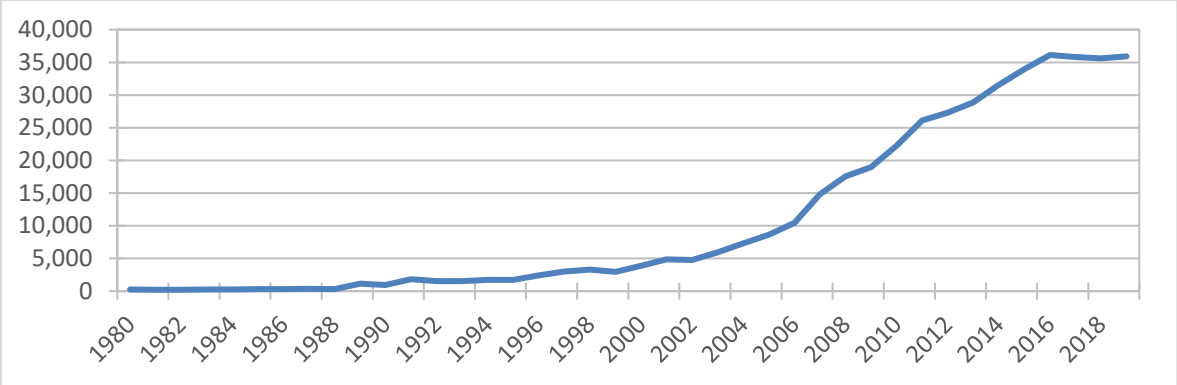
Table 5: List of 'Nanoscience & Nanotechnology' Journal Titles, 1980-2019.

'Nanoscience & Nanotechnology' Journals, 1980-2019			
1	Advanced Materials	48	ACS Nano
2	Scripta Materialia	49	Biomicrofluidics
3	Materials Science & Engineering A: Structural Materials: Properties, Microstructure and Processing	50	IEEE Nanotechnology Magazine

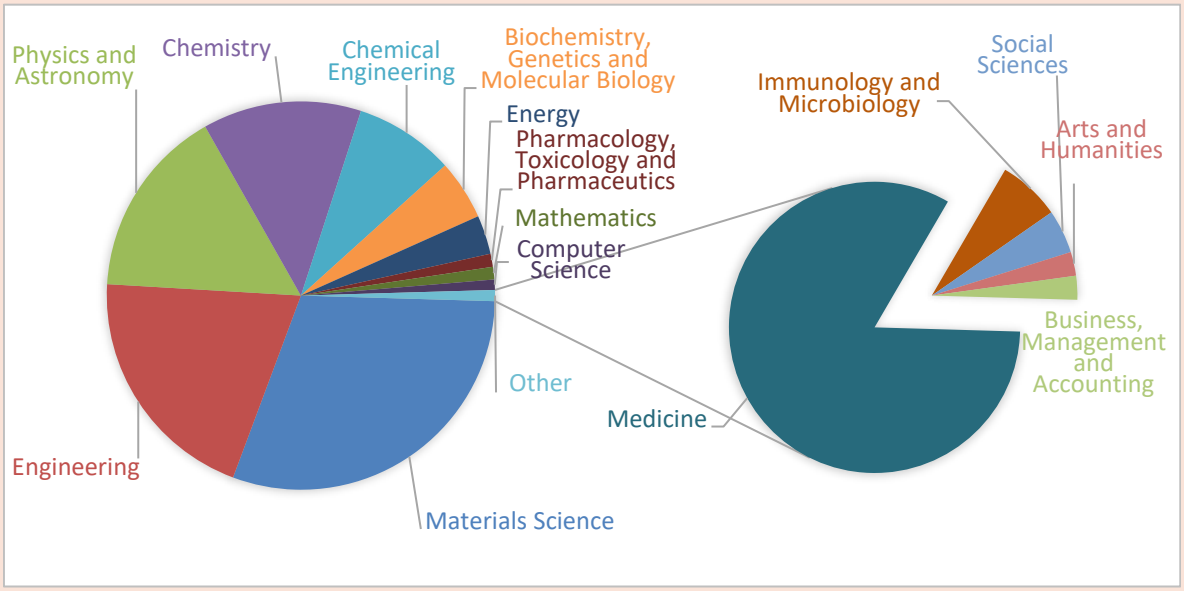
'Nanoscience & Nanotechnology' Journals, 1980-2019			
4	Biomaterials	51	International Journal of Nano and Biomaterials
5	Biosensors and Bioelectronics	52	Journal of Biomedical Nanotechnology
6	Nanotechnology	53	International Journal of Nanoparticles
7	Journal of Micromechanics and Microengineering	54	Journal of Bionanoscience
8	Physica E: Low-Dimensional Systems and Nanostructures	55	ACS Applied Materials & Interfaces
9	Microelectronic Engineering	56	Digest Journal of Nanomaterials and Biostructures
10	Microporous and Mesoporous Materials	57	International Journal of Green Nanotechnology: Biomedicine
11	Fullerenes Nanotubes and Carbon Nanostructures	58	International Journal of Green Nanotechnology: Materials Science and Engineering
12	Precision Engineering	59	International Journal of Green Nanotechnology: Physics and Chemistry
13	Advanced Functional Materials	60	Journal of Laser Micro Nanoengineering
14	Microsystem Technologies	61	Journal of Nanoelectronics and Optoelectronics (discontinued)
15	Biomedical Microdevices	62	Journal of Nanomaterials
16	Microelectronics Journal	63	Nami Jishu yu Jingmi Gongcheng/ Nanotechnology and Precision Engineering
17	Microelectronics Reliability	64	Nanomedicine
18	Journal of Nanophotonics	65	Nanoscale Research Letters
19	Journal of Physical Chemistry C	66	Nano Today
20	Journal of Surface Investigation	67	Nature Nanotechnology
21	Journal of Nanoparticle Research	68	Plasmonics
22	Journal of Nanoscience and Nanotechnology (discontinued)	69	Micro and Nano Letters
23	Lab on a Chip - Miniaturisation for Chemistry and Biology	70	NanoEthics
24	Nano Letters	71	Nanotoxicology
25	IEEE Transactions on Nanobioscience	72	Recent Patents on Nanotechnology
26	IEEE Transactions on Nanotechnology	73	Journal of Micro-Nano Mechatronics
27	Journal of Micro/ Nanolithography, MEMS, and MOEMS	74	Journal of Nano Research
28	IET Nanobiotechnology	75	Nano
29	Journal of Nanobiotechnology	76	Nanotechnology Perceptions
30	Photonics and Nanostructures - Fundamentals and Applications	77	Nano Biomedicine and Engineering
31	Reviews on Advanced Materials Science	78	Nano-Micro Letters
32	International Journal of Nanoscience	79	Nano Research
33	International Journal of Nanotechnology	80	Nanoscale
34	Journal of Computational and Theoretical Nanoscience	81	Nanotechnologies in Russia
35	Microfluidics and Nanofluidics	82	Science of Advanced Materials (discontinued)
36	International Journal of Nanomechanics Science and Technology	83	Wiley interdisciplinary reviews. Nanomedicine and nanobiotechnology
37	Proceedings of the Institution of Mechanical Engineers, Part N: Journal of Nanoengineering and Nanosystems	84	Beilstein Journal of Nanotechnology
38	ACM Journal on Emerging Technologies in Computing Systems	85	Journal of Nanotechnology in Engineering and Medicine
39	e-Journal of Surface Science and Nanotechnology	86	Journal of Physical Chemistry Letters
40	Journal of Nanostructured Polymers and Nanocomposites	87	Micro and Nanosystems
41	Nanomedicine: Nanotechnology, Biology, and Medicine	88	Nanoscience and Nanotechnology Letters (discontinued)
42	Nanotechnology Law and Business	89	Nanotechnology, Science and Applications
43	Small	90	Nanopages
44	Current Nanoscience	91	AIP Advances
45	International Journal of Nanomanufacturing	92	Materials Express
46	International Journal of Nanomedicine	93	Nanoscience and Nanotechnology - Asia
47	Journal of Experimental Nanoscience		

Box 5: Statistics of the individual 'Nanoscience & Nanotechnology' Documents, retrieved from the corresponding Journals.

(a) Number of individual documents in 1980-2019 'Nanoscience & Nanotechnology' journals (according to SJR Ranking 1999-2019 (cumulative))



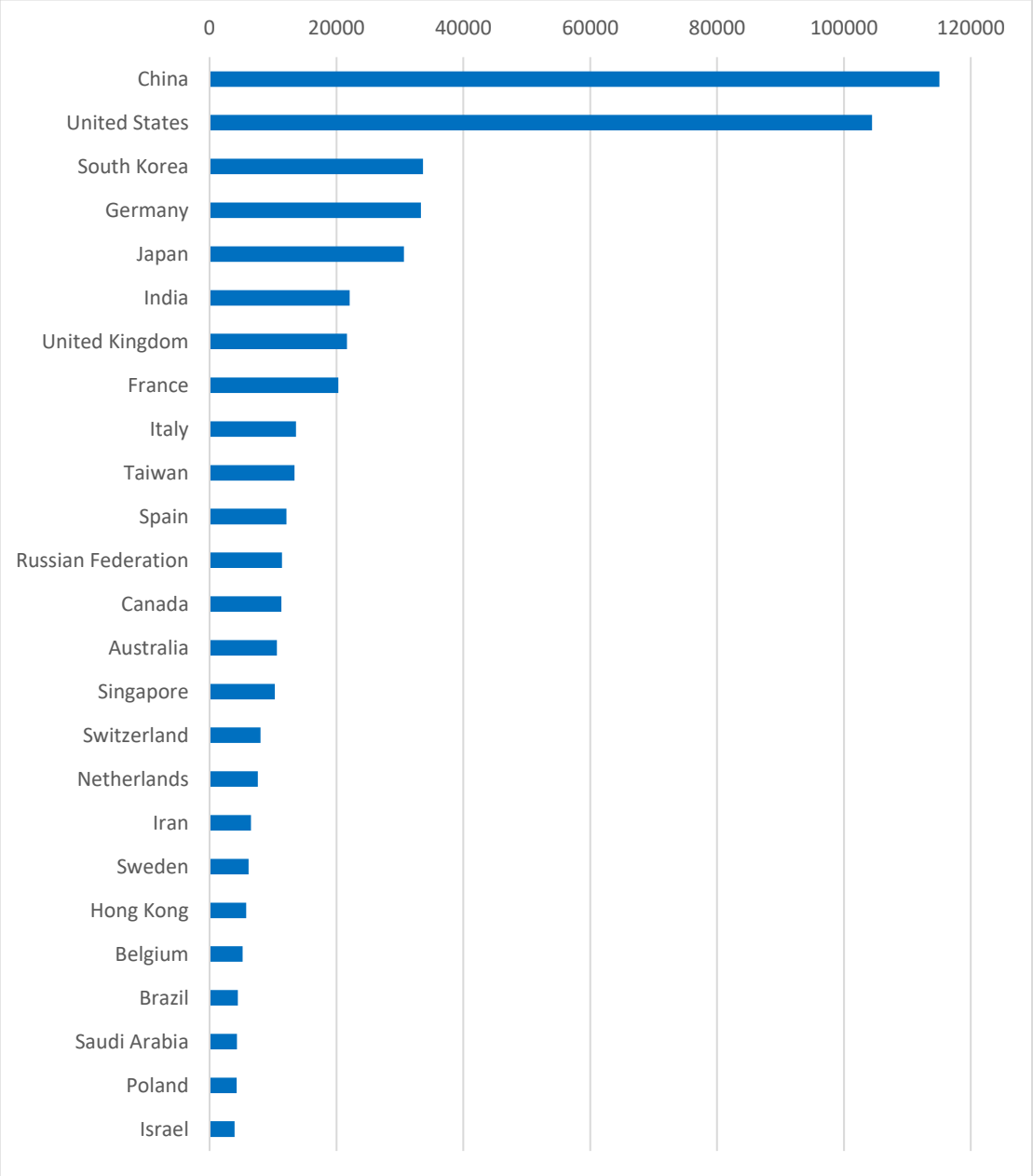
(b) 'Nanoscience & Nanotechnology' documents (1980 – 2019) categorised into Scopus Subject Areas



[NOTE: documents may be assigned to more than one Scopus Subject Area]

Box 6: Statistics of the origin of the authors of documents in 'Nanoscience & Nanotechnology' journals, 1980-2019.

Top 25 origins of the authors of documents in 'Nanoscience & Nanotechnology' journals, 1980-2019



ANNEX – A1.b: Meta-Data: Documents in the Field of 'Sustainability'

In the case of 'technology sustainability', a subset of relevant journals was identified according to the process described in in the NanoFabNet report entitled 'Methodology for Stakeholders' Identification & Profiling' (D1.1, PU, published 24.06.2020); the category of 'sustainability' journals was defined through iterative refinement of keyword search results and informed reviews conducted by the NanoFabNet team. The subsequent mapping exercise was conducted within the thus identified subset of journals concerned with 'sustainability', following the same process as the one applied to the 'nanoscience & nanotechnology' journals. Box 7 below shows the resulting query string, and Table 6 lists the corresponding journal titles.

Box 7: Query String for the Advanced Search of Journals concerned with 'sustainability' (1980-2019)

SCOPUS 'Advanced Search' query string for all journals on 'Sustainability', 1980-2019

ISSN ("20711050" OR "13640321" OR "09596526" OR "18791786" OR "21680485" OR "22106707" OR "00489697" OR "18791026" OR "19417012" OR "19447450" OR "19447442" OR "1387585X" OR "15732975" OR "10958630" OR "03014797" OR "17433541" OR "03014215" OR "09218009" OR "19493029" OR "09669582" OR "17477646" OR "09730826" OR "17452627" OR "13504509" OR "09213449" OR "18790658" OR "10440046" OR "15407578" OR "10000933" OR "18722032" OR "18736785" OR "03605442" OR "1540756X" OR "10549811" OR "03062619" OR "23984902" OR "02648377" OR "1470160X" OR "03781127" OR "09441344" OR "16147499" OR "09500618" OR "14676370" OR "0308597X" OR "19961073" OR "18773435" OR "20734441" OR "1678809" OR "10991719" OR "09680802" OR "09601481" OR "14639262" OR "14639270" OR "17730155" OR "17740746" OR "10763333" OR "16617827" OR "16604601" OR "1439073" OR "20711050" OR "0013936" OR "15205851" OR "09608524" OR "18732976" OR "03603199" OR "18624065" OR "18624057" OR "09645691" OR "1743761X" OR "17437601" OR "22839216" OR "1864564X" OR "18645631" OR "10990836" OR "09644733" OR "20462069" OR "22131388" OR "0956053X" OR "18792456" OR "17083087" OR "1478646X" OR "14786451" OR "10026819" OR "0364152X" OR "14321009" OR "18736416" OR "14629011" OR "15730697" OR "01674544" OR "03787788" OR "09619534" OR "15822559" OR "01676369" OR "15732959" OR "15568334" OR "15568318" OR "01406736" OR "1474547X" OR "09483349" OR "16147502" OR "02731223" OR "03783774" OR "01692046" OR "20507496" OR "20507488" OR "01968904" OR "16547209" OR "00447447" OR "0308521X" OR "18732267" OR "26883627" OR "01487191" OR "18666299" OR "18666280" OR "23989629" OR "14696711" OR "13549839" OR "14784629" OR "17517680" OR "13858947" OR "00401625" OR "10881980" OR "15309290" OR "19448244" OR "19448252" OR "00221694" OR "13706071" OR "19397038" OR "19397046" OR "00448486" OR "18727026" OR "03043800" OR "21683565" OR "21683573" OR "14337851" OR "15213773" OR "07981015" OR "0305750X" OR "18735991" OR "14735903" OR "1747762X" OR "16713990" OR "1618954X" OR "01657836" OR "14787466" OR "14746778" OR "24682039" OR "26727226" OR "18238556" OR "09258574" OR "00157546" OR "20297017" OR "20297025" OR "09204741" OR "15731650" OR "17460573" OR "17460581" OR "15353958" OR "15353966" OR "13899341" OR "14695871" OR "13504622" OR "15729680" OR "01674366" OR "23450282" OR "09601406" OR "17415268" OR "14712458" OR "13600559" OR "09640568" OR "2352801X" OR "19994907" OR "1664462X" OR "09266690" OR "00063207" OR "01973975" OR "02642751" OR "08885885" OR "15205045" OR "1099145X" OR "10853278" OR "15829596" OR "19950748" OR "19981074" OR "19443994" OR "19443986" OR "09593780" OR "18729495" OR "03601323" OR "17489326" OR "10959289" OR "10543139" OR "00119164" OR "01671987" OR "00163287" OR "00431354" OR "18792448" OR "01959255" OR "09405550" OR "22105379" OR "14777835" OR "14726963" OR "09255273" OR "01650203" OR "14778947" OR "10019332" OR "0734242X" OR "10963669" OR "00456535" OR "19961944" OR "20724292" OR "24522236" OR "03043894" OR "00207543" OR "1366588X" OR "15729710" OR "09603115" OR "18726852" OR "03784290" OR "15728366" OR "0889048X" OR "13115065" OR "00167185") AND (LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2007) OR LIMIT-TO (PUBYEAR , 2006) OR LIMIT-TO (PUBYEAR , 2005) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000) OR LIMIT-TO (PUBYEAR , 1999) OR LIMIT-TO (PUBYEAR , 1998) OR LIMIT-TO (PUBYEAR , 1997) OR LIMIT-TO (PUBYEAR , 1996) OR LIMIT-TO (PUBYEAR , 1995) OR LIMIT-TO (PUBYEAR , 1994) OR LIMIT-TO (PUBYEAR , 1993) OR LIMIT-TO (PUBYEAR , 1992) OR LIMIT-TO (PUBYEAR , 1991) OR LIMIT-TO (PUBYEAR , 1990) OR LIMIT-TO (PUBYEAR , 1989) OR LIMIT-TO (PUBYEAR , 1988) OR LIMIT-TO (PUBYEAR , 1987) OR LIMIT-TO (PUBYEAR , 1986) OR LIMIT-TO (PUBYEAR , 1985) OR LIMIT-TO (PUBYEAR , 1984) OR LIMIT-TO (PUBYEAR , 1983) OR LIMIT-TO (PUBYEAR , 1982) OR LIMIT-TO (PUBYEAR , 1981) OR LIMIT-TO (PUBYEAR , 1980)) AND (LIMIT-TO (SRCTYPE , "j")) AND (EXCLUDE (EXACTSRCTITLE , "Undefined"))

Table 6: List of Journal Titles concerned with 'sustainability', 1980-2019

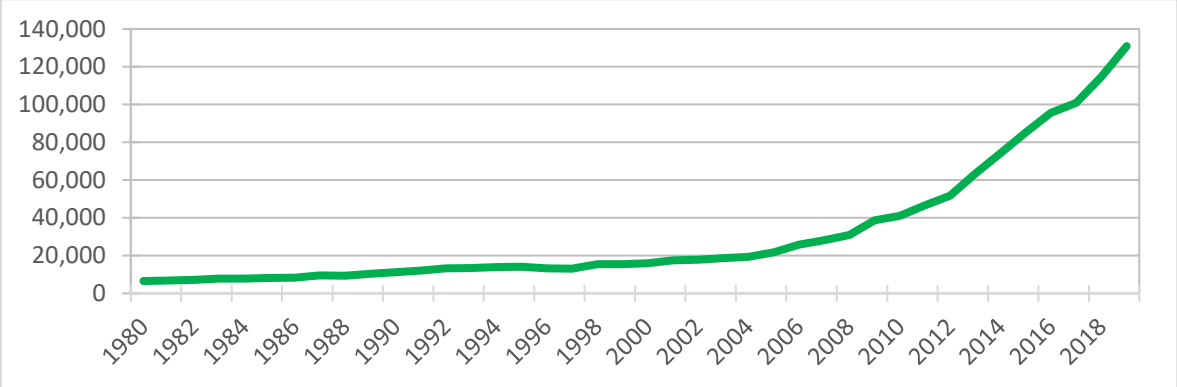
Journals concerned with 'Sustainability', 1980-2019			
1	Lancet	81	Resources Conservation And Recycling
2	SAE Technical Papers	82	Environmental Engineering And Management Journal
3	Rsc Advances	83	Forests
4	Angewandte Chemie International Edition	84	Geoforum
5	Industrial And Engineering Chemistry Research	85	Ambio
6	Science Of The Total Environment	86	Ocean And Coastal Management
7	ACS Applied Materials And Interfaces	87	Futures
8	Chemosphere	88	Agricultural Systems
9	International Journal Of Hydrogen Energy	89	Quality Access To Success
10	Environmental Science And Technology	90	Forestry Chronicle
11	Bioresource Technology	91	Agroforestry Systems
12	Water Science And Technology	92	Waste Management And Research
13	Chemical Engineering Journal	93	Habitat International
14	Journal Of Hazardous Materials	94	Cities
15	Water Research	95	Ecology And Society
16	Energy	96	Environmental Science And Policy
17	Journal Of Cleaner Production	97	International Journal Of Life Cycle Assessment
18	Sustainability Switzerland	98	Journal Of Renewable And Sustainable Energy
19	Journal Of Materials Chemistry A	99	Journal Of Environmental Protection And Ecology
20	Environmental Science And Pollution Research	100	Global Environmental Change
21	Construction And Building Materials	101	Land Degradation And Development
22	Aquaculture	102	Environmental Progress And Sustainable Energy
23	Journal Of Hydrology	103	Forest Policy And Economics
24	International Journal Of Environmental Research And Public Health	104	Sustainable Cities And Society
25	Applied Energy	105	Clean Technologies And Environmental Policy
26	Nongye Gongcheng Xuebao Transactions Of The Chinese Society Of Agricultural Engineering	106	Environmental Impact Assessment Review
27	BMC Public Health	107	Journal Of Environmental Planning And Management
28	Energies	108	Journal Of Industrial Ecology
29	Forest Ecology And Management	109	Agriculture And Human Values
30	Desalination	110	IEEE Transactions On Sustainable Energy
31	Energy Conversion And Management	111	Environment Development And Sustainability
32	Desalination And Water Treatment	112	Journal Of Sustainable Tourism
33	Energy Policy	113	Energy For Sustainable Development
34	Renewable Energy	114	Journal Of Sustainable Agriculture
35	Environmental Monitoring And Assessment	115	Local Environment
36	Materials	116	International Journal Of Sustainable Development And World Ecology
37	Frontiers In Plant Science	117	Natural Resources Forum
38	Shengtai Xuebao Acta Ecologica Sinica	118	Environmental Education Research
39	Journal Of Environmental Management	119	Journal Of Sustainable Forestry
40	Chemical Engineering Transactions	120	Business Strategy And The Environment
41	International Journal Of Production Research	121	Management Of Environmental Quality An International Journal
42	Remote Sensing	122	International Journal Of Sustainability In Higher Education
43	Renewable And Sustainable Energy Reviews	123	Gaia
44	Energy And Buildings	124	Current Opinion In Environmental Sustainability
45	Chinese Journal Of Applied Ecology	125	Resource Engineering And Technology For Sustainable World
46	Environmental Earth Sciences	126	Agronomy For Sustainable Development
47	Biological Conservation	127	Acta Ecologica Sinica
48	Ecological Modelling	128	Lancet London England
49	Journal Of Business Ethics	129	Sustainable Energy And Fuels
50	BMC Health Services Research	130	Sustainable Development
51	Industrial Crops And Products	131	International Journal Of Sustainable Development And Planning

Journals concerned with 'Sustainability', 1980-2019			
52	Angewandte Chemie International Edition In English	132	Sustainability Science
53	ACS Sustainable Chemistry And Engineering	133	Corporate Social Responsibility And Environmental Management
54	Green Chemistry	134	International Journal Of Sustainable Energy
55	Water Switzerland	135	Sustainability
56	Espacios	136	Sustainable Energy Technologies And Assessments
57	Waste Management	137	Proceedings Of The Institution Of Civil Engineers Engineering Sustainability
58	Building And Environment	138	International Journal Of Sustainable Transportation
59	International Journal Of Production Economics	139	Geo Eco Trop
60	World Development	140	Sustainable Environment Research
61	Wit Transactions On Ecology And The Environment	141	International Journal Of Environment And Sustainable Development
62	Ecological Indicators	142	International Journal Of Agricultural Sustainability
63	Biomass And Bioenergy	143	International Journal Of Sustainable Engineering
64	Ecological Economics	144	Journal Of Sustainability Science And Management
65	Fisheries Research	145	The Journal Of Applied Ecology
66	Ecological Engineering	146	International Journal Of Sustainable Development
67	Agricultural Water Management	147	World Review Of Entrepreneurship Management And Sustainable Development
68	Field Crops Research	148	Agroecology And Sustainable Food Systems
69	ICES Journal Of Marine Science	149	Journal Of Security And Sustainability Issues
70	Environmental Management	150	American Eurasian Journal Of Sustainable Agriculture
71	Biodiversity And Conservation	151	Nature Sustainability
72	Land Use Policy	152	Entrepreneurship And Sustainability Issues
73	Marine Policy	153	Ying Yong Sheng Tai Xue Bao The Journal Of Applied Ecology
74	Chemsuschem	154	Waste Management Research
75	Soil And Tillage Research	155	Sustainable Computing Informatics And Systems
76	Technological Forecasting And Social Change	156	Current Opinion In Green And Sustainable Chemistry
77	Water Resources Management	157	Groundwater For Sustainable Development
78	Environmental Research Letters	158	Angewandte Chemie International Ed In English
79	Landscape And Urban Planning	159	Chinese Journal Of Eco Agriculture
80	Science Of The Total Environment The	160	Land Degradation Development

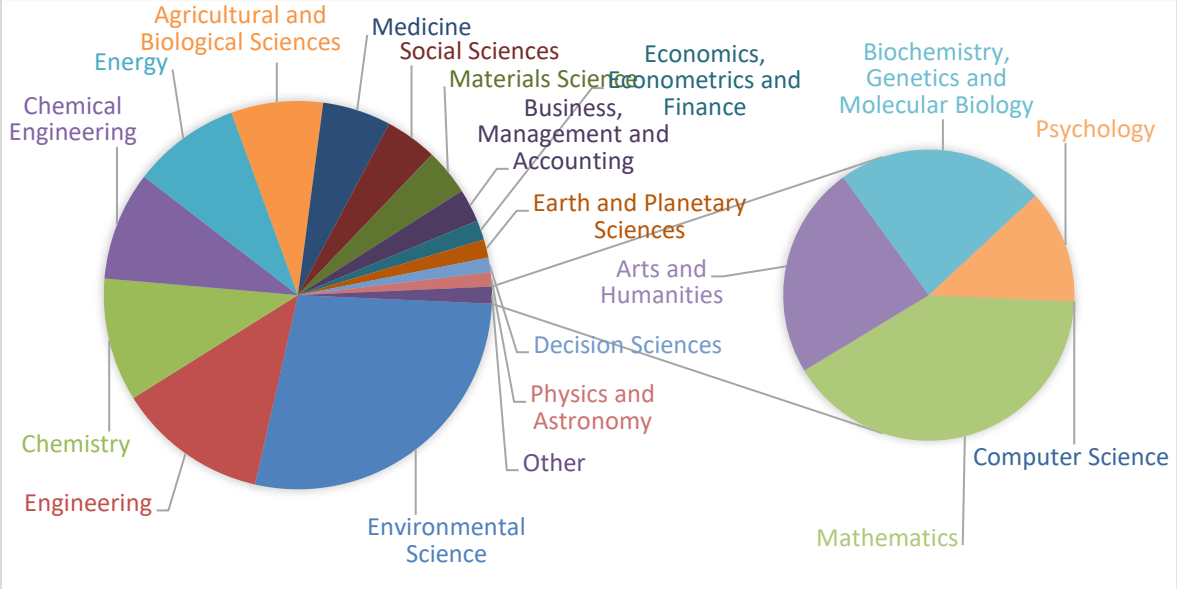
Box 8 describes the statistics of (a) number count and (b) subject area of the individual 'sustainability' documents, retrieved from the corresponding journals; Box 9 shows statistics of the origins of the document's authors.

Box 8: Statistics of the individual 'sustainability' documents, retrieved from the corresponding journals.

(a) Number of individual documents in 1980-2019 'sustainability' journals

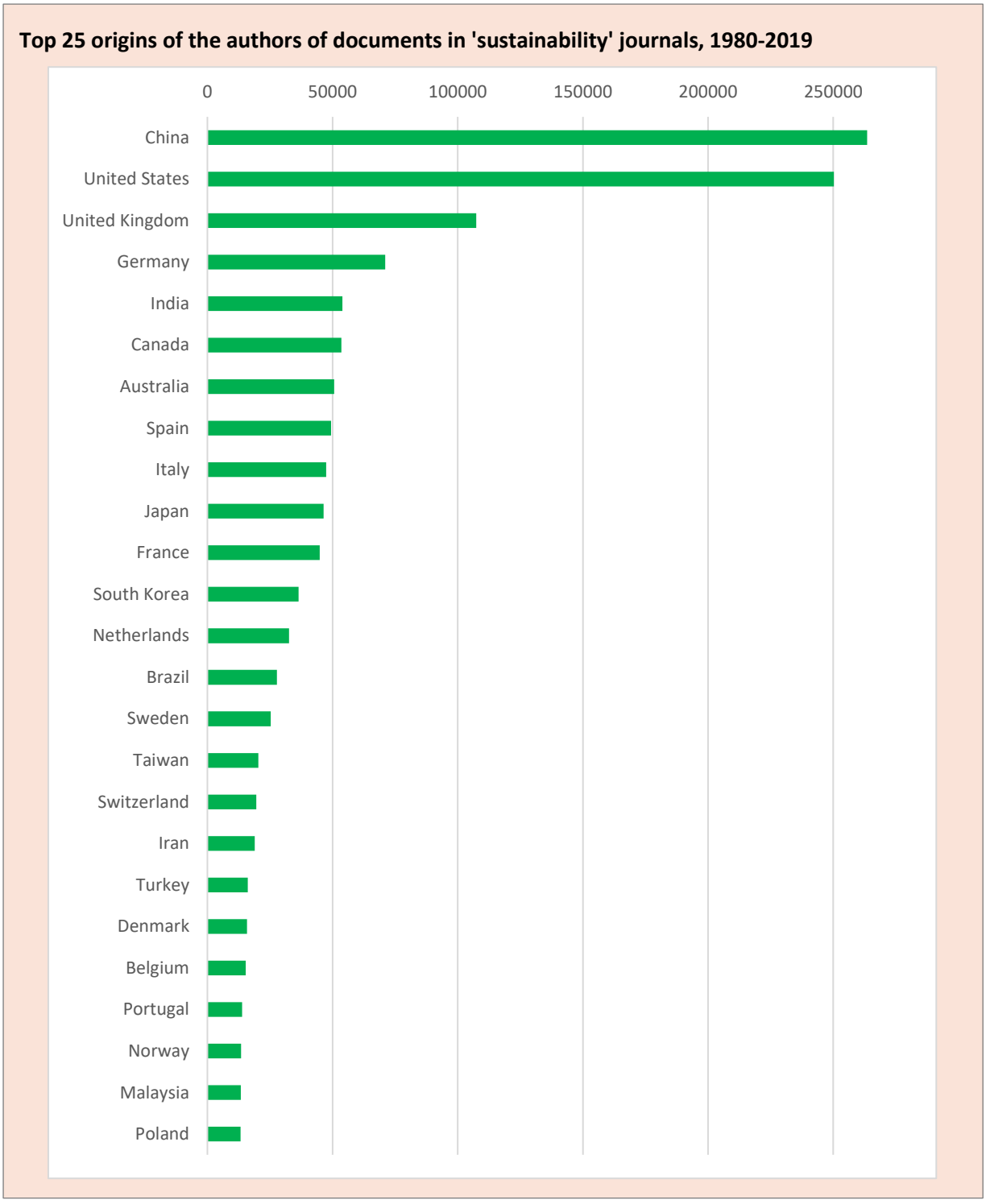


(b) 'Sustainability' documents (1980 – 2019) categorised into Scopus Subject Areas



[NOTE: documents may be assigned to more than one Scopus Subject Area]

Box 9: Statistics of the origin of the authors of documents in 'sustainability' journals, 1980-2019.



ANNEX – A2.a: Top 50 'Nanoscience & Nanotechnology' Keywords

Figure 13 provides a density map of the Top 50 keywords used in the titles of publication in the scientific journal category 'nanoscience & nanotechnology' from 1980 to 2019. A full list of the 50 keywords, their weight (i.e. number of occurrences) and score (i.e. average publication year) can be found in Table 7 below. [NOTE: The Top 50 keywords are dominated by those used most often in recent years, due to the strong increase of publications in the past 15-20 years.]

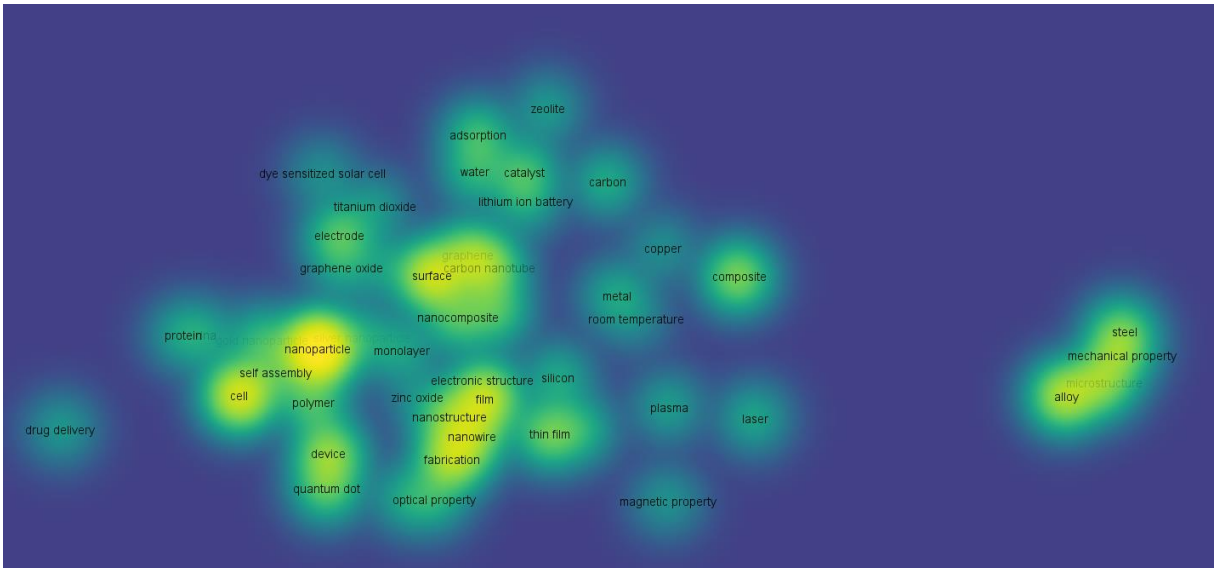


Figure 13: 2D density map of the Top 50 keywords occurring in all document titles of 1980 – 2019 in the journal category 'nanoscience & nanotechnology'.

Table 7: List of the Top 50 keywords occurring in all document titles of 1980 – 2019 in the journal category 'nanoscience & nanotechnology'; the list, weight and score were computed using the VOSviewer programme.

Keyword	weight<Occurrences>	score<Avg. pub. year>
nanoparticle	23024	2013.13
cell	13771	2012.82
surface	12124	2011.52
film	10728	2011.15
alloy	10099	2008.79
fabrication	9581	2011.16
device	7969	2011.61
carbon nanotube	7365	2011.25
composite	7303	2010.17
microstructure	7157	2010.60
nanowire	6701	2011.55
graphene	6269	2014.59
thin film	6068	2011.67
steel	5491	2009.95
nanostructure	5468	2011.82
quantum dot	5316	2011.07
electrode	5179	2012.41
mechanical property	4988	2011.46
nanocomposite	4613	2012.82
interface	4573	2012.34
polymer	4545	2010.75
catalyst	4265	2013.37
adsorption	4215	2012.29
gold nanoparticle	3680	2012.60
water	3107	2013.55

Keyword	weight<Occurrences>	score<Avg. pub. year>
morphology	2966	2011.74
carbon	2924	2012.89
self assembly	2789	2012.59
silicon	2724	2009.79
optical property	2657	2012.06
metal	2647	2010.70
laser	2553	2011.31
monolayer	2406	2011.95
protein	2375	2011.93
diode	2363	2011.63
silver nanoparticle	2345	2013.58
lithium ion battery	2314	2015.06
plasma	2121	2010.24
zeolite	1941	2010.87
graphene oxide	1939	2015.03
drug delivery	1890	2013.82
titanium dioxide	1814	2012.47
single walled carbon nanotube	1750	2010.66
dna	1675	2012.44
magnetic property	1633	2011.00
dye sensitized solar cell	1534	2012.46
copper	1435	2010.35
electronic structure	1117	2012.18
room temperature	1027	2012.02
zinc oxide	1012	2013.00

ANNEX – A2.b: Top 50 Keywords in Journals concerned with 'Sustainability'

Figure 4 provides a density map of the Top 50 keywords used in the titles of publication in the scientific journal category 'sustainability' from 1980 to 2019. A full list of the 50 keywords, their weight (i.e. number of occurrences) and score (i.e. average publication year) can be found in Table 7 below. [NOTE: The Top 50 keywords are dominated by those used most often in recent years, due to the strong increase of publications in the past 15-20 years.]

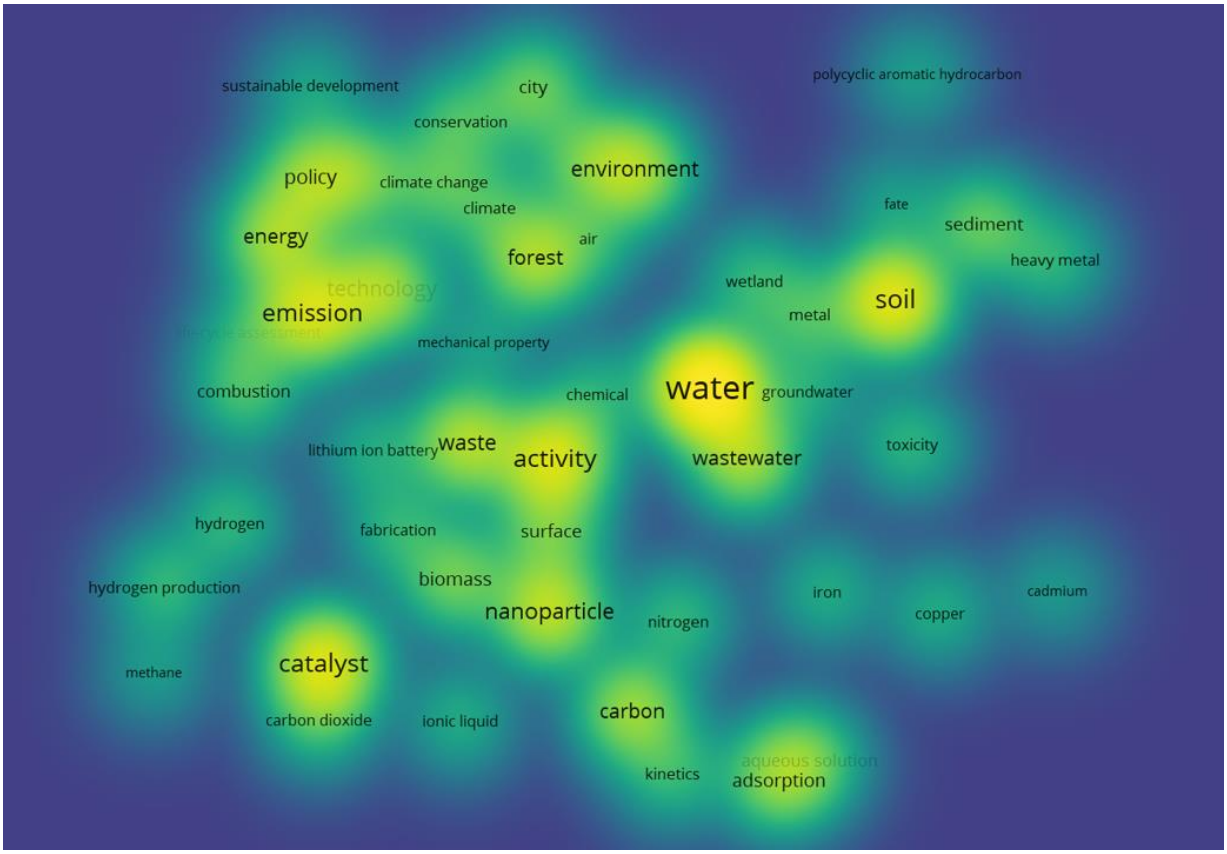


Figure 14: 2D density map of the Top 50 keywords occurring in all document titles of 1980 – 2019 in scientific journals concerned with 'sustainability'.

Table 8: List of the Top 50 keywords occurring in all document titles of 1980 – 2019 in scientific journals concerned with 'sustainability'; the list, weight and score were computed using the VOSviewer programme.

Keyword	weight<Occurrences>	score<Avg. pub. year>
water	26780	2009.18
soil	17962	2009.82
catalyst	16777	2012.62
activity	16049	2012.45
emission	15050	2010.38
nanoparticle	13329	2014.98
waste	12044	2011.68
environment	11956	2009.62
technology	11318	2009.07
forest	10836	2009.98
wastewater	10716	2010.55
energy	10429	2011.51
carbon	10413	2012.56

Keyword	weight<Occurrences>	score<Avg. pub. year>
policy	8877	2009.09
adsorption	8265	2011.76
biomass	7770	2012.45
city	7314	2012.62
sustainability	7108	2012.89
sediment	6985	2009.06
surface	6778	2011.85
aqueous solution	6164	2011.44
patient	5391	2003.33
combustion	5301	2009.38
conservation	5193	2008.02
climate change	5073	2013.19
metal	5024	2009.88
carbon dioxide	4704	2011.47
kinetics	4593	2009.42
hydrogen production	4468	2012.58
nitrogen	4438	2011.59
hydrogen	4301	2009.79
toxicity	4255	2009.22
wetland	4191	2011.14
heavy metal	4181	2009.77
climate	4112	2012.12
fabrication	4048	2015.13
air	3611	2008.03
chemical	3535	2009.05
ionic liquid	3518	2013.40
copper	3513	2009.74
iron	3513	2011.27
lithium ion battery	3349	2015.72
life-cycle assessment	3289	2012.83
groundwater	3136	2009.99
sustainable development	2923	2011.00
polycyclic aromatic hydrocarbon	2657	2010.18
fate	2566	2008.68
mechanical property	2486	2014.82
methane	2390	2011.39
cadmium	2264	2007.53

NanoFabNet
international Hub for sustainable industrial-scale Nanofabrication