

Critical review of the relevance and reliability of data sources, methods, parameters and determining factors to produce market studies on manufactured nanomaterials on the EU market

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Disclaimer

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Abstract

This report presents the results of a critical review on the relevance and reliability of data sources, methods, parameters and determining factors to produce market studies on manufactured nanomaterials on the EU market. This project serves as a basis for conducting and producing new studies on European nanomaterials market. It begins with analysing the data sources, methods and parameters already used for such market studies, and further identifies, proposes and analyses a further optimal combination of these data sources, methods, parameters and determining factors. A methodology comprising five work packages was developed. Searching for data sources from 2011 to present was conducted using publicly available online search tools as well as relevant authorities' websites such as ECHA, EC, Member States, etc.

From all sources identified and structured as commercial market studies, EU sources, Member States sources, data base sources and other data sources; 25 sources have been found to have: very high relevance, high relevance or relevance (17 commercial market studies, 5 EU sources, 2 Member States sources and 1 other data sources). As an overall conclusion, we suggest combining primary research, complemented by a Delphi method inviting different experts, and secondary research, based on three market studies identified as the most relevant.

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1. Executive summary

Applications of nanomaterials have increased at a growing rate in the past decade and have become part in healthcare, electronics, cosmetics and other areas of daily lives. Physical and chemicals properties of materials at the nanometre scale (e.g. antimicrobial properties and self-cleaning surfaces) enable novel applications. A segmentation of the heterogeneous market for nanomaterials follows both on the basis of material type and on the basis of applications. A precise definition for nanomaterials has been undertaken in a Commission Recommendation of 2011, which still provides a valid standard and is taken as a baseline for the scope of this study.

The objectives of this study comprise the following essential components:

- Gathering, analysis and summary of data sources, study methods, parameters and determining factors used for the production of market studies on manufactured nanomaterials
- Assessment of the relevance and reliability of the studies, methods, parameters and factors

Analysis started with the data sources, methods and parameters used for existing market studies, and it identified and analysed an optimal combination of these data sources, study methods, parameters and determining factors. This will serve as an input to produce a new market study on the European market of manufactured nanomaterials.

Methodology

The study has been structured into four consecutive tasks.

In **Task 1** a search was conducted to gather the main data sources. Several relevant sources have already been known in advance, such as official documents and information of EU authorities on nanomaterials, studies in this context with a focus on the market estimation and structure for nanomaterials, existing commercial market studies on nanomaterials, databases and inventories. In addition to those sources, an internet search on Google as well as on relevant authorities' websites (European Commission, European Chemicals Agency, etc.) and from Member States was conducted. Studies and other sources older than 2011 were not taken into consideration.

In **Task 2** the criteria for assessing the relevance and reliability of study methods, parameters and determining factors were defined considering the main outcomes of Task 1. The following five assessing criteria were defined:

- Criterion 1: Does the data source provide market data for a defined specific baseline year? This criterion will be as yes or no. In case of yes, it would be specified how differentiated is the market data (e.g. countries, regions, types of nanomaterials, etc)
- Criterion 2: Does the data source provide market forecasts into the future? This criterion will be as yes or no. In case of yes, it would be specified how differentiated is the market data (e.g. countries, regions, types of nanomaterials, etc)
- Criterion 3: Criteria for relevance and reliability of study methods and additional general assessment criteria. This criterion focuses on the study methods applied, including the type of source (primary, secondary, etc.). In addition, it addresses the independence/neutrality, credibility or tendentiousness of the study and source itself (author or editor) in general.

- Criterion 4: Specific assessment criteria applicable for particular types of studies only. This criterion addresses if there is any specific data or questions addressed in the study (e.g. it provides additional specific data input to other studies). Thus, the criterion will be yes/no and if yes, specify.
- Criterion 5: Does this study in particular address the different roles and specific importance of EU Member States (MS) for the nanomaterials market? This criterion addresses if there are any specific issues on Member States (e.g. availability of country-specific information). Thus, the criterion will be yes/no and if yes, specify.

These criteria were used to assess the relevance of the studies in the subsequent tasks 3 and 4. In **Task 3** it was described and analysed whether the data sources and study methods come across in different studies are both relevant and reliable for the purpose of gathering information in order to produce further market studies. This task also comprises suggestions for further adaptations and combinations in order to further increase the usefulness of market studies for manufactured nanomaterials.

In parallel to the evaluation done in Task 3, particular relevant parameters and determining or influential factors appearing either in all or in particular studies (such as general or specific growth rates) were recorded and systemized in **Task 4**. It is also examined whether there is an agreement on parameters or significant deviations can be observed, e.g. contrary opinions in the future market development or major differences in the view of the present markets versus future market projections. Draft conclusions were drawn on the combination and modification of parameters in order to improve results, and remaining information gaps identified.

The project results allow an answer to the following central questions of interest, pertaining both to the data sources and study methods on the whole (Task 3), but also on the specific parameters and factors used in detail (Task 4):

- What would be most relevant and reliable data sources and study methods or their combinations, but also most relevant and reliable parameters/factors or their combinations to produce a market study on current European market of manufactured nanomaterials?
- Why certain sources and methods, and certain parameters/factors are more relevant and reliable than others?
- Are there completely irrelevant and/or unreliable sources and methods as well as irrelevant and/or unreliable parameters/factors?

Main results

1.1 Initial decisions at the beginning of a market study

As a starting point, the definition of nanomaterials (in general or specific) has a high importance for carrying out a new market study on nanomaterials. Therefore, a principal decision shall be whether the (still valid) nanomaterial definition from the Commission Recommendation of 2011 shall be the only reference, or whether potential review options are of specific interest for the market study. This includes a fundamental decision which materials will be considered as nanomaterials. For this decision, the relevant EU documents are the main data sources.

Having identified by this decision which nanomaterials according to the definition applied overall exist in the European market, the next decision shall be whether the total market of nanomaterials shall be the focus of the study or some specific markets with regard to material types and/or applications. This shall also be decided upon on the basis of the main

purpose and interest for this study.

1.2 Relevance and reliability of data sources, study methods and their combinations to gather information

Regarding the relevance and reliability of data sources, study methods and their combinations to gather information; 12 data sources were found of very high relevance or high relevance (9 commercial market studies, 1 EU source, 1 Member States source and 1 other source). Database sources were not found relevant for producing market studies, since they contain very specific technical data but not quantitative data on volumes and market trends and developments.

The most relevant market studies and further data sources are listed in Table 14.

Table 1: Market studies and further sources assessed as most relevant

Ranking / No. of studies	Market study / data sources
Very high relevance (3 studies)	<ul style="list-style-type: none"> Commercial market studies from Allied Market Research: Europe Nanomaterials Market by Type of Material and End User Opportunity Analysis and Industry Forecast, 2014 – 2022 European Recommendation on nanomaterials (2011/696/EU) World market for nanomaterials: structure and trends (Inshakova, et al., 2017)
High relevance (9 studies)	<ul style="list-style-type: none"> Nanomaterials Market (Metal Oxide, Metals, Chemicals & Polymers and Others) for Construction, Chemical Products, Packaging, Consumer Goods, Electrical and Electronics, Energy, Health Care, Transportation and Other Applications: Global Market Perspective, Comprehensive Analysis and Forecast, 2016 – 2022, Zion Market Research Nanomaterials Market - Trends, Investment Analysis and Future scope to 2022, Mordor Intelligence Nanomaterials Market: Global Industry Analysis and Opportunity Assessment 2015-2025, Future Market Insights Nanomaterials Market Global Industry Analysis 2013 – 2017 and Opportunity Assessment 2018 – 2028, Future Market Insights World Silver Nanomaterials as Transparent Conductor Market - Opportunities and Forecasts, 2017-2023, Allied Market Research Nanomaterials Market by Type - Global Opportunity Analysis and Industry Forecast, 2014-2022, Allied Market Research Silver Nanoparticles Market Size by Application, Industry Analysis Report, Regional Outlook, Growth Potential, Price Trends, Competitive Market Share & Forecast, 2016–2024, 2017, Global Market Insights Carbon Nanotubes Market Size By Product, By Application, Industry Analysis Report, Regional Outlook, Growth Potential, Price Trends, Competitive Market Share & Forecast, 2016 – 2024, Global Market Insights

	<ul style="list-style-type: none"> Carbon nanotubes: Types, products, market, and provisional assessment of the associated risks to man and the environment. Ministry of Environment and Food of Denmark, 2015.

In order to produce a new market study, existing commercial market studies shall be consulted as primarily relevant sources because their authors had to come to a similar decision which parameters and factors to identify and select as the most relevant. This type of source includes a considerable amount of market variables and parameters (e.g. CAGR, market size, etc.). In addition, other types of sources may provide supplemental information and arguments for a decision.

Besides the market studies assessed as the most relevant, another secondary source, a journal paper of (Inshakova, et al., 2017), provides a good overview and critical review of existing market studies. This type of papers is relevant to produce market studies as it may be considered a good base for identifying sources as well as for providing both a general overview and to a certain extent also an evaluation of some of the market studies.

We do not agree with the ex-ante conjecture that some data or methods used in general have proved completely irrelevant. However, we would highlight two aspects:

The number of nanotechnology patents registered has been suggested and used as an indicator both for the general dynamics and development of the market over the years as well as for the contribution of Member States to the state of technology. Although this is a quantitative and countable metric indicator, it is not known (without the contribution of additional information by experts) which share of these patents registered are in a phase of already being exploited in the market. Moreover, the market is too new and dynamic to have enough ex-post data for verification or falsification of forecasts in the past.

In addition, data sources which are based on products available in the market, products and companies that declared nanoparticles, nanomaterials and indicators considering science cited/indexed nano-articles) and innovation (patents) and based on the number of publications and nano related projects were found irrelevant.

1.3 Relevance and reliability of parameters, factors and their combinations to produce market studies

Considering the relevance and reliability of single parameters, factors and their combinations to produce market studies, commercial market studies include a considerable amount of market variables and parameters. The following combination of parameters is recommended for producing market studies on nanomaterials:

- Market segmentation

Most of the commercial market studies contain market segmentation by geographical region and/or country, by key player, by application, by end-use or by type of nanomaterial. Since the scope of the project is the European nanomaterials market, it is suggested that market studies analysing the market on the EU region as well as at Member States level (in particular Germany, UK, Italy or Spain) are relevant for the production of market studies. From the aspect of nanotechnology patents applied for in each Member State, also France and the Netherlands should be attributed a particular role in the modelling of future markets for manufactured nanomaterials. A comparison of the EU market versus world market may be also relevant, as market studies focusing in the EU market would probably include market shares for EU and MS as well as MS specific information and role/importance. Segmentation by end-use and/or by type of nanomaterial is also

quite common in commercial market studies. These two types of segmentation are relevant as they allow the analysis of nanomaterials markets by use and by production.

- Market forecasts and growth rate

Most of the commercial market studies estimated the market forecast in the future also by market segmentation. Market forecast are relevant to estimate the evolution of the market in the future. The majority of studies use the Compound Annual Growth Rate (CAGR) which seems to be a commonly accepted and central parameter to quantify the market annual growth for a period of time. A general formula for the CAGR is defined as:

$$\text{CAGR}(t_0, t_n) = (V(t_n)/V(t_0))^{\frac{1}{t_n - t_0}} - 1$$

$V(t_0)$: start value, $V(t_n)$: finish value, $t_n - t_0$: number of years.

This formula exactly describes a geometric mean of annual growth rates and is used in most of the market studies. The growth rate applied gives an indicator whether the market study follows a "pessimistic (or conservative) view", "neutral view" or "optimistic view".

- Other variables/parameters

Commercial market studies also use several further variables and types of analysis that are relevant for the production of market studies. The most common and relevant are the following:

- **Market size.** In some cases, it was calculated by revenue generated from the sales of nanomaterials manufacturers or by market value (e.g. million US\$) and market volume (tonnes)
- **Market share,** calculated by region, country or company. This variable is really relevant in the case the market share is estimated for EU or EU Member States.
- **Market trends** on prices (of nanomaterials and raw materials), demand, consumption and sales, revenue, volume and/or profit margin.
- **Porter's Five Forces model.** This model serves normally to evaluate market profitability by considering power of the supplier, power of the buyer, threat of substitute, competitive rivalry and threat of new entrants. This model may be relevant for considering the profitability of nanomaterials markets in general, but even more for specific nanomaterials markets.
- **PESTEL (Political, Economic, Social, Technological, Environmental and Legal) analysis.** PESTEL analyses the macro-environmental factors that have impact in a company. In some commercial market studies, this analysis is performed providing an overview of the macro-environmental factors of the nanomaterials markets for the companies. This analysis is relevant because it provides an overview of the macro-environmental factors that companies are facing at the nanomaterials market.
- **SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis** by key player. In some of the commercial market studies a SWOT analysis is performed for the main players of the industry. This analysis allows the identification of opportunities in the market and company threats. This performs the analysis on a microeconomic and company level.
- **Value Chain Analysis** which serves to identify value-adding activities and reduce costs by eliminating those activities that do provide added value. This analysis is performed in some of the commercial market studies.

- **Industry ecosystem analysis.** This provides an overview of raw material suppliers, manufacturers and distribution channel analysis and it is included in some of the commercial market studies.
- **Competitive scenario and product portfolio of key vendors.** In addition to these variables found in the data sources the project team (based on their own experience on market analysis) suggests that the following variables/factors should be given more emphasis in the production of a new market study:
- **Imports and exports (from an EU perspective).** These variables are not commonly used in commercial market studies. They are included only in one of commercial market studies. The project team emphasises that imports and exports in volume and value between EU and other non-EU countries may be relevant for producing market studies, in particular in view of specific EU policy measures, e.g. a change in legal requirements for nanomaterials.
- Primary and secondary research as two components of methodology applied

Most of the commercial market studies follow a methodology based on primary and secondary research, which seems to be commonly accepted, in particular if it uses the combination of different sources independent from one another. This allows to verify data from industry as well as filling possible gaps. Primary research is based on online and telephone based survey, i.e. interviews with several key experts with different functions in the market – from industry, trade and customers, associations and external experts such as researchers. Secondary research is based on all kinds of publicly or commercially available sources, such as publications and further information published from industry (annual reports, company websites, press releases, industry journals and trade publications), relevant databases (government, patent, statistics, markets), scientific and technical writings for product information, scientific articles, and further paid data sources.

1.4 Conclusion: Approach suggested to produce a new market study on manufactured nanomaterials

We suggest the production of a new market study on manufactured nanomaterials be based on the findings of the critical review of existing sources and use a combined approach of secondary and primary research. In the following first this general combination of primary and secondary research is explained, then an operational selection of parameters and factors suggested to be considered.

For the primary research, a telephone-based or online survey of the first stage should be combined with a Delphi method bringing together the expert answers of the first round in a second and third round. The Delphi method is a structured communication technique or method, developed as a systematic, interactive forecasting method which relies on a panel of experts; it is also used for market research, business forecasting and general decision-making. Experts are encouraged to revise their earlier answers in light of the replies of other members of their panel. During this process the range of the answers will decrease and the group will converge towards the most reliable answer or solution.

The experts should be recruited from different fields and stakeholder groups representing different views towards the market for nanomaterials, and should comprise representatives of at least the following groups:

- Industry participants (CEOs, VPs, marketing/product managers, market intelligence managers and national sales managers)
- Representatives of relevant industry associations
- Top-level dealers and distributors of nanomaterials

- Market research experts, e.g. of the market studies examined in this study
- Experts of competent authorities at the level of the most relevant EU Member States (e.g. involved in REACH registrations)
- University and non-university research experts in nanochemistry and nanotechnology
- Experts for banking and investment (including e.g. the European Investment Bank)
- Key customers and clients, e.g. producers of relevant consumer products containing nanomaterials

An online Delphi system can e.g. guarantee that the participants remain anonymous to each other. However, anonymity up to the end is not a general prerequisite for this study, and the level of anonymity can be decided when designing the final survey. Questions asked to the experts shall comprise the main parameters and assumptions identified in this study, starting e.g. with the CAGR for certain markets, but also additional qualitative factors and estimations.

For the secondary research, we suggest taking as a first basis those existing market studies as an input which have been identified as the most relevant. The project team suggests a purchase of the following reports which should be used as a main starting point:

- Allied Market Research: Europe Nanomaterials Market by Type of Material and End User Opportunity Analysis and Industry Forecast, 2014 – 2022 (study identified as the most relevant and reliable)
- Nanomaterials Market - Trends, Investment Analysis and Future scope to 2022, Mordor Intelligence (study identified as a “pessimistic view”/“conservative” by (Inshakova, et al., 2017))
- Nanomaterials Market by Type - Global Opportunity Analysis and Industry Forecast, 2014-2022, Allied Market Research (study identified as an “optimistic view” by (Inshakova, et al., 2017))

It seems appropriate to estimate central values as point estimates but also upper and lower bounds of a scenario, defined by the respective assumptions and data sources. The central estimates can then be the basis of a business-as-usual scenario, compared to scenarios with additional regulatory action on the EU level.

The analysis of these central studies should at least be complemented by an update of relevant scientific articles (by keyword search) and databases. Primary and secondary research should be combined in a circular process, e.g. by asking the experts which secondary data sources but also which parameters they evaluate as the most relevant ones.

The new market study on nanomaterials should consider a set of basic parameters, i.e. the minimum parameters required to produce a new market study, and additional parameters, considered for producing a more fine-tuned market study with a larger degree of variables and interactions.

Basic parameters comprise:

- Market analysis by segmentation (geographical region and/or country, key players, applications, end-uses or type of nanomaterial). Furthermore, specific focus should be done on European region in comparison with global market.
- Market forecasts and growth rate (CAGR)
- Market share by region, country or company
- Market trends (e.g. consumption, demand, etc.)
- Competitive scenario and product portfolio of key vendors

Additional parameters include:

- Porter's Five Forces model
- Value Chain Analysis
- Imports and exports (from an EU perspective)
- PESTEL
- SWOT analysis

2. Subject of the service

The title of this service is "Critical review of the relevance and reliability of data sources, methods, parameters and determining factors to produce market studies on manufactured nanomaterials on the EU market."

The background of this study can be summarised in the following:

Applications of nanomaterials have increased at a growing rate in the past decade and have become part of daily lives, such as in healthcare, electronics, cosmetics and other areas. Physical and chemical properties of materials at the nanometre scale (e.g. antimicrobial properties and self-cleaning surfaces) enable novel applications.

For an overview of the heterogeneous market for nanomaterials, segmentation follows both the basis of the material type and the basis of applications. This segmentation is followed by most market studies, e.g. (Allied Market Research, 2016b), (Future Market Insights, 2018) and (Zion Market Research, 2017) on the global level. Material types comprise metal oxides, metals, non-metallic chemicals and polymers, nanotubes as well as other conventional and new materials. Based on applications, the global nanomaterials market can be roughly segmented as construction, packaging, consumer goods, electrical and electronics, energy, health care, transportation and others.

The global nanomaterials market is expected to grow further in the following ten years, with North America and Europe the two dominant regions that are projected to control the global nanomaterials market. An increasing volume of mass production also enables a decrease in prices, which further facilitates the growth of the markets. The Asia-Pacific region also shows high growth rates, due to a greater demand of nanomaterials in the developing regions like India and China as well as continuous research and development activities – see e.g. a general market overview of (Inshakova, et al., 2017). The electronics segment is expected to account for around 30% of global market share, which is the highest single share in the market. The highest growth rate is expected in the aerospace sector in future.

A precise definition for nanomaterials has been undertaken in a Commission Recommendation of the year 2011 (European Commission, 2011), with several review reports of the definition prepared and published by JRC in 2014 and 2015 (Roebben, et al., 2014) (Rauscher, et al., 2014) (Rauscher, et al., 2015). The actual definition of 2011 still provides a valid standard and is therefore taken as a baseline for the scope of this study.

According to the specific terms of reference, the objectives of this service request comprise the following essential components:

- *Gathering, analysis and summary of data sources, study methods, parameters and determining factors used for the production of market studies on manufactured nanomaterials*
- *Assessment of the relevance and reliability of the studies, methods, parameters and factors*

Therefore, this analysis begins first with the data sources, methods and parameters already used for such market studies, and further identifies but shall also propose and analyse a further optimal combination of these data sources, study methods, parameters and determining factors in order to produce a new market study on the European market of manufactured nanomaterials.

The tasks are further structured into five consecutive work packages, combined with respective defined deliverables.

3. Methodology

For the service, a methodology comprising five tasks is shown in Table 2 which presents the tasks performed by the project team. This final report (including its annexes) comprises all results of the project which were previously included in the first interim report (Task 1 and Task 2) and the second interim report (Task 3 and Task 4).

Table 2: Methodology and task performed during the project

Tasks
Task 1: Summary of main data sources, study methods, parameters and determining factors for market studies on manufactured nanomaterials
Task 2: Criteria for assessing the relevance and reliability of study methods, parameters and determining factors
Task 3: Detailed analysis of relevance and reliability of data sources, study methods and their combinations to gather information
Task 4: Detailed analysis of relevance and reliability of parameters, factors and their combinations to produce market studies
Task 5: Preparation of the final report

Task 1 and 2

During Task 1, the project team conducted a search to gather the main data sources. As starting point, the sources already listed in the tender document were considered. Furthermore, an internet search on Google as well as on relevant authorities' websites from EU (ECHA, EU Commission, etc.) and from some Member States was conducted. More exhaustive searches, such as systematic search in literature databases (e.g. PubMed, Science Direct, etc.), were not performed due to the limited time allocated for the project. Furthermore, market studies or other data, study or literature sources older than 2011 were not taken into consideration for this study. The reason to assess only the period 2011-2018 was that:

- the current EC recommendation for a definition of nanomaterials is taken as a baseline and starting point for the study, which dates from 2011 and
- considering such a rapidly developing and changing market as the nanomaterials market any data or forecasts older than 2011 can be considered as outdated
- In addition, if possible a change in the definition (as currently discussed in the review process and potential revision of the EU recommendation) may impact the carrying out of market studies in the future. This aspect may be analysed in case that a clear impact is identified; however, this shall not be a core aspect of the study.

A detailed list of all gathered data sources is provided in Section 3.1 (Task 1). These data sources were collected in an Excel table which contains all relevant information gathered.

In Task 2, the criteria for assessing the relevance of the studies were defined considering the main outcomes of Task 1. A more detailed explanation of the methodology followed for Task 1 and 2 is described in sections 3.1 and 3.2, respectively.

Task 3 and 4

The objective of Task 3 has been to describe and analyse whether the data sources and study methods come across in different studies are both relevant and reliable for the purpose of gathering information in order to produce further market studies. This task also comprises suggestions for further adaptations and combinations in order to further increase the usefulness of market studies for manufactured nanomaterials.

In parallel to the evaluation done in Task 3, particular relevant parameters and determining or influential factors appearing either in all or in particular studies (such as general or specific growth rates) have been recorded and systemised. It is also examined whether there is an agreement on parameters or significant deviations can be observed, e.g. contrary opinions in the future market development or major differences in the view of the present markets versus future market projections. Draft conclusions have been drawn on the combination and modification of parameters in order to improve results, and remaining information gaps identified.

The project results allow an answer to the following question (specified in the Terms of reference):

- What would be most relevant and reliable parameters/factors or their combinations to produce a market study on current European market of manufactured nanomaterials?
- Why certain parameters/factors are more relevant and reliable than others?
- Are there completely irrelevant and/or unreliable parameters/factors?

These final results are presented and explained in detail in Section 4.

3.1 Task 1: Summary of main data sources, study methods, parameters and determining factors for market studies on manufactured nanomaterials

The purpose of Task 1 is to present a summarised overview of the relevant input information for the production of market studies on nanomaterials that have been manufactured. This information is stated more precisely as data sources, methods used for performing the study, parameters used and further determining factors.

3.1.1 Exact scope of the study

For an assessment on market studies on manufactured nanomaterials on the EU market, the exact focus should comprise several perspectives and components of the relevant market.

In particular, the EU market was examined both from the production perspective and from the use perspective. Therefore, the main market data as flow figures under interest (referred e.g. to one calendar year) are:

- Production of nanomaterials within the European Union
- Imports of nanomaterials into the European Union
- Exports of nanomaterials outside of the European Union
- Use of nanomaterials in the European Union

One reason that both the production and the use aspects were taken as a focus is the

context of the following aspects under interest:

- A REACH-based approach provides both obligations of manufacturers and regulatory issues and constraints on imports, i.e. this approach focuses on all chemicals available inside the EU
- The next step is the focus in which applications both imports and production are used, i.e. the segmentation of end uses. For estimating this extent, the share that is exported outside of the EU is also crucial because this share is not used within the EU.
- Another focus shall be on the segmentation of final products in which nanomaterials are used.

Therefore, the required and suitable level of differentiation of the market for manufactured nanomaterials was not defined a priori but resulted as one of the outcomes of the analysis.

One important aspect focused on in studies is the potential impact of regulatory issues (relevant legislation such as REACH and others). Regulatory actions might be taken for certain chemical materials or for nanomaterials as a whole. These regulatory actions can represent limiting factors in the future and can be used as policy instruments. Besides these instruments, further exogenous constraints and limiting factors currently and in future should be addressed.

For completeness of a national accounting framework, stock data at the beginning and end of a year as well as data on depreciation, taxes and subsidies, etc. should be taken into account as well. We assume that storage of nanomaterial does not play a significant quantitative role, but these quantities are recorded as well in case they are reported in data sources.

Therefore, the aspect of potential relevant influential factors has ex ante been kept open for a broad perspective.

For the scope and delimitation of manufactured nanomaterials, the current Commission Recommendation 2011/696/EU (European Commission, 2011) was used as current definition. Consequently, the point in time when this Commission Recommendation was issued and defined an agreement on the term of nanomaterial was the starting point for the research in this study.

In addition, if possible a change in the definition (as currently discussed in the review process and potential revision of the EU recommendation) may impact the carrying out of market studies in the future. This aspect was intended to be analysed in case that a clear impact is identified; however, this was not a core aspect of the study.

3.1.2 Principles for identification of data sources

After the scope of the study has been clarified in detail, data sources have been identified as relevant for the scope of this service. The information has been retrieved primarily from public domains and also included available information from market studies. The data sources are categorised into the following categories:

- EU data sources
- Member States data sources
- Commercial market/research data sources
- Databases
- Other data sources

In addition, a screening was also performed for international institution data sources such as OECD and WHO (e.g. OECD Working Party on Nanotechnology (WPN) or Working Party on Manufactured Nanomaterials). However, both organisations' websites contain information on nanomaterials but more from the health and environmental risk assessment perspective than on market analysis for nanomaterials. Data sources from each of the categories was identified first through official reports, such as from the European Commission, publications commissioned by such public organisations, and data sources within such publications. Further, additional data sources were identified through the review of industry and market reports and otherwise. Additionally, a Google search was performed by using terms such as "nanomaterials market" or "nanomaterials industry".

As a starting point for this study, in October 2011 the European Commission published a European Recommendation on nanomaterials (2011/696/EU) (European Commission, 2011) which proposed a definition for nanomaterial. This definition is summarised in the Annex in Section 6.1.1 after Table 24. As part of the Recommendation, the European Commission also specified that the definition would be reviewed in 2014. The Joint Research Centre of the European Commission (JRC) completed three scientific/technical reports in a series, with the purpose of reviewing the definition proposed in 2011. The JRC series is titled "Towards a review of the EC Recommendation for a definition of the term nanomaterial" (Rauscher, et al., 2014), (Roebben, et al., 2014) and (Rauscher, et al., 2015), with the three parts of the series described in detail in the Annex in Section 6.1.1 (Table 24, Table 25 and Table 26). This JRC series concludes that there are many clarification issues, and challenges when implanting the definition, and provides discussion and potential solutions to some of these issues.

In the last years, several Member States authorities (e.g. from France, UK, Denmark, The Netherlands, Sweden, Norway or Belgium) have established some initiatives for regulating and increasing transparency on nanomaterial market (Risk & Policy Analysts Ltd., BiPRO, 2015). Considering this, Member States data sources (e.g. chemical and environmental agencies) were also checked and searched in order to consider relevant sources. These sources are described in detail in the Annex in Section 6.2.

Commercial market research reports were also searched and identified. This type of source may be relevant as they contain market data on nanomaterials assessed per region (e.g. EU) and countries as well as from applications/ product perspectives.

Commercial market research reports were available neither to ECHA nor to the project team and a purchase of this type of literature was not envisaged within the project budget. Therefore, the content description information is based on publicly available information, either from the information disclosed by the producer (table of contents, summary, structure, methodology), or from reviews of such commercial market studies, e.g. as articles in scientific journals.

Based on the analysis, a recommendation is given that up to three of the existing commercial market studies, which have been identified as the most relevant and reliable, can be purchased. All commercial market studies sources that have been identified are described in detail in the Annex in Section 6.3.

Databases on chemicals and nanomaterials were also searched. They were identified by the sources already checked (e.g. reports or authorities' websites) as well as the databases already known from previous work, e.g. in the context of the REACH Regulation. Database sources are described in detail in the Annex in Section 6.4.

One final residual category of sources which did not fit into one of the previous categories of sources was categorised as "other data sources". It comprises two scientific papers on nanomaterials and a website on worldwide actual information and statistics in nano-based

science, technology and industry. These other sources are described in detail in the Annex in Section 6.5.

3.2 Task 2: Criteria for assessing the relevance and reliability of data sources, study methods, parameters and determining factors

The purpose of Task 2 was to identify and define the criteria that are suitable to assess both the relevance and the quality and reliability of the studies and methods examined in Task 1. This task had some overlap with the core work of Task 1: The description of the studies identified makes obvious several aspects of the criteria to be identified and applied.

3.2.1 Evaluation of the aspects identified for suitability as general assessment criteria for studies

This step served for an examination how different aspects, e.g. the specific purpose of the study, scope in terms of geography and time frame, documents, elements of verification, sensitivity analysis, discussion and others, may serve as general and relevant criteria for the evaluation.

The following overview serves to identify and group the main questions and elements that central and general assessment criteria accessible for all or most studies comprise:

1. Does the data source provide market data for a defined specific baseline year? (yes/no)

If yes: How differentiated are these market data, according to:

- Countries / world regions
- Production
- Imports/exports
- Types of nanomaterials
- Uses of nanomaterials
- Status of one year versus development over time
- Further literature and data sources quoted

2. Does the data source provide market forecasts into the future? (yes/no)

If yes: How differentiated are the data of this forecast, according to:

- Countries / world regions
- Production
- Imports/exports
- Types of nanomaterials
- Uses of nanomaterials
- Time steps (monthly/quarterly/annually/...)
- Lower bound/central estimate/upper bound
- General and specific compound annual growth rates (CAGR)

- Additional parameters used as explanatory variables (e.g. nanotechnology patents)
- Uncertainties and gaps addressed

3. Criteria for relevance and reliability of study methods and additional general assessment criteria:

- Relevance of the study method in general
- Reliability of the study method in general
- Relevance of the study method applied in this market study
- Reliability of the study method applied in this market study
- Primary source / secondary source (meta-analysis, review of other studies)
- Evaluation of the independence/neutrality, credibility or tendentiousness of the study source (international authority, national authority, NGO, company, company association)

4. Specific assessment criteria applicable for particular types of studies only

- Does this study provide any relevant information for the production of market studies on manufactured nanomaterials on the EU market?
- Does this source provide additional specific data input to other studies (e.g. parameters)?
- Does this study address or answer a specific question that is relevant for market studies?
- Does information in this source support and substantiate (verify) assumptions made in other studies?
- Is information in this source contradictory to assumptions made in other studies?
- Is information in this source prone for certain types of bias?

5. Does this study in particular address the different roles and importance of EU Member States (MS) for the nanomaterials market?

This pertains to several aspects such as:

- Availability of country-specific information (e.g. already existing country-specific nano registers)
- Market shares of MS for the market for manufactured nanomaterials in total
- Importance of MS for specific core areas, e.g. clusters of excellences, research and development
- MS with minor or no relevant markets for nanomaterials

The availability of studies dealing with certain MS only (e.g. Denmark, France), but also differentiated information available for specific but not for all MS gives indications how to answer this question. For a final evaluation of this aspect, the following crucial questions shall be answered:

- Which MS are valuable for a particular role in estimating or modelling the market for manufactured nanomaterials?
- Can MS, therefore, be grouped or clustered, and if so, according to which criteria?
- Which MS can be regarded as negligible or grouped in a category such as “other”?

These central and general assessment criteria will serve in Task 3 to assess the relevance of the different data sources gathered. The applicability of these criteria for the evaluation are as follows:

- **Criterion 1: Does the data source provide market data for a defined specific baseline year?** This criterion will be as yes or no. In case of yes, it would be specified how differentiated is the market data (e.g. countries, regions, types of nanomaterials, etc.)
- **Criterion 2: Does the data source provide market forecasts into the future?** This criterion will be as yes or no. In case of yes, it would be specified how differentiated is the market data (e.g. countries, regions, types of nanomaterials, etc.)
- **Criterion 3: Criteria for relevance and reliability of study methods and additional general assessment criteria.** This criterion focuses on the study methods applied, including the type of source (primary, secondary, etc.). In addition, it addresses the independence/neutrality, credibility or tendentiousness of the study and source itself (author or editor) in general.
- **Criterion 4: Specific assessment criteria applicable for particular types of studies only.** This criterion addresses if there is any specific data or questions addressed in the study (e.g. it provides additional specific data input to other studies). Thus, the criterion will be yes/no and if yes, specify.
- **Criterion 5: Does this study in particular address the different roles and specific importance of EU Member States (MS) for the nanomaterials market?** This criterion addresses if there are any specific issues on Member States (e.g. availability of country-specific information). Thus, the criterion will be yes/no and if yes, specify.

At the end of this step, for the criteria identified suitable scales and their specifications are defined, suggested and discussed. These are:

- qualitative (nominal or ordinal) or quantitative (metric or ratio)
- selective yes/no criteria
- continuous scales, e.g. subjective evaluation scales from 1 to 5 or 1 to 10
- key figures, ratios and indices
- free text answers

3.2.2 Identification and discussion of further, more abstract criteria and their evaluation scale

In order to complement the criteria identified during the examination of data sources, additional potential criteria were examined and discussed.

Expert judgement with regard to nanomaterials has been dealt with in several articles during the last more than ten years. A main aspect of such an expert judgement has concentrated on the assessment of human health and environmental risks of nanomaterials. This is relevant in view of several contexts:

- In the context of current national, EU and international legislation (e.g. the REACH Regulation and its current way of implementation for nanomaterials in general and in particular).
- In the context of adapting national, EU and international legislation (e.g. assessment of the effects of changing the REACH requirements for nanomaterials in future or establishing legally relevant classification systems for nanomaterials) or establishing new legislation specifically addressing nanomaterials.
- In the context of establishing public participation and governance.
- In the context of insurance and insurability of risks.

All these aspects have a qualitative, but potentially severe influence on the development of nanomaterials in the future, due to:

- legal prohibitions of certain nanomaterials or products,
- factors for supporting or hindering investments of industry in the research and development of nanomaterials, nanotechnology and products containing nanomaterials,
- potential crowding-out effects between EU and non-EU countries in case of different legislation or prohibition within and outside of the EU/EEA,
- further expectations of investors and relevant associations (e.g. CEFIC).

In overlap but also addition to these criteria, an existing review of existing market studies (Inshakova, et al., 2017) mentioned the following drivers of the world nanomaterials market, commonly addressed in other market studies:

- Increase in market penetration of materials.
- Decrease in prices for nanomaterials.
- Improvement of properties of nanomaterials.
- Expending Research & Development (R&D) activities related to new materials (measured in both private and public expenditure for nanotechnology research).
- Growing support of government institutions.
- Rapid development of materials and applications.
- Effectivity of partnerships and strategic alliances (domestic and international).
- Collaboration among industry players (in research and production).

All these factors have been identified as having a positive impact on the development of the world market for nanomaterials and the growth of market indicators.

On the other side, factors restraining in particular the future development of the global nanomaterials market have been identified in the same review study as:

- Concerns of impact to human health and the environment, referring to:
 - The toxicity of the nanomaterials themselves, but also of solvents, intermediate compounds, wastes stemming from processing and manufacturing.
 - Requirements of government environmental regulation (in particular by ECHA for the EU market and the US-EPA for the US market).

This might be e.g. general quality criteria or specific appraisal checklists applicable for market studies.

In the following tasks (3 and 4) a differentiation was made explicitly between aspects

referring to the study sources and methods in general (Task 3), and aspects referring to single or specific parameters and factors as well as their combinations applied in the studies (Task 4). In order to address this differentiation of these aspects, criteria identified here were distinguished whether they are rather relevant for the focus of Task 3 and/or Task 4.

3.2.3 Relationships between aspects described for the data sources and studies and criteria identified

In the following, the aspects specified in the description of the data sources were combined which criteria identified in the steps before are relevant for these aspects:

Table 3: Aspects of the studies regarding the approach, methodology, sources and elements and usefulness for criteria identified

Study examined (title and reference)
Purpose of the study: Market study (baseline year and/or forecast) or specific questions; specific countries addressed?
Scope and disaggregation in spatial terms: Applicable to market studies (world market, EU as a whole, EU differentiated according to MS, particular MS only)
Time horizon and time steps: Applicable to market studies (present market and/or forecast into the future; discussion on reasonable (maximum) time horizon)
Aggregation level regarding the production and different uses: Relevant information for production sector, uses of nanomaterials and/or products containing nanomaterials
Documentation: Addresses credibility, validity and traceability of results, as well as references to other sources
Study methods used: Relevance of study method; reliability of study method (both in general and in its specific application)
Sources used: References to other sources; relevance of sources
Additional verification of assumptions: Addresses credibility, validity and traceability of results
Further elements: May address: Important parameters and factors (or potential combinations) identified Addressing of imports and exports Influential factors for future development (drivers and restraining factors) Regulatory issues and their impacts (e.g. in the context of REACH) – constraints or drivers
Discussion: Are limitations or gaps addressed in the study? Are further research questions to be addressed identified? How can they be handled?

Considering these aspects, a summary of the important information contained in each of the relevant studies is provided in the Annex in Table 18 to Table 57. The relevant studies

are classified as EU sources, Member States sources, commercial market studies, databases and others.

This structuring of information from the different relevant sources proved helpful to combine this information and allowed to draw conclusions what are the most relevant and reliable data sources, study methods, parameters and determining factors.

3.3 Task 3: Detailed analysis of relevance and reliability of data sources, study methods and their combinations to gather information

This task used as an input the market studies and further literature gathered which has been described in detail in Section 3.2.3 and from Table 18 to Table 57 in the Annex. Each data source has been summarised there in a separate table with regard to a selected set of aspects. This information has been combined with the five assessment criteria developed and described in Section 3.2.1 and potential further criteria listed in Section 3.2.2.

3.3.1 Analysis which findings of previous work packages (both the studies and study methods identified and the assessment criteria) shall be utilised for further analysis

As described in Section 3.2.1, the assessment criteria have been structured in five criteria clusters. This cluster of criteria serves among others for answering the questions:

- which market studies and which further literature referring to nanomaterials and their markets (which has been identified in Task 1) can be decided upon as relevant or irrelevant for further examination, and
- which particular results and findings will bring specific added value for a development and designing of new market studies?

These decisions are substantiated by general and specific arguments.

For this purpose, a matrix structure was established to document this evaluation, so that the outcome of this working step has been a matrix worksheet in Excel format containing:

- Literature and data sources, grouped according to types of source, as rows.
- Criteria clusters, broken down into single criteria, as columns.

The rows of this matrix contain the following content (see Table 4):

Table 4: Rows of the evaluation matrix: Sources, clustered to types of sources

Type of source	Number of sources per source type
EU sources	7 sources
Sources of single EU Member States	10 sources
Commercial market studies	29 sources
Databases sources	7 sources
Other data sources	3 sources

The columns of the evaluation matrix have been structured in the following sections, divided into single fields (see Table 5):

Table 5: Columns of the evaluation matrix: Sources, clustered to types of sources

Section of columns/ Overall criterion cluster	Column / Single criterion or feature characteristic
General information on the source	ID Number
	Documentation: Date/Expert(s) in charge/Comments
	Sample of the market study (yes/no)
	Nanomaterials market / others
Criterion 1: Does the data source provide market data for a defined specific basis year?	Market data for baseline year? (yes/no)
	If yes: differentiated according to: <ul style="list-style-type: none"> • Countries/world regions • Production • Imports/Exports • Types of NMs • Uses of NMs • One year only or development over time
	Literature / data sources quoted
Criterion 2: Does the data source provide market forecasts into the future?	Market forecasts into the future? (yes/no)
	If yes: differentiated according to: <ul style="list-style-type: none"> • Countries/world regions • Production • Imports/Exports • Types of NMs • Uses of NMs
	Total time horizon
	Time steps (months/quarters/years)
	General and specific compound annual growth rates (CAGR) used
	Additional parameters / units used as explanatory variables
	Uncertainties and gaps addressed, lower bound/ central estimate/ upper bound
Criterion 3: Criteria for relevance and reliability of study methods and additional general assessment criteria	Relevance of study method in general
	Reliability of study method in general
	Relevance of study method applied in this market study

	Reliability of study method applied in this market study
	Primary source versus secondary source (meta-analysis, review)
	Independence, neutrality, credibility, tendentiousness of study source
Criterion 4: Specific assessment criteria applicable for particular types of studies only	Does this study provide relevant information for production of market study (yes/no)
	Which specific information, data or specific questions relevant for market studies
	Substantiation / verification or contradiction to other studies?
	Is information prone to bias (specify)?
Criterion 5: Does this study specifically address the different roles and specific importance of EU Member States (MS) for the nanomaterials market?	Does study address roles/importance of specific EU Member States? (yes/no)
	Country-specific information (e.g. nano registers)?
	Market shares of EU-MS?
	Importance of EU-MS for specific core areas; EU-MS with minor or no relevant market; clustering of MS to certain criteria?
Summary evaluation with explanation; ranking for relevance	Conclusion: Ranking from * (Source irrelevant) to ***** (Very high relevance)

Each market study or further source has been evaluated separately according to the single operationalised criteria (as far as they were applicable at all to the particular study). An overall general evaluation of the different groups of study types has been done in the next steps.

One main finding of the evaluation of the fields of the matrix has been that the single criteria are focused on those studies whose main content is indeed a market study for nanomaterials and/or nanotechnologies, either in total or for specific materials and uses. Therefore, most of the criteria could not reasonably be applied and evaluated for other sources providing additional thematically related information. In this case, the respective cell entries have been specified as not applicable or not available.

3.3.2 Conclusions of the matrix evaluation

As explained in Section 3.3.1, for each of the different types of sources a comparison and evaluation has been performed separately. This assessment is presented in the following, starting with the central focus on commercial market studies.

3.3.2.1 Assessment of commercial market studies

Commercial market research reports that have been identified are the most relevant type of sources as they contain market data on nanomaterials assessed both per region (e.g. EU) and countries as well as from applications and product perspectives.

A total of 29 commercial market studies from 14 different sources – consultant companies that have specialised in elaborating commercial market studies (e.g. Allied Market Research) were identified and assessed. These studies analyse the nanomaterials market (19 studies), the nanotechnologies markets (5 studies) or the nanoparticles market (5 studies). Considering the studies analysing nanomaterials markets, 8 studies were focusing on the general nanomaterials market and 11 studies on specific nanomaterial markets (e.g. carbon nanomaterials, silver nanomaterials, nanoclay market, etc.). Figure 1 presents the percentage that represents each of them, the studies that focus on nanomaterials market and the studies that focus on specific nanomaterials market.

At the time of the study, the most actual version available has been examined. However, most of the market studies are updated in regular intervals. Information on the mode of updates has been asked for. Table 5 gives an overview on updates of the market studies.

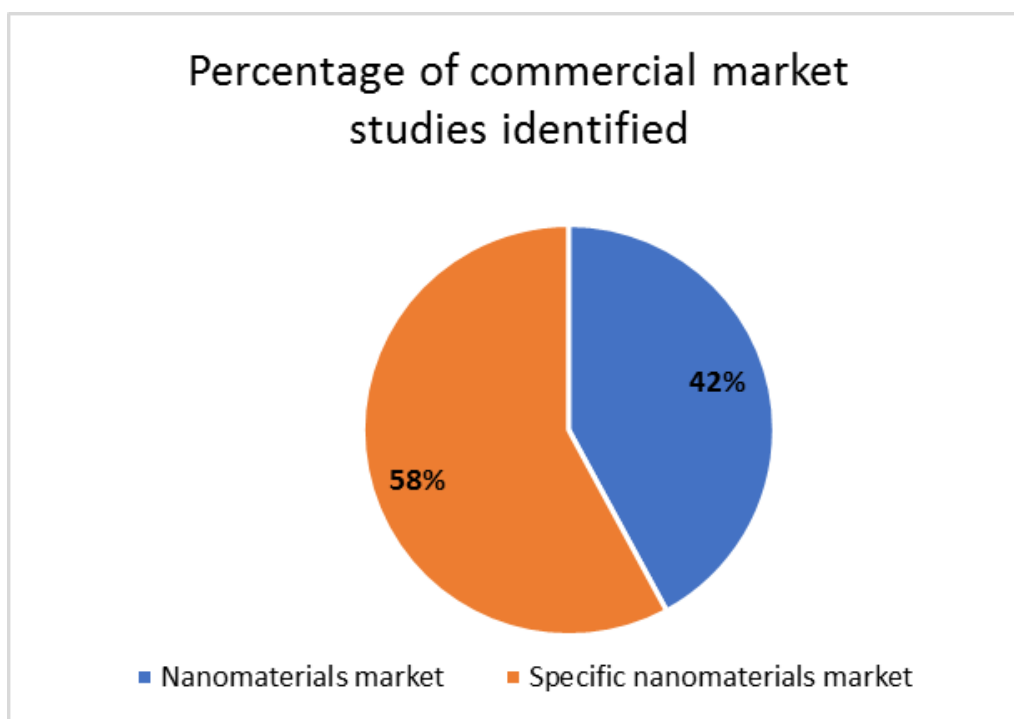
Table 5: Regular updates of commercial market studies

Name of the commercial market study	Regular updates
Nanomaterials Market (Metal Oxide, Metals, Chemicals & Polymers and Others) for Construction, Chemical Products, Packaging, Consumer Goods, Electrical and Electronics, Energy, Health Care, Transportation and Other Applications: Global Market Perspective, Comprehensive Analysis and Forecast, 2016 – 2022, Zion Market Research	Yes, annually
Silver Nanoparticles Market Size by Application, Industry Analysis Report, Regional Outlook, Growth Potential, Price Trends, Competitive Market Share & Forecast, 2016–2024, 2017, Global Market Insights	Yes, annually or up to twice a year
Carbon Nanotubes Market Size by Product, by Application, Industry Analysis Report, Regional Outlook, Growth Potential, Price Trends, Competitive Market Share & Forecast, 2016 – 2024, Global Market Insights	Yes, annually or up to twice a year

Gold Nanoparticles Market Size by Application (Electronics, Medical & Dentistry, Catalysis), Industry Analysis Report, Regional Outlook, Application Potential, Price Trend, Competitive Market Share & Forecast, 2017 – 2024, Global Market Insights	Yes, annually or up to twice a year
Nanocellulose Market – Global Industry Analysis, Forecast 2015–2023, Transparency Market Research	Yes, annually and for some reports and particular market situations also twice a year
Nanoclay Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2015 – 2023 (updated report: 2017 – 2026), Transparency Market Research	Yes, annually and for some reports and particular market situations also twice a year
Nanomaterials Market - Trends, Investment Analysis and Future scope to 2022, Mordor Intelligence	Yes, on half-yearly and yearly basis, plus individual update to customers
Complex-Oxide Nanomaterials Market - Analysis of Growth, Trends and Forecast (2016 - 2022), Mordor Intelligence	Yes, on half-yearly and yearly basis, plus individual update to customers
North America Nanosilver Market to garner substantial proceeds over 2017-2024, biomedical applications to drive the industry growth, Fractovia	Yes, annually or up to twice a year
APAC Carbon Nanotubes Market to observe highest growth rate over 2016-2024, high demand from the electronics sector to stimulate the industry growth, Fractovia	Yes, annually or up to twice a year
Smart textiles to stimulate the silver nanoparticles market over 2016-2024, Fractovia	Yes, annually or up to twice a year
Gold Nanoparticles market outlook: Medical & Dentistry applications to stimulate industry growth over 2016-2022, Fractovia	Yes, annually or up to twice a year
Nanomaterials Market: Global Industry Analysis and Opportunity Assessment 2015-2025 (updated report: Global Industry Analysis 2013 – 2017 and Opportunity Assessment 2018 – 2028), Future Market Insights	Yes, typically annually; quarterly updates if ordered
Metal & Metal Oxide Nanoparticles Market: Global Industry Analysis and Opportunity Assessment, 2016–2026, Future Market Insights	Yes, typically annually; quarterly updates if ordered
The Global Market for Nanomaterials 2010-2027, Research and markets	Yes, generally annually

Global Nanotechnology Market Outlook 2024, RNCOS	Yes, annually (in January)
Europe Nanomaterials Market by Type of Material and End User Opportunity Analysis and Industry Forecast, 2014 – 2022, Allied Market Research	Yes, each report gets updated every year
Nanomaterials Market by Type - Global Opportunity Analysis and Industry Forecast, 2014-2022, Allied Market Research	Yes, each report gets updated every year
World Silver Nanomaterials as Transparent Conductor Market - Opportunities and Forecasts, 2017-2023, Allied Market Research	Yes, each report gets updated every year
The Maturing Nanotechnology Market: Products and Applications, BCC Research	Yes, updates occur based on market changes, typically every two years
Production and applications of carbon nanotubes, carbon nanofibers, fullerenes, graphene and nanodiamonds: a global technology survey and market analysis", Innovative Research and Products, Inc.	One-off study, no update
Nanotechnology and nanomaterials: types, current/emerging applications and global markets, Innovative Research and Products, Inc.	One-off study, no update
Nanotechnology Update: U.S. Leads in Government Spending Amidst Increased Spending Across Asia, Lux Research Inc.	One-off study, no update
Is Graphene the Next Silicon ... Or Just the Next Carbon Nanotube? Lux Research Inc.	One-off study, one reply in 2015 referring to this study with an updated conclusion
Carbon Nanomaterials Update 2017 Edition, Lux Research Inc.	Update occurred at least in 2016 and 2017, further updates expected
World Nanomaterials - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders, Freedonia	One-off study, no schedule for an update
Advanced Manufacturing in a highly connected world, 2015, Deloitte	One-off study, no update

Figure 1: Percentage of commercial markets identified



In the case of specific nanomaterials markets, they are focused on:

- Complex-Oxide Nanomaterials Market
- Graphene
- Carbon nanomaterials or carbon nanotubes market
- Nanosilver market
- Nanocellulose
- Nanoclay market

All the market studies identified have been assessed according to the five assessment criteria described in Task 2. For each criterion different parameters have been included and analysed. The following sections assess the identified market studies according to these five assessment criteria.

Criterion 1: Does the data source provide market data for a defined specific baseline year?

The criteria belonging to this cluster assess if the market study uses a baseline year in the analysis as well as the market differentiation. It also includes the criterion whether the literature or the sources are quoted. From the 29 commercial market studies 26 used a baseline year and for 3 commercial market studies this information is not available. Table presents the results for the 26 studies that use a baseline year in the analysis of nanomaterial markets considering the level of differentiation.

Table 6: Results on the assessment for the 26 studies using the baseline year by considering the level of differentiation

Topic	No. studies	Content
Baseline/ historic data	26	All studies use a period of time, some historical data (e.g. 2001 or 2006) and some only one-year baseline period.
Key players on the market	22	Almost all studies analysed the producers or main players on the market.
Market segmentation by region and/or country	21	Most of the market studies differentiated the market by region and/or country. For example, by region (North America, Latin America, Europe, Asia-Pacific, Middle East & Africa). At the country level, for example: the United States, Canada, Brazil, Mexico, Germany, the United Kingdom, France, Italy, Spain, Russia, China, India, Japan, Taiwan or South Africa are the most commonly analysed.
Market segmentation by type of nanomaterial	12	Half of the studies make market differentiation by type of nanomaterial. For example, for the nanomaterials studies differentiates by metal oxides, chemicals and polymers, metals and nanotubes.
Market segmentation by end-use	12	Half of the studies make market differentiation by the end-use. For example, the nanocellulose market differentiates by composites, paper processing, paints/coatings, and food/beverages.
Market segmentation by application	8	Only a limited number of the market studies differentiate the market by application. For example, for the carbon nanotubes market differentiates by polymers, energy and electronics.
Drivers, opportunities and restraints for the nanomaterials market	5	Almost none of the market studies analysed the drivers, opportunities and restraints of the market.
Import and export	1	Only one market study analyses imports and exports. This market study focuses in the nanoclay market.

Furthermore, 13 of these 29 commercial market studies contained the literature or the sources quoted, if not in general (e.g. interviews, press releases or annual reports) in more detail (e.g. Global Market Insights, Inc., Hoovers or U.S. Food & Drug Association (FDA)).

In total 26 studies meet Criteria 1. Considering these 26 studies, the most common differentiation on the market is by segmentation of the market by region and/or country and by key players on the market.

Criterion 2: Does the data source provide market forecasts into the future?

These criteria assess if the market study provides market forecasts into the future as well as the market differentiation. This criterion also assesses other parameters as the total time horizon, time steps (months/quarters/years), general and specific compound annual growth rates (CAGR) used, additional parameters / units used as explanatory variables and uncertainties and gaps addressed, lower bound/central estimate/upper bound.

From the 29 commercial market studies, 27 provide market forecast and in 2 commercial market studies this information is not available. Table presents the results for the 27 studies that provide market forecast in the analysis of nanomaterial markets by considering the level of differentiation.

Table 7: Results on the assessment for the 27 studies providing market forecast by considering the level of differentiation

Topic	No. studies	Content
Market forecast	27	All studies use a period for market forecast. For example, from 2018 to 2025.
Key players on the market	22	Almost all the studies analysed the producers or the main players on the market.
Market segmentation by region and/or country	21	Most of the market studies differentiated the market by region and/or country. For example, by region (North America, Latin America, Europe, Asia-Pacific, Middle East & Africa). At the national level for example: the United States, Canada, Brazil, Mexico, Germany, the United Kingdom, France, Italy, Spain, Russia, China, India, Japan, Taiwan or South Africa are the most common analysed ones.
Market segmentation by type of nanomaterial	12	Half of the studies make market differentiation by type of nanomaterial. For example, for the nanomaterials studies, by metal oxides, chemicals and polymers, metals, nanotubes.
Market segmentation by end-use	12	Half of the studies make market differentiation by the end-use. For example, for the nanocellulose market, by composites, paper processing, paints & coatings, and food & beverages.
Market segmentation by application	8	Only few of the market studies differentiate the market by application. For example, for the carbon nanotubes market by polymers, energy, electricals & electronics.
Drivers, opportunities and restraints for the nanomaterials market	5	Almost none of the market studies analysed the drivers, opportunities and restraints of the market.
Import and export	1	Only one market study analyses imports and exports. This market study focuses in the nanoclay market.

In total 27 studies meet Criteria 2. Considering these 27 studies, the most common differentiation on the market is by segmentation of the market, by region and/or country and by key players on the market.

In the case of the other parameters also included in Criterion 2, Table presents the main results for the 29 commercial market studies by considering these other parameters.

Table 8: Results on the assessment for the 29 studies by considering other parameters

Topic	No. studies	Content
Time horizon	27	All the studies present a time horizon for a period of time. Most of them start from 2016, 2017 or 2018. Some are studies done years ago and the forecast is no longer applicable. For example, a study done in 2011 with the forecast from 2011-2014.
Time steps (months/quarters/years)	27	All of these studies analyse the market on annual values (years).
General and specific compound annual growth rates (CAGR)	19	More than half of the studies used the growth rate or CAGR to estimate the expected growth of the market during the forecasted period. For seven studies this information is not available.
Additional parameters / units	24	Almost all studies include other additional parameters or variables apart from the CAGR or growth rates. For example, some of the studies presented prices, demand, market size, market share, SWOT Analysis or Porter's Five Forces model. Few studies also presented PESTEL analysis. For 2 studies this information is not available.
Uncertainties and gaps addressed, optimistic/ neutral/ pessimistic view	10	This parameter is not relevant for 19 studies, resulting in information being available from 10 studies. Uncertainties are not addressed in any of the reports considering the publicly available information. In the case of lower bound/ central estimate/ upper bound, for the ones that information is available it seems that all adopt a neutral view.

Considering the other parameters included in Criterion 2, almost all commercial market studies meet all parameters, except in the case of uncertainties and gaps addressed, lower bound/ central estimate/ upper bound of a potential range. For this parameter there is a lack of information as for more than half of the studies it was not possible to assess the parameter because information is not publicly available.

Criterion 3: Criteria for relevance and reliability of study methods and additional general assessment criteria

This criterion focuses on the study methods applied, including the type of source (primary, secondary, etc.). In addition, it addresses the independence/neutrality, credibility or tendentiousness of the study and source itself (author or editor) in general. Table summarises the main results on this assessment criteria.

Table 9: Results on the assessment for the 29 studies by considering Criteria 3 parameters

Topic	No. studies	Content
Relevance of study method in general	17	In more than half of the studies the method/methodology used is explained. There are 12 studies for which information on the method/methodology use is not publicly available.
Reliability of study method in general	17	Considering the studies that explained the method/methodology, they seem reliable considering the publicly available information.
Primary source versus secondary source (meta-analysis, review)	29	All studies are primary sources.
Independence, neutrality, credibility, tendentiousness of study source	13	For most of the studies considering the information publicly available, it seems that they are neutral and credible studies. However, since for all of them information from industry was used as one of the main sources (e.g. CEOs interviews), there may be a risk on the independency of these reports. Aside from the 13 studies, another 16 studies did not have publicly available information.

Criterion 4: Specific assessment criteria applicable for particular types of studies only

This criterion addresses if there is any specific data or questions addressed in the study (e.g. it provides additional specific data input to other studies).

Table summarises the main results on this assessment criteria.

Table 10: Results on the assessment for the 29 studies by considering Criteria 4 parameters

Topic	No. studies	Content
Does this study provide relevant information for production of market study?	18	More than half of the studies provides relevant information for production of market studies. In addition to these 18 studies, for 11 studies information is not publicly available.

Which specific information, data or specific questions relevant for market studies?	18	Mostly of the studies that specify information and data on market studies are about the leading country in the market or the study method. Some also address regional and country leading markets, nanomaterials to be included in the study as well as variables used. For example, one study finds that China and India have the highest demand growth and that the fastest growing markets are: energy and construction. As explained in the previous criteria, information for 11 studies is not publicly available.
Substantiation / verification or contradiction to other studies?	11	Less than half of the studies present contradiction to other studies by considering for example market value or growth rate. Additionally, to these 11 studies for 18 studies information is not publicly available.
Is information prone to bias (specify)?	14	Approximately half of the studies may be prone to bias as private companies are one of the sources used. Aside from these 14 reports, another 15 studies do not have publicly available information.

Criterion 5: Does this study in particular address the different roles and specific importance of EU Member States (MS) for the nanomaterials market?

This criterion addresses if there are any specific issues on Member States (e.g. availability of country-specific information). Table 6 summarises the main results on this assessment criteria.

Table 6: Results on the assessment for the 29 studies by considering Criteria 5 parameters

Topic	No. studies	Content
Does the study address roles/ importance of specific EU Member States?	20	Most of the studies addressed EU Member States importance in the nanomaterials markets. However, for 7 studies this information was not publicly available.
Country-specific information (e.g. nano registers)?	17	More than half of the studies present country specific information. They focus mainly on market data at country level and some of them on country specific R&D of nanomaterials. For example, some of the most common EU Member States addressed are: France, Germany, Italy, Poland, Spain and the United Kingdom. Aside from these 17 studies, another 7 studies did not have publicly available information. For 2 studies Europe was addressed as a region, therefore it was not possible to assess country specific information as addressed.

Market shares of EU-MS?	3	Few studies present market shares of EU-MS. Aside from these 3 studies, 8 studies may include market shares of EU-MS as they address EU region, but it was not clear from the publicly available information. Another 13 studies did not have publicly available information, therefore they could not be assessed according to this parameter.
Importance of EU-MS for specific core areas; EU-MS with minor or no relevant market; clustering of MS to certain criteria?	2	Few studies addressed the importance of EU-MS for specific core areas considering the public available information. Aside from the two studies listed here, another 24 studies the information was not publicly available.

Conclusion

In order to assess and identify the most relevant commercial market studies, they have been evaluated considering the five assessment criteria and by using a ranking for relevance indicated by the number of asterisks (* - *****) with higher relevance demonstrated by a higher number of asterisks. Table 7 presents the results on the evaluation of all 29 commercial market studies.

Table 7: Summary of final results from the assessed commercial market studies

Ranking	No. studies	Name of the commercial market study
Very high relevance *****	1	<ul style="list-style-type: none"> Commercial market studies from Allied Market Research: Europe Nanomaterials Market by Type of Material and End User Opportunity Analysis and Industry Forecast, 2014 - 2022
High relevance ****	8	<ul style="list-style-type: none"> Nanomaterials Market (Metal Oxide, Metals, Chemicals & Polymers and Others) for Construction, Chemical Products, Packaging, Consumer Goods, Electrical and Electronics, Energy, Health Care, Transportation and Other Applications: Global Market Perspective, Comprehensive Analysis and Forecast, 2016 – 2022, Zion Market Research Nanomaterials Market - Trends, Investment Analysis and Future scope to 2022, Mordor Intelligence Nanomaterials Market: Global Industry Analysis and Opportunity Assessment 2015-2025, Future Market Insights Nanomaterials Market Global Industry Analysis 2013 – 2017 and Opportunity Assessment 2018 – 2028, Future Market Insights

		<ul style="list-style-type: none"> • World Silver Nanomaterials as Transparent Conductor Market - Opportunities and Forecasts, 2017-2023, Allied Market Research • Nanomaterials Market by Type - Global Opportunity Analysis and Industry Forecast, 2014-2022, Allied Market Research • Silver Nanoparticles Market Size by Application, Industry Analysis Report, Regional Outlook, Growth Potential, Price Trends, Competitive Market Share & Forecast, 2016-2024, 2017, Global Market Insights • Carbon Nanotubes Market Size by Product, by Application, Industry Analysis Report, Regional Outlook, Growth Potential, Price Trends, Competitive Market Share & Forecast, 2016 - 2024, Global Market Insights
Relevant ***	8	<ul style="list-style-type: none"> • The Maturing Nanotechnology Market: Products and Applications, BCC Research • Complex-Oxide Nanomaterials Market - Analysis of Growth, Trends and Forecast (2016 - 2022), Mordor Intelligence • Metal & Metal Oxide Nanoparticles Market: Global Industry Analysis and Opportunity Assessment, 2016-2026, Future Market Insights • Gold Nanoparticles Market Size by Application (Electronics, Medical & Dentistry, Catalysis), Industry Analysis Report, Regional Outlook, Application Potential, Price Trend, Competitive Market Share & Forecast, 2017 - 2024, Future Market Insights • Smart textiles to stimulate the silver nanoparticles market over 2016-2024, Fractovia • Nanocellulose Market - Global Industry Analysis, Forecast 2015-2023, Transparency Market Research • Nanoclay Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2015 - 2023, Transparency Market Research • Nanoclay Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2017 - 2026, Transparency Market Research

Low relevance **	7	<ul style="list-style-type: none"> • The Global Market for Nanomaterials 2010-2027, Research and markets • Global Nanotechnology Market Outlook 2024, RNCOS • World Nanomaterials - Demand and Sales Forecasts, Market Share, Market Size, Market Leaders, Freedonia • Production and applications of carbon nanotubes, carbon nanofibers, fullerenes, graphene and nanodiamonds: a global technology survey and market analysis", Innovative Research and Products, Inc. • North America Nanosilver Market to garner substantial proceeds over 2017-2024, biomedical applications to drive the industry growth, Fractovia • APAC Carbon Nanotubes Market to observe highest growth rate over 2016-2024, high demand from the electronics sector to stimulate the industry growth, Fractovia • Gold Nanoparticles market outlook: Medical & Dentistry applications to stimulate industry growth over 2016-2022, Fractovia
Irrelevant *	5	<ul style="list-style-type: none"> • Nanotechnology Update: U.S. Leads in Government Spending Amidst Increased Spending Across Asia, Lux Research Inc • Is Graphene the Next Silicon ... Or Just the Next Carbon Nanotube?, Lux Research Inc. • Carbon Nanomaterials Update 2017 Edition, Lux Research Inc • Advanced Manufacturing in a highly connected world, 2015, Deloitte • Nanotechnology and nanomaterials: types, current/emerging applications and global markets, Innovative Research and Products, Inc.
TOTAL	29	

Of the 29 assessed commercial market studies, 17 have been found to be of very high relevance, high relevance or relevant. The other 13 commercial market studies have been found to be of low relevance or irrelevant. The most relevant study is "Europe Nanomaterials Market by Type of Material and End User Opportunity Analysis and Industry Forecast, 2014 – 2022" from Allied Market Research. This study focuses on the European nanomaterials market for the period from 2014 to 2022. It provides a market forecast from 2016-2022 (including CAGR) as well as additional parameters (e.g. market revenue). The study contains market segmentation by type of nanomaterial (Carbon Based

Nanomaterials, Metal & Non-Metal Oxides, Metal Based Nanomaterials, Dendrimers Nanomaterials, Nanoclay and Nanocellulose) by end-user (paints & coatings, adhesives & sealants, health care & life science, energy, electronics & consumer goods, personal care and others) and by country (France, Germany, Italy, Spain and United Kingdom). Furthermore, it analyses the major market players, factors that drive and restrict the growth of the world nanomaterials market. This study follows the common methodology applied in commercial market studies: primary research (3,300 product literatures, industry releases, annual reports, industry journals, trade associations' releases and government websites) and secondary research (35 hours of interviews and discussion with a wide range of stakeholders). The study seems reliable; however, it may be prone to bias as some of the information is from sources such as commercial and private companies. It also contains detailed information on EU Member States (e.g. market share or EU leading country in nanomaterials European market -Germany-).

However, some information in the report also appears to be found in the report *Nanomaterials Market by Type – Global Opportunity Analysis and Industry Forecast, 2014-2022*, Allied Market Research, as this report has a worldwide focus and not only at EU level.

Since most of the commercial market studies analyse the nanomaterials market by segmentation (by region and by type of nanomaterial), key players, variables (e.g. CAGR), baseline years and market forecast, they are a good source for elaborating market studies on nanomaterials. However, these market studies are highly priced, thus it is important to know that some of the market studies may contain market data, but they may not include data analysis. For this reason, prior to purchasing a market analysis report, it may be helpful to request a sample and carefully evaluate the relevance.

3.3.2.2 Assessment of EU sources

This group comprises both official reports or working papers by EU authorities, in particular the European Commission, including the Institute for Health and Consumer Protection (IHCP) of the Joint Research Centre (JRC), and study reports commissioned, approved and published by the European Commission.

A total of 7 EU sources were identified and assessed. These sources give a recommendation proposing a definition for nanomaterial of the year 2011 which is still relevant (1 study), three reports on a review of this recommendation in 2014 including clarification issues, challenges of implementing and recommendations (which have, however, not led to a revision of the original definition). The reports include: one working paper on types of uses of nanomaterials, which mainly focuses on safety aspects, and two impact assessments focusing on policy alternatives related to nanomaterials (changing the REACH requirements for nanomaterials, and possible legislation to increase transparency on nanomaterials on the market).

Since these sources provide baseline information or address specific questions rather than serving as market studies, they can in general not be assessed in the same way according to the criteria clusters as the market studies. Therefore, in the following results, the criteria are not displayed in the same manner as for the commercial market studies, rather only the relevant aspects that can be applied to the criteria. This also pertains to the other types of sources evaluated in the following sections.

For Criterion 1 (Does the data source provide market data for a defined specific baseline year?), only two sources specify an explicit baseline year. A (limited) forecast into the future has only been made in the assessment of (BiPRO, Öko-Institut e.V., 2013). This study covers a time frame of 2012-2022; however, the main focus within this time frame are the REACH registration deadlines and duties within this time frame, not data attributed to single years. Within the impact assessment, health benefits have also been assessed for

the following time frame of 2022-2042; this is due to latency effects and a time profile of health risks due to cancers.

While these studies are reliable and the sources neutral and credible, they do not contain relevant study methods for market studies, since they address different focuses and questions. However, some of them contain relevant additional information for the production of market studies:

Criterion 4: Specific assessment criteria applicable for particular types of studies only

This criterion addresses if there is any specific data or questions addressed in the study (e.g. it provides additional specific data input to other studies). Table 8 summarises the main results on this assessment criteria.

Table 8: Results on the assessment for the 7 studies by considering Criteria 4 parameters

Topic	No. of studies	Content
Does this study provide relevant information for production of market study?	4	Four of the seven studies provide some relevant information for production of market studies. The studies dealing with the review of the EC Recommendation for a definition of the term nanomaterial, however, do not provide additional relevant information for market studies, since they basically verify the nanomaterial definition agreed upon in 2011.
Which specific information, data or specific questions relevant for market studies?	4	Each of the four sources provides specific information: the official recommended definition for nanomaterials for the EU, the regulatory context of REACH registrations and the potential use of real data from processes under REACH (registrations, authorisations and restrictions), data on nanomaterial production inside and outside the EU, sometimes distributed between types of nanomaterial, and some further (limited) relevant background information regarding nanomaterials in the EU.
Substantiation / verification or contradiction to other studies?	7	These sources in general verify each other or are based on each other. Other sources reviewed and analysed also confirm each other.

Conclusion

In spite of the limitations for an application of the specific criteria catalogue, studies also belonging to this category have been evaluated by considering the five assessment criteria and by using a ranking for relevance (* - *****). Table 9 presents the results on the evaluation of all seven EU sources.

Table 9: Summary of final results from the assessed EU sources

Ranking	No. studies	Name of the report/study
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Very high relevance *****	1	<ul style="list-style-type: none"> European Recommendation on nanomaterials (2011/696/EU)
High relevance ****	0	
Relevant ***	4	<ul style="list-style-type: none"> Towards a review of the EC Recommendation for a definition of the term nanomaterial. Part 1: Compilation of the information concerning the experience with the definition (Rauscher, et al., 2014) Towards a review of the EC Recommendation for a definition of the term nanomaterial. Part 2: Assessment of collected information concerning the experience with the definition (Roebben, et al., 2014) Towards a review of the EC Recommendation for a definition of the term nanomaterial. Part 3: Scientific-technical evaluation of options to clarify the definition and to facilitate its implementation (Rauscher, et al., 2015) Examination and assessment of consequences for industry, consumer, human health and the environment of possible options for changing the REACH requirements for nanomaterials (BiPRO, Öko-Institut e.V., 2013)
Low relevance **	1	<ul style="list-style-type: none"> Commission Staff Working Paper: Types and uses of nanomaterials, including safety aspects (European Commission, 2012)
Irrelevant *	1	<ul style="list-style-type: none"> Study to assess the impact of possible legislation to increase transparency on nanomaterials on the market (Risk & Policy Analysts Ltd., BiPRO, 2015).
TOTAL	7	

Five of the seven EU sources assessed have been found to be of very high relevance or relevant. The other two sources have been found of low relevance or irrelevant. Due to the fundamental definition used for this study, the most relevant document is the European Recommendation on nanomaterials (2011/696/EU). This is still the valid definition, since the three documents by JRC "Towards a review of the EC Recommendation for a definition of the term nanomaterial" did not come to a conclusion resulting in a change of this definition as of writing.

The study "Examination and assessment of consequences for industry, consumer, human health and the environment of possible options for changing the REACH requirements for nanomaterials" (BiPRO, Öko-Institut e.V., 2013) is mainly relevant due to the regulatory

context of REACH and the possibilities for ECHA how to utilise (now and in future more actual available) REACH data for market studies and estimations. However, the market data used there are partly outdated in 2018, and, although the approach and assumptions for this study have been supported and critically reviewed by CASG-Nano experts, the way of extrapolation from case studies to the total nanomaterials market is prone to high uncertainties.

3.3.2.3 Assessment of sources of single EU Member States

This group also comprises both official reports or working papers by Member State authorities and study reports commissioned and approved by those authorities. A total of 10 such sources were identified and assessed. These sources have very heterogeneous contents; one study assesses the impacts of a European Register of products containing nanomaterials, with a similar but narrower focus than the newer and broader EU study (Risk & Policy Analysts Ltd., BiPRO, 2015). The other sources have a specific focus on Member States (four on the Danish market, one on Sweden and one on France) and/or on specific products and technologies (carbon nanotubes, nanosilver in textiles, products with nanosized pigment). One study addresses physical-chemical properties and aquatic toxicity which is irrelevant for this purpose.

Due to their heterogeneity and the specific questions addressed, i.e. sources do not serve as market studies, they could also in general not be assessed in the same way according to the criteria clusters as the market studies, but only a few aspects highlighted that can be applied to the criteria.

For Criterion 1 (Does the data source provide market data for a defined specific baseline year), four of the ten studies specified a baseline year. Only one of these studies provides a forecast into the future: (Jensen, et al., 2015) produces a forecast of the global market trade value of carbon nanotubes. Only this study of (Jensen, et al., 2015) and the assessment of Impacts of a European Register of Products Containing Nanomaterials (Hermann, et al., 2014) include relevant study methods for market estimations. The other studies do not contain centrally relevant additional information for the production of market studies:

Criterion 4: Specific assessment criteria applicable for particular types of studies only

This criterion addresses if there is any specific data or questions addressed in the study (e.g. it provides additional specific data input to other studies). Table 10 summarises the main results on this assessment criteria.

Table 10: Results on the assessment for the 10 studies by considering Criteria 4 parameters

Topic	No. studies	Content
Does this study provide relevant information for production of market study?	4	Four of the ten studies provide some relevant information for the production of market studies.

Which specific information, data or specific questions relevant for market studies?	4	Each of the four sources provides specific information: a method for the estimates of number of companies and nanoproducts per sector, the global market value & production volume for carbon nanotubes, publications of nanomaterial-related documents as an indicator of increased research (which is however of limited relevance), and some specific data for France on the basis of an already existing national register.
Substantiation / verification or contradiction to other studies?	1	For the Danish study on carbon nanotubes (Jensen, et al., 2015), multiple secondary sources follow the same trend globally. For the other nine studies, information on the relationship to other studies is not available.

Conclusion

Despite the limitations for an application of the specific criteria catalogue, this heterogeneous group of studies from EU Member States has also been evaluated considering the five assessment criteria and by using a ranking for relevance (* - *****). Table 11 presents the results on the evaluation of all ten sources of single EU Member States.

Table 11: Summary of final results from the assessed sources of single EU Member States

Ranking	No. studies	Name of the report/study
Very high relevance *****	0	
High relevance ****	1	<ul style="list-style-type: none"> Carbon nanotubes (Jensen, et al., 2015)
Relevant ***	1	<ul style="list-style-type: none"> Assessment of Impacts of a European Register of Products Containing Nanomaterials (Hermann, et al., 2014)
Low relevance **	2	<ul style="list-style-type: none"> Mapping research and development within the nanofield in Sweden (Swedish Chemicals Agency, 2012) Assessment of nanosilver in textiles on the Danish market (Tønning, et al., 2012)
Irrelevant *	6	<ul style="list-style-type: none"> Considerations about the relationship of nanomaterial's physical-chemical properties and aquatic toxicity for the purpose of grouping (Hund-Rinke, et al., 2017) Better control of nanomaterials (Christensen, et al., 2015)

		<ul style="list-style-type: none"> • Supplementary Survey of Products on the Danish Market Containing Nanomaterials (Tønning, et al., 2014) • Nanomaterials in Commercial Aerosol Products on the Danish Market (Fischer, et al., 2014) • Éléments issus des déclarations des substances à l'état nanoparticulaire RAPPORT D'ETUDE 2017 • Survey of products with nanosized pigment (Sørensen, et al., 2015)
TOTAL	10	

Only two of the ten sources of single EU Member States have been found to be of high relevance or relevant. The other eight sources have been found to be of low relevance or irrelevant.

The Danish study on carbon nanotubes (Jensen, et al., 2015), countries and application are considered as highly relevant for this specific market, since the study method details market value and the rate of change over several years. Global market value and production volume is also displayed for industrial sectors. Some of the information is based on private commercial sources.

The study on the assessment of impacts of a European register of products containing nanomaterials (Hermann, et al., 2014) provides relevant data available, broken down by sector and product type, and the annual production volumes of selected nanomaterials. However, the primary goal of the document is not a market study, and the foreword of the editing authority (German Environment Agency) contains a caveat that the reliability of some data estimations is limited.

3.3.2.4 Assessment of database sources

This group comprises seven databases and inventories either on the EU level including Member States, or on Member States level only (Germany, Denmark). Depending on the respective database, the focuses are nanomaterials but also nano products, in particular consumer products containing nanomaterials, and nanotechnology. Therefore, some of them contain current and past market data, but are no market study.

For the databases, at the time of the study the actual status available has been examined. However, information has been gathered whether the databases are still being updated and in which way new information is collected. Table 17 gives an overview on updates of the databases.

Table 17: Update status of databases and other data sources

Name of the database	Information on updates
The Nanodatabase (DTU Environment).	The database is continuously updated. New products can be reported by a form on the website that are examined and their publication in the database authorised by DTU Environment.

Nanowatch – Nanoprodukt Datenbank (Nanoprodukte im Alltag) (BUND, 2018)	Last new entries have been made in June 2016, but further update is planned (subject to future third-party funds).
Consumer Products Inventory (of nanomaterials in consumer products) (PEN, 2018)	The database is continuously updated: By crowdsourcing expertise the goal of PEN is to create a living inventory for the exchange of accurate information on nano-enabled consumer products. Registered users are encouraged to submit relevant data pertaining to nanoparticle function, location, properties, potential exposure pathways, toxicity and life cycle assessment. Registered users can update product information and add new products.
Nanotechnology in the real world: Redeveloping the nanomaterial consumer products inventory (Vance, et al., 2015)	One-off scientific article referring to and describing the development of the Consumer Products Inventory (PEN, 2018)
DaNa – Information about nanomaterials and their safety assessment (DaNa, 2018)	The database is in a continuous update process so that latest research findings are examined and integrated. This is currently financed by the research project DaNa 2.0 (Data and knowledge on Nanomaterials - Processing of socially relevant scientific facts) with a duration up to 31.07.2019 (see https://www.nanopartikel.info/en/projects/current-projects/dana-2-0); a follow-up project is scheduled.
Nanowerk – Nanomaterials Database (Nanowerk, 2018)	The database is continuously updated and news published, as well as guest articles in the "Nanotechnology Spotlight" series. For all news and articles the date of posting is documented but not the date of new database entries. Update information for the database can be reported using a contact form.
Nanowerk – Global nanotechnology markets section / Nanotechnology Company & Research Labs Directory section / Nanotechnology relevant publications	All sections of the Nanowerk database website are continuously updated and news published. Contact form for updates of companies and organisations is provided.
Status on Nano-Science Technology and Innovation (StatNano website)	Annual reports, published for 2015, 2016 and 2017 (issued each in March of the following year), as well as further StatNano publications on nanotechnology, see http://statnano.com/publications .

For Criterion 1 (Does the data source provide market data for a defined specific baseline year?), five of the seven databases contain market data for a baseline year. One of them – the Consumer Products Inventory (of nanomaterials in consumer products) (PEN, 2018) was last updated on 03 October 2011 so it is no longer up to date. According to the nature of databases and inventories, none of them provides a forecast into the future. Since databases do not provide any method or relevant data for market studies, apart from the function that the nanomaterials can be filtered, e.g. by country of origin (exports) and country of production, categories and manufacturers (The Nanodatabase; DTU

Environment) or by categories, sub-categories, date and manufacturers (Nanowatch – Nanoprodukt Datenbank; BUND, 2018), the question of relevance of the study method in general is not applicable. As far as information on this is applicable, the sources seem reliable and independent. The databases provide relevant information for the production on market studies, but only for the collection of data and information, not for methodological issues.

Criterion 4: Specific assessment criteria applicable for particular types of studies only

This criterion addresses if there is any specific data or questions addressed in the study (e.g. it provides additional specific data input to other studies). Table 12 summarises the main results on this assessment criteria.

Table 12: Results on the assessment for the 7 studies by considering Criteria 4 parameters

Topic	No. studies	Content
Does this study provide relevant information for production of market study?	6	Six of the seven studies provide some relevant information for data and/or information collection for the production of market studies.
Which specific information, data or specific questions relevant for market studies?	6	Three of the database contain information for data collection, the other three on more general information collection. In one case e.g. listed products include information on the manufacturer, country of origin, product category, claims supporting the application of nanotechnology, and further supplemental data on the nanomaterial.
Substantiation / verification or contradiction to other studies?	1	The percentages of nanomaterial compositions in the Consumer Products Inventory 2.0 are in agreement with those of the Danish Nanodatabase. For the other databases, data are not available, or the question of verification or contradiction is not applicable.

Conclusion

Although the specific criteria catalogue for market studies could not be applied here, the database sources have been evaluated considering the five assessment criteria and by using a ranking for relevance (* - *****).

Table 13 presents the results on the evaluation of all seven database sources.

Table 13: Summary of final results from the assessed database sources

Ranking	No. studies	Name of the report/study
Very high relevance *****	0	
High relevance ****	0	

Relevant ***	0	
Low relevance **	4	<ul style="list-style-type: none"> • The Nanodatabase (DTU Environment) • Nanowatch – Nanoprodukt Datenbank (Nanoprodukte im Alltag) (BUND, 2018) • Consumer Products Inventory (of nanomaterials in consumer products) (PEN, 2018) • Nanotechnology in the real world: Redeveloping the nanomaterial consumer products inventory (Vance, et al., 2015)
Irrelevant *	3	<ul style="list-style-type: none"> • DaNa – Information about nanomaterials and their safety assessment (DaNa, 2018) • Nanowerk – Nanomaterials Database (Nanowerk, 2018) • Nanowerk – Global nanotechnology markets section / Nanotechnology Company & Research Labs Directory section / Nanotechnology relevant publications
TOTAL	7	

All the seven database sources have been found of low relevance or irrelevant. The four databases evaluated as of low relevance do not provide any methodology or variables for production of market studies. However, they might be used as a tool for gathering additional specific information for the production of market studies. The other three databases do not contain any data that can be used for production of market studies.

3.3.2.5 Assessment of other data sources

This residual (and heterogeneous) category of sources which did not fit into one of the previous categories of sources comprises two scientific papers on nanomaterials and a website on worldwide actual information and statistics in nano-based science, technology and industry (StatNano). Thus, a total of 3 sources were identified and assessed. One paper focuses on the world market for nanomaterials, its structure and trend, based on and evaluating other market studies (Inshakova, et al., 2017), the other on processes for manufacturing nanomaterials and nanoparticles and applications (Charitidis, et al., 2014). These sources have been assessed as well with regard to those aspects that can be applied to the criteria.

For criterion 1 (Does the data source provide market data for a defined specific baseline year), all three sources specify a baseline year. The two journal papers also provide forecasts into the future: studies (Inshakova, et al., 2017) for a time horizon from 2008 to 2024, (Charitidis, et al., 2014) from 2011 to 2016. The paper of (Inshakova, et al., 2017) explains, compares and evaluates relevant study methods applied in existing market studies for nanomaterials and shows a good comprehension of these study methods. For the paper of (Charitidis, et al., 2014) the study method is irrelevant for market studies, for the StatNano website this criterion is not applicable.

Criterion 4: Specific assessment criteria applicable for particular types of studies only

This criterion addresses if there is any specific data or questions addressed in the study (e.g. it provides additional specific data input to other studies). Table 14 summarises the main results on this assessment criteria.

Table 14: Results on the assessment for the 3 other data sources by considering Criteria 4 parameters

Topic	No. studies	Content
Does this study provide relevant information for production of market study?	1	One source provides relevant information for the production of market studies.
Which specific information, data or specific questions relevant for market studies?	1	The study of (Inshakova, et al., 2017) provides a comparison of several different market studies, quoted in the reference list, with regard to their approaches and assumptions. Where further information on these commercial market studies were accessible, this reference list has served for a supplement of market studies examined in Section 3.3.2.1.
Substantiation / verification or contradiction to other studies?	1	This study reviews market studies and identifies information asymmetry, heterogeneity and inconsistencies in the market studies and databases available. Although it has a specific focus on the Russian market, it also reviews worldwide sources and market data.

Conclusion

An evaluation of this heterogeneous residual group of other studies in the same way as for the other groups considered the five assessment criteria and used the ranking for relevance (* - *****).

Table 15 presents the results on the evaluation of these three other sources.

Table 15: Summary of final results from the assessed "other" sources

Ranking	No. studies	Name of the report/study
Very high relevance *****	1	<ul style="list-style-type: none"> World market for nanomaterials: structure and trends (Inshakova, et al., 2017)
High relevance ****	0	
Relevant ***	0	

Low relevance **	1	<ul style="list-style-type: none"> Manufacturing nanomaterials: from research to industry (Charitidis, et al., 2014)
Irrelevant *	1	<ul style="list-style-type: none"> Status on Nano-Science Technology and Innovation (StatNano website)
TOTAL	3	

One of the three other sources have been found to be of very high relevance. The other two sources have been found to be of low relevance or irrelevant.

The paper of (Inshakova, et al., 2017) is considered as very highly relevant for this specific market for manufactured nanomaterials because it has already raised and addressed some of the questions that also have been subject of this study, e.g. which are crucial indicators and parameters for commercial market studies. Therefore, this study also provides valuable input for Task 4 and a starting point of issues to evaluate and review, in particular the conclusions drawn in this paper.

The paper of (Charitidis, et al., 2014) provides some additional information for the understanding of industrial production. The information on the StatNano website considers the role of science (cited/indexed nano-articles) and innovation (patents). Thus, apart from this peripheral information, relevant market information is very limited.

3.3.2.6 Overall conclusions of the evaluation

Overall from all the sources evaluated 25 have been found very high relevance, high relevance or relevant (17 commercial market studies, 5 EU sources, 2 Member States sources and 1 other data source). In the case of data bases none of the sources are relevant.

Some potential questions have been raised in preparation of the study that were expected to be answered by the analysis of commercial market studies, in particular those evaluated as of very high relevance or of high relevance. Thus, after completion of the matrix some draft conclusions have been drawn. They address in particular these questions:

- Is there a preference or ranking for data sources and methods to be applied?

Although information on the methodological approach and data used in commercially available market studies was not completely available, the operational set of criteria allowed a qualitative ranking for these market studies as well as other, complementing data sources and methods applied on a 5-point scale.

- Has the question or assumption been addressed whether markets for manufactured nanomaterials and their future development might be constrained by the demand or by the supply side?

Market studies usually worked with growth rates as parameters but did not explicitly address whether the demand (driven by industrial technologies used and/or products, e.g. for the consumer, that require specific nanomaterials) determines the growth rate or the production capacity for nanomaterials that cannot grow by the same rate as the demand. Obviously, this is a theoretical question known from post-Keynesian and neo-classic growth models, not addressed in rather mechanical market studies. However, some market studies seem to have a main focus on the development of demand, which indicates that this is

mainly the limitation side of the market. Production capacity has explicitly been modelled as a parameter in one study only. In practice, the influence of supply versus demand may vary from one specific nanomaterial market to another and change over time due to steps of technological progress.

- Which methods or methodological elements can be combined or modified to improve results? What approaches seem most promising for that and why?

For answering this question, a closer look at some of the market studies classified with “very high relevance” and “high relevance” should be examined with complete information. The selection will also depend on which specific nanomaterial markets are regarded as the most interesting or relevant for ECHA.

- Which methods are most suitable for describing and assessing the market development in the past and current markets?

This depends on the questions to be addressed with the study and the interest behind the market development (e.g. highly aggregated or disaggregated market information required). This can be illustrated by two opposed examples showing different approaches specifically targeted to the central goal of the studies:

- The study of (Hermann, et al., 2014) conducted an impact assessment of a “Concept for a European Register of Products Containing Nanomaterials” (ENPR concept) proposed by the German Environment Agency (UBA) and a comparison between this concept, which foresees a horizontal register built on the present substance-related and product-related regulations, and the alternative of a new, separate register independent from existing EU product- and substance-related regulations. In order to estimate costs for notifiers and competent authorities as well as benefits for all actors and the environment that are associated with such an ENPR, the study of Hermann, et al. (2014) estimated in detail the number of companies and the number of notifications per company affected in each product sector, in order to give a detailed estimation on total costs. This level of detail was suitable and adequate for the specific study focus. On the other hand, the time frame for this study has been modelled only very roughly over five years, without taking into account detailed assumptions on growth of the market within this period.
- In contrast, the market study of Allied Market Research for Europe (Allied Market Research, 2016a) had as a main focus an extensive analysis of trends and emerging dynamics for 2014 to 2022, including a comprehensive analysis of factors that drive and restrict the growth of the market. For this purpose, compared to the specific study of (Hermann, et al., 2014), the model shows a rougher aggregation with regard to type of material and end-user industries and has, apart from specific data from a few selected main producers, not a focus on too detailed data on companies and notifications. Instead, in this study the growth process of the market has been estimated in much more detail in annual steps up to the year 2022. Also, the specific roles of the five most important countries for nanomaterials are modelled in more detail.

Other examples commonly found in mostly all current commercial market studies is the description of the market base on the region or country, on the type of nanomaterial and the end-use of the nanomaterial.

In a particularly detailed manner, the market study “Europe Nanomaterials Market by Type of Material and End User Opportunity Analysis and Industry Forecast, 2014 – 2022” from Allied Market Research (Allied Market Research, 2016a) describes the European nanomaterials market by:

- region (Europe) and country (UK, Germany, France, Spain, and Italy),
- type of material (carbon based nanomaterials (carbon nanotubes, fullerenes & POSS, and graphene), metal (titanium dioxide, zinc dioxide, silicon dioxide, aluminium oxide, and others) & non-metal oxides, metal based nanomaterials (silver, gold, nickel, and quantum dots), dendrimers nanomaterials, nanoclay and nanocellulose),
- end-user industries (paints & coatings, adhesives & sealants, health care & life science, energy, electronics & consumer goods, personal care and others (including food & beverages, textiles, etc.)

Furthermore, the market study "Nanomaterials Market - Trends, Investment Analysis and Future scope to 2022" from Mordor Intelligence (Mordor Intelligence, 2017b) also describes the global market of nanomaterials by:

- Region (Europe, Asia-Pacific, North America).
- End-user (electronics, Health-care, energy & power, aerospace, water filtration and some other major end-users).
- Type of material (nano-particles, nano-fibres, nano-tubes, nano-clays and nano-wires).
- Which methods can be applied for projections into the future?

In principle, a suitable set of independent determining variables can be applied for future projections. The comparative review of (Inshakova, et al., 2017) spotted that existing market studies showed "information asymmetry, heterogeneity and even inconsistency of the information", in particular from existing databases used, and very different views on the positive dynamics and prospects on the global value of nanomaterials that can be described as a range from optimistic, neutral and pessimistic (Inshakova, et al., 2017) (which correspond to a lower bound, central estimate and upper bound). Thus they span a corridor for forecasts that diverges in a diagram the more the forecasts are projected into the future. However, in order to perform an evaluation of the empirical methodology used in the individual approaches, the complete information and documentation of the studies would be inevitable.

- Which data and methods have proved irrelevant, negligible or unreliable?

It showed that there has been a variety of additional information on nanomaterials that might be important for a forecast at first glance but cannot be expressed with a deterministic or stochastic relationship. We do not agree with this ex-ante conjecture that some data or methods used in general have proved completely irrelevant. However, we would highlight the following two aspects:

Regarding the number of nanotechnology patents registered at the European Patent Office and other international patent offices, which are indeed suggested and used as an indicator both for the general dynamics and development of the market over the years as well as for the contribution of Member States to the state of technology, this is indeed a quantitative and countable metric indicator. However, it is not known (without the contribution of additional information by experts) which share of these patents registered are in a phase of already being exploited in the market. Moreover, the market is too new and dynamic to have enough ex-post data for verification or falsification of forecasts in the past.

In addition, data sources which are based on products available in the market, products and companies that declared nanoparticles, nanomaterials and indicators considering science cited/indexed nano-articles) and innovation (patents) and based on the number of publications and nano related projects were found irrelevant.

- Which developments could be well foreseen? Have there been innovations, influences, developments or structural interruptions in the market that have not been predicted?

For this question, some additional sources (e.g. on technology development in the past years) and in particular qualitative expert interviews of relevant university and non-university research institutions and company associations should be consulted.

- Are there considerable information gaps due to confidential business information not publicly available?

This is certainly the case since information on research & development within companies is not made public if the company is not forced to do so (e.g. in the analysis of alternatives within the REACH authorisation documents).

- Lessons learned from previous studies and their methodological approaches

In particular, the involvement in previous studies on nanomaterials and the methodology to estimate the relevant markets and market structure for analysing specific questions about the market and its development, e.g. for impact assessments, have revealed that there is still a high degree of uncertainty in the knowledge of this issue. This uncertainty is also addressed in specific scientific communities and project series on technology assessment (e.g. NanoTrust, coordinated by the Institut für Technikfolgenabschätzung in Vienna, Austria).

3.4 Task 4: Detailed analysis of relevance and reliability of parameters, factors and their combinations to produce market studies

In the market studies examined in detail in Section 3.3.2.1, several assumptions on influential factors for the market for nanomaterials have been made and sometimes also justified. The spectrum of these influential factors reach from a qualitative description of market conditions, expectations and general framework, from the economic and political view, e.g. on EU or Member State level. In Task 4, the central and peripheral parameters and factors are analysed which have been used in the market studies. It can be seen to which extent there are common but also diverging approaches in the studies.

It shall be emphasised that, since the full version and the data of the market studies were not available to the contractor, information could only be gathered that was publicly available, either from the information disclosed by the producer (table of contents, summary, structure, methodology) from sample documents requested and received or from the website of the producer, or from reviews of such commercial market studies, e.g. as articles in scientific journals. A particularly valuable paper for this information has been the review of (Inshakova, et al., 2017), on the world market for nanomaterials.

In the end, based on the analysis of the findings a suggestion is given which of the existing commercial market studies have been identified as the most relevant and reliable and therefore can or should be purchased, since they also represent and cover the spectrum of assumptions leading to rather lower bound, central estimate or upper bound values within a range. assumptions.

3.4.1 Identification and discussion of single parameters and determining factors

In market studies forecasting the development of nanomaterials in the future, it is obvious that the central parameter is the annual growth rate of production or use data. In principle growth rates can differ, and the following growth rates can be distinguished:

- Annual growth rate of the gross domestic product (GDP) for the EU or individual Member States
- Annual growth rate of the market for manufactured nanomaterials in general
- Annual growth rates of the market for specific manufactured nanomaterials
- Annual growth rate of the market for specific products in which nanomaterials are used
- Specific growth rates of the market in the identified most relevant Member States

From the use of historical data in studies, it was detected that part of the studies only start from one baseline year while others use historical data, starting from the years 2006, 2008, 2010, 2012 or 2014 (see Table). It is a common approach for developing scenarios spreading into the future to estimate an average growth rate as a geometric mean from the time horizon from t_0 to t_n (points in time are usually years, but might also constitute quarters or months) for which historical data are available, and extrapolate data from the baseline year into the future using the average growth rate. This is legitimate as long as there is no justified indication that future growth rate will deviate systematically from past growth rates, e.g. by the influence of other exogeneous parameters on the growth rate rather than time.

Since the nanomaterials market is relatively young and developing, historical data are not available for a longer time, unlike e.g. the market for a technically mature industrial product.

The majority of studies use the compound annual growth rate (CAGR) which seems to be the commonly accepted parameter. A general formula for the CAGR is defined as:

$$\text{CAGR}(t_0, t_n) = (V(t_n)/V(t_0))^{\frac{1}{t_n - t_0}} - 1$$

$V(t_0)$: start value, $V(t_n)$: finish value, $t_n - t_0$: number of years.

This formula exactly describes a geometric mean of annual growth rates and is used in most of the market studies.

However, the level of CAGR assumed in different studies differ, as will be explained in Section 3.4.2. In the comparison of studies (Inshakova, et al., 2017), the authors categorise the different studies examined to have either a rather "pessimistic view" or "conservative estimate" or an "optimistic view" with regard to the global value of nanomaterials. The project team prefers using the terms "lower estimate"/"lower bound" versus "upper estimate"/"upper bound" commonly used in sensitivity analysis, which are more neutral and do not imply negative or positive connotations.

In this comparison, the estimates of Mordor Intelligence (Mordor Intelligence, 2017b) for the global nanomaterials market have been described as a pessimistic view (with a development from 1.1 billion US-\$ in 2010 to 11.3 billion US-\$ in 2020), whereas those of Allied Market Research (Allied Market Research, 2016b) have been described as an optimistic view (with a development from 1.7 billion US-\$ in 2010 to 55.0 billion US-\$ in 2020). Both of these market studies have been evaluated in this study as well and received

– based on the information available – an overall evaluation of “*****” (high relevance).

Further parameters identified in some of the market studies have been:

- Market sizes
- Market shares of companies and market structure changes (Acquisitions & Mergers)
- Prices and price developments
- Technology readiness level (TRL)
- Traceability of nanomaterials in products
- Macroeconomic indicators
- Per-capita Gross Domestic Product (GDP)
- Country and regional demand and prices
- Production capacity
- Profit margin trends

An important insight is that the aspect of imports and exports has only been explicitly addressed in one market study. This one had a focus in the nanoclay market only, not on the total market for nanomaterials. Also, an explicit analysis of drivers, opportunities and restraints of the market has only been addressed in a very minor share (5 of 29 market studies).

Apart from quantitative parameters, a set of qualitative influential factors can be addressed and described.

One field of additional criteria is the scientific assessment, but also the attitude in public towards human health and environmental risks of nanomaterials. This is relevant in view of several contexts:

- in the context of legislation on national, EU and international level (e.g. the REACH Regulation and its current way of implementation for nanomaterials in general and in particular)
- in the context of adapting national, EU and international legislation (e.g. assessment of the effects of changing the REACH requirements for nanomaterials in future or establishing legally relevant classification systems for nanomaterials) or establishing new legislation specifically addressing nanomaterials
- in the context of establishing public participation and governance
- in the context of insurance and insurability of risks

All these aspects have a qualitative, but potentially severe influence on the development of nanomaterials in the future, due to

- Legal prohibitions of certain nanomaterials or products
- Factors for supporting or hindering investments of industry in the research and development of nanomaterials, nanotechnology and products containing nanomaterials
- Potential crowding-out effects between EU and non-EU countries in case of different legislation or prohibition within and outside of the EU/EEA
- Further expectations of investors and relevant associations (e.g. CEFIC) and their future policies

Another sphere of parameters which have a qualitative rather than quantitative influence is the field of research & development activities related to new materials and technologies. This comprises both private and public expenditure for nanotechnology research. From the public side, this represents an influential economic policy issue on EU as well as Member state level. This can be shaped both with elements of regulatory policy and of process policy (e.g. research & development funds of the European Union). Only in few market studies expectations on future policy is qualitatively addressed. In particular (Luxresearch, 2015) focuses on governments, corporations and private investors (venture capitalists) investments. This report concludes that U.S. government leads the funding over all other governments and U.S. corporations also lead global spending on R&D on nanotechnology. Furthermore, (Abraham, 2011) focuses on the national government investments from 1997-2012 and the regional R&D on nanotechnology.

Although the private and public expenditures on R&D are a quantitative parameter and their trends can be analysed, the quantitative link between R&D expenditures and other economic market data is not always clear. This even more applies to other indicators of R&D activities, in particular the amount of scientific publications on nanomaterials and nanotechnologies and the nanotechnology patents registered in the European Patent Office and in the United States Patent and Trademark office (USPTO). This issue is explained by (Inshakova, et al., 2017), using the data of (StatNano 2016) from 2012 to 2016. Although further assumptions have to be made to which extent these patents can be and have been exploited in order to estimate their influences and their statistical relationship on other parameters of the models used in the market studies, this parameter of nanotechnology patents can serve as an indicator which Member States play a predominant role in nanotechnology and should therefore be addressed with a particular emphasis in a market study. Only four EU Member States are among the top ten countries of nanotechnology patents. These are shown in Table 16.

Table 16: Nanotechnology patents in EPO and USPTO 2012-2016, ranking of EU Member States most important

Member State	EPO rank of countries worldwide	EPO rank of EU Member States	USPTO rank of countries worldwide	USPTO rank of EU Member States
Germany	2	1	6	1
France	3	2	7	2
United Kingdom	6	3	9	4
Netherlands	8	4	8	3

Source: (Inshakova, et al., 2017), based on data of StatNano (2016)

The review of existing market studies by (Inshakova, et al., 2017), also mentions several drivers of the world nanomaterials market, which are also commonly addressed in some of the market studies examined:

- Increase in market penetration of materials
- Decrease in prices for nanomaterials

- Improvement of properties of nanomaterials
- Expending R&D activities related to new materials (measured in both private and public expenditure for nanotechnology research)
- Growing support of government institutions
- Rapid development of materials and applications
- Effectivity of partnerships and strategic alliances (domestic and international)
- Collaboration among industry players (in research and production)

All these factors have been identified as having a positive impact on the development of the world market for nanomaterials and the growth of market indicators.

On the other side, factors restraining in particular the future development of the global nanomaterials market have been identified in the same review study as:

- Concerns of impact to human health and the environment, referring to:
 - the toxicity of the nanomaterials themselves, but also of solvents, intermediate compounds, wastes stemming from processing and manufacturing
 - Requirements of government environmental regulation (in particular by ECHA for the EU market and the US-EPA for the US market).

Since this study had more detailed and complete information on some of the market studies, these conclusions of (Inshakova, et al., 2017) can generally be adopted.

3.4.2 Spectrum of parameters and determining factors

In this section it has been examined whether:

- parameters have been introduced and used within several studies in the same or in a completely different way, and;
- for those parameters that have been used coherently within several studies (this refers in particular to the CAGR that has been explained in Section 3.2.1) there is a common concordance on the range, or rather considerable variations.

The latter aspect comprises several different aspects, such as:

- whether there are e.g. contrary opinions in the future market development among different stakeholders (resulting in an upper and lower bound of scenarios);
- and whether there are major differences in the view of the present markets versus future market projections. This refers to the assumption whether the development of the past is supposed to continue or to be superseded by a different framework of market conditions.

The matrix structure used in Section 3.3.1 is the basis for this analysis. Since data in general are not available from the sample information of the market studies examined, a direct comparison of all market studies is not always possible. However, evidence can be given on one parameter of market studies for which a central role has been identified: the CAGR. In the comparison of market studies by (Inshakova, et al., 2017) the authors identified a considerable deviation between a lower bound and an upper bound of a range within existing market studies on nanomaterials. This gap already originates from a difference in absolute levels at the starting point (here of the year 2010); however, the range further opens up over time by differences in CAGR assumed.

3.4.3 Conclusions of the evaluation of parameters and factors

From completion and assessment of the evaluation matrix of the studies, some draft conclusions can be drawn addressing questions identified as a motivation for this study:

- Market studies show that the compound annual growth rate (CAGR), as explained in Section 3.2.1, is used throughout all studies as a central parameter determining the future growth of the nanomaterials market. It is generally assumed as much higher than the average growth rate of the total economy; however, the range of CAGRs derived from the market development of the past and forecast into the future reflects a lower bound, central estimate or upper bound of future development. Therefore, the way the selection of a CAGR is explained in a transparent way, justified and substantiated in a study (or the fact that the substantiation is lacking or not traceable) is an indication for the quality and reliability of the study.
- Other parameters and factors used are rather heterogeneous dependent on the complexity and the mechanisms of the models, so that no other central parameters with an outstanding relevance have been identified. However, these parameters even they were not found an outstanding relevance, they were used in some of the studies. Such as parameters and factors are market shares/size/trends, Porter's Five Forces model, SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis and competitive scenario and key players on the market.
- Beside quantitative parameters, a lot of fuzzy or qualitative influential factors have been mentioned and explained, such as public policy and public attitude towards and acceptance of nanomaterials and products containing nanomaterials. Other parameters are in itself quantitative (such as number of nanotechnology patents and their development over time); however, their influence on the market, i.e. on the marketability of nanomaterials, can only be described qualitatively.
- In several market studies, the input of experts from industry and research via interviews (primary research) but also secondary research (e.g. company websites and reports and databases) increases the relevance and reliability of parameters and factors as data from both types of research can be compared and subsequently parameters and factors verified. Such parameters and factors are (but are not limited to) market shares, value or growth. Furthermore, primary research offers authentic information about market size, share, growth and forecast. Some market studies performed primary research based on hours of interviews and discussions or /and online surveys. For more detailed information on how and which elements were included in primary and secondary research see Table 17.
- Secondary research from company information to customers can also be of high validity, in case that this information has a binding and warranting character, e.g. on applications and uses of the products. In any case, it can be verified by personal interviews with a company representative. In case of publications the quality and reliability of the journal or source has an impact on the validity of information as well.
- Demand is usually regarded as the main constraint of future market growth rather than production capacity.
- Confidential business information as assumed to result in a general information gap as companies are not willing to share confidential information or that their information gets disclosed. One way to mitigate this gap is to aggregate confidential data on specific parameters as averages and/or upper or lower bounds as well as extrapolating, estimating and modelling. Another possibility is to ask experts of key companies or relevant associations (which have an overall overview over their industry branch) to confirm and verify certain figures or assumptions. These experts can also be integrated in a Delphi method (as explained below in Section 4.4).

As a practical recommendation gained from the analysis of market studies, the project team suggests the following pragmatic action plan:

In the summary evaluation of commercial market studies displayed in Table 7, one study of Allied Market Research has been identified as “of very high relevance” and eight further ones as “of high relevance”. Since different reports of the same consulting companies have been valued separately in the evaluation matrix, these nine reports valued as of very high and high relevance have been produced by only five companies:

- Allied market research
- Zion Market Research
- Mordor Intelligence
- Future Market insights
- Global Market Insights

4. Overall conclusions

4.1 Initial decisions at the beginning of a market study

As a general starting point, the definition of nanomaterials (in general or specific) has a high importance for carrying out a new market study on nanomaterials. Therefore, a principal decision in the beginning shall be whether the (still valid) nanomaterial definition from the Commission Recommendation (European Commission, 2011) shall be the only reference, or whether potential review options (e.g. those discussed in 2014 and 2015 – (Rauscher, et al., 2014), (Roebben, et al., 2014) and (Rauscher, et al., 2015) – or even newer aspects expressed since then) are of specific interest for the market study. This includes a fundamental decision which materials will be considered as nanomaterials. First and foremost, this is a normative question and can only be decided by EU authorities. For this decision, the EU documents cited are the main data sources.

Having identified by this decision which nanomaterials according to the definition applied overall exist in the European market, the next decision shall be whether the total market of nanomaterials shall be the focus of the study or some specific markets with regard to material types and/or applications. This shall also be decided upon on the basis of the main purpose and interest to carry out a new market study.

4.2 Relevance and reliability of data sources, study methods and their combinations to gather information

Regarding the relevance and reliability of data sources, study methods and their combinations to gather information, 25 data sources were found of very high relevance, high relevance or relevant (17 commercial market studies, 7 EU sources, 5 Member States sources and 1 other sources). In the case of database sources, none have been found relevant. Within the specific types of sources, the following are the most relevant:

- Commercial market studies: “Europe Nanomaterials Market by Type of Material and End User Opportunity Analysis and Industry Forecast, 2014 – 2022” from Allied Market Research.
- EU sources: Examination and assessment of consequences for industry, consumer, human health and the environment of possible options for changing the REACH requirements for nanomaterials” (BiPRO, Öko-Institut e.V., 2013)
- Member State sources:
 - The Danish study on carbon nanotubes (Jensen, et al., 2015)
 - The study on the assessment of impacts of a European register of products containing nanomaterials (Hermann, et al., 2014)
- Other data sources: The paper of (Inshakova, et al., 2017) on structure and trends of the world market for nanomaterials

These studies mentioned are of particular interest in case the main question addressed in this particular source has a direct relationship with the motivation to conduct or commission a new market study on manufactured nanomaterials, or if the market study is (at least potentially) intended to be used or consulted for revisiting such a question, e.g. on:

- revising the REACH Regulation in any way with regard to nanomaterials,
- designing and installing a register, licensing or other concept for increasing transparency on the nanomaterials market,

- actions aimed at specific nanomaterials, e.g. carbon nanotubes.

At the next step, a selection of already existing market studies (at least those identified as the most relevant) can be the starting point and basis for generating a new one. This describes the state of the art as a starting point. Since the purpose of these types of source is in fact the analysis of the market by determining and assessing different market variables, at this stage these types of sources are the most relevant.

A comparison of the main assumptions and approaches of selected market studies leads to well-founded decisions such as:

- Which aspects and approaches should be adopted?
- Which specific primary and secondary research sources might be used (adopted or accessed again)?
- Where there is a need for an update?
- Where is a need for modification or improvement of approaches chosen?
- Where there is a need for addressing and modelling additional specific questions?

This is dependent on the specific purpose and questions to be addressed by this new market study.

Commercial market studies are in general reliable and use a reliable study method, as most of the studies base the methodology on primary and secondary research. Primary research includes the input of experts from industry and research via interviews whereas secondary research includes Internet search (e.g. literature research, company websites and reports and databases). This will be described in more detail in Table 17.

Most of the commercial market studies provide markets forecast, thus they are relevant to study future markets. Also with regard to this aspect, a comparison and evaluation of approaches and sources used is necessary to decide where to adopt, to update and to modify. However, EU and Member States sources may be less relevant for producing current market studies, as they contain only few current market data and no projections to the future.

In the case of some type of data sources as the data bases, they are irrelevant for producing market studies as none of the databases was found relevant. They contain very specific technical data on nanomaterials and nanotechnologies, but even though the source is in general reliable, this data may not be relevant for producing market studies because quantitative data on volumes and the development of the markets are not available.

For other data, the paper of (Inshakova, et al., 2017) provides a good overview of market studies. This type of papers is relevant to produce market studies as it may be considered a good base for identifying sources as well as for providing both a general overview and to a certain extent also an evaluation of some of the market studies.

4.3 Relevance and reliability of parameters, factors and their combinations to produce market studies

Considering the relevance and reliability of parameters, factors and their combinations to produce a new market study, existing commercial market studies shall be consulted as primarily relevant sources because their authors had to come to a similar decision which parameters and factors to identify and select as the most relevant. Ideally this decision is substantiated and documented in the study. This type of source includes a considerable amount of market variables and parameters (e.g. CAGR, market size, etc), whereas other

types of sources only can provide supplemental information and arguments for a decision. Considering the most common used parameters described in Section 3.4.1, the project team has identified and recommends the following combination of parameters for producing market studies on nanomaterials.

- **Market segmentation**

Most of the commercial market studies contain market segmentation by geographical region and/or country, by key player, by application, by end-use or by type of nanomaterial. Since the scope of the project is European nanomaterials market, the project team suggest that market studies analysing the market on the EU region as well as at Member States level (in particular Germany, United Kingdom, Italy or Spain) are relevant for the production of market studies. From the aspect of nanotechnology patents applied for as a parameter, France and the Netherlands should also be attributed a particular role in the modelling of future markets for manufactured nanomaterials. Furthermore, a comparison of the EU market versus world market may also be relevant. This is also relevant as market studies focusing in the EU market would probably include market shares for EU and MS as well as MS specific information and role/importance.

Segmentation by end-use and/or by type of nanomaterial is also quite common in commercial market studies. These two types of segmentation are relevant as they allow the analysis of nanomaterials markets by use and by production. In addition, these segmentations are important as they allow to observe the existing market differences between nanomaterials (e.g. the complex-oxide nanomaterials market may not have same market trends as other nanomaterials).

- **Market forecasts and growth rate**

Most of the commercial market studies also estimated the market forecast in the future by market segmentation. Market forecasts are relevant to estimate the evolution of the market in the future. The CAGR is commonly accepted and used in almost all commercial market studies to quantify the market annual growth for a period of time. This variable gives an overview on if the market study follows a lower bound, central estimate or upper bound of a potential range.

- **Other variables/parameters**

Commercial market studies also use several further variables and types of analysis that are relevant for the production of market studies. The most common and relevant are the following:

- **Market size.** In some cases, it was calculated by revenue generated from the sales of nanomaterials manufacturers or by market value (e.g. million US\$) and market volume (tonnes)
- **Market share,** calculated by region, country or company. This variable is very relevant in the case the market share is estimated for EU or EU Member States.
- **Market trends** on prices (of nanomaterials and raw materials), demand, consumption and sales, revenue, volume and/or profit margin.
- **Porter's Five Forces model.** This model serves normally to evaluate market profitability by considering power of the supplier, power of the buyer, threat of substitute, competitive rivalry and threat of new entrants. This model may be relevant for considering the profitability of nanomaterials markets in general, but even more for specific nanomaterials markets.
- **PESTEL (Political, Economic, Social, Technological, Environmental and Legal) analysis.** PESTEL analyses the macro-environmental factors that have

impact in a company. In some commercial market studies, this analysis is performed providing an overview of the macro-environmental factors of the nanomaterials markets for the companies. This analysis is relevant because it provides an overview of the macro-environmental factors that companies are facing at the nanomaterials market.

- **SWOT (Strengths, Weaknesses, Opportunities, and Threats)** analysis by key player. In some of the commercial market studies a SWOT analysis is performed for the main players of the industry. This analysis allows the identification of opportunities in the market and company threats. This performs the analysis on a microeconomic level (company level).
 - **Value Chain Analysis** which serves to identify value-adding activities and reduce costs by eliminating those activities that do provide added value. This analysis is performed in some of the commercial market studies.
 - **Industry ecosystem analysis.** This provides an overview of raw material suppliers, manufacturers and distribution channel analysis and it is included in some of the commercial market studies.
 - **Competitive scenario and product portfolio of key vendors**
 - In addition to these variables found in the data sources, the project team (based on their own experience on market analysis) suggests that the following variables/factors should be given more emphasis in the production of a new market study:
 - **Imports and exports (from an EU perspective).** These variables are not commonly used in commercial market studies. They are included only in one of the commercial market studies reviewed. The project team wants to emphasise that imports and exports in volume and value between EU and other non-EU countries may be relevant for producing market studies, in particular from the viewpoint of specific EU policy measures, e.g. a change in legal requirements for nanomaterials.
- **Methodology**

Most of the commercial market studies follow a methodology based on **primary and secondary research**. Table 17 summarises on which sources are used in each type of research.

Table 17: Sources used by type of research

Type of research	Based on
Primary	<p>Online and telephone based survey, interviews with:</p> <p>Industry participants (CEOs, VPs, marketing/product managers, market intelligence managers and national sales managers</p> <p>Vendor briefing</p> <p>Key opinion leaders (KOL) and demand-side participants at regional/country level</p> <p>Channel partners and top-level distributors</p> <p>Outside experts: banking, investment, and valuation experts and key opinion leaders (KOLs) and research analysts specializing in specific markets</p> <p>Purchasing managers, technical personnel, distributors and resellers</p> <p>Key customers and B2B clients.</p>

Type of research	Based on
Secondary	Industry sources: company SEC filings, annual reports, company websites, annual reports, broker & financial reports, press releases, investor presentations for competitive scenario and shape of the industry, industry journals and trade publications Patent and regulatory databases for understanding of technical & legal developments Scientific and technical writings for product information and related pre-emption Regional government and statistical databases for macro-analysis as well as national government documents and government and regulatory published material Authentic new articles, web-casts, and other related releases for market evaluation Internal and external proprietary databases, key market indicators, and relevant press releases for market estimates and forecasts Paid data sources as databases and paid data sources such as ICIS, Factiva, OneSource

This research methodology seems to be commonly accepted on for producing market studies as lot of them follow this approach. From the project team experience on market analysis, this approach seems to be reliable and relevant as it includes industry involvement, thus giving a specific overview of the market, as well as it includes government and other sources, thus allowing to compare industry data with this other type of data. This comparison allows for the verification of data from industry as well as filling possible gaps.

Furthermore, some commercial market studies follow a bottom-up methodology and / or top-down methodology. The bottom-up methodology is used more frequently and is based on considering regional market separately, taking into consideration domestic as well as international dynamics to arrive at market numbers. Global data is obtained by integrating regional information.

4.4 Approach suggested to produce a new market study on nanomaterials

For an explanation of the concept, we suggest the production of a new market study on manufactured nanomaterials be based on the findings of the critical review of existing sources. We will explain in a first step the general combination of primary and secondary review, and in a second step suggest an outline for an operational selection of parameters and factors to be considered for such a new market study on nanomaterials.

4.4.1 Combine primary and secondary research for a new market study

Based on the sources listed in Table 17, the project team suggests a combined approach of secondary and primary research.

We suggest that for the primary research, the telephone-based or online survey of the first stage should be combined with a Delphi method bringing together the expert answers of the first round in a second and third round.

The Delphi method (named after the Oracle of Delphi) is a structured communication technique or method, which was originally developed as a systematic, interactive

forecasting method which relies on a panel of experts and is still used for forecasting and predicting future technologies and developments but also for all kinds of market research, business forecasting and general decision-making. The experts answer questionnaires in two or more rounds. After each round, a facilitator or change agent provides an anonymised summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgments. Experts are, therefore, encouraged to revise their earlier answers in light of the replies of other members of their panel. During this process the range of the answers will decrease and the group will converge towards the correct or most reliable answer. Finally, the process is stopped after a predefined stop criterion (e.g. number of rounds, achievement of consensus, stability of results; usually the mean or median scores of the final rounds determine the results).

Behind this method there is a principle that forecasts or decisions from a structured group of individuals are more accurate than those from unstructured groups. Since the Delphi method has been widely used for business forecasting and has advantages over other structured forecasting approaches, it is an appropriate and promising instrument to come to a consistent scenario of the future development of the market for manufactured nanomaterials.

The experts should be recruited from different fields and stakeholder groups representing different views towards the market for nanomaterials, and should comprise representatives of at least the following groups:

- Industry participants (CEOs, VPs, marketing/product managers, market intelligence managers and national sales managers)
- Representatives of relevant industry associations
- Top-level dealers and distributors of nanomaterials
- Market research experts, e.g. of the market studies examined in this study
- Experts of competent authorities at the level of the most relevant EU Member States (e.g. involved in REACH registrations)
- University and non-university research experts in nanochemistry and nanotechnology
- Experts for banking and investment (including e.g. the European Investment Bank)
- Key customers and clients, e.g. producers of relevant consumer products containing nanomaterials

An online Delphi system can e.g. guarantee that the participants remain anonymous to each other. However, anonymity up to the end is not a general prerequisite for this study, and the level of anonymity can be decided when designing the final survey.

Questions asked to the experts shall comprise the main parameters and assumptions identified in this study, starting e.g. with the CAGR for certain markets, but also additional qualitative factors and estimations.

For the secondary research, in order not to start from scratch again, we suggest taking as a first basis those existing market studies as an input which have been identified as the most relevant. The project team suggests a purchase of the following reports (ideally all three ones listed if possible):

- Allied Market Research: Europe Nanomaterials Market by Type of Material and End User Opportunity Analysis and Industry Forecast, 2014 – 2022 (study identified as the most relevant and reliable)

- Nanomaterials Market - Trends, Investment Analysis and Future scope to 2022, Mordor Intelligence (study identified as a "pessimistic view"/"conservative" by (Inshakova, et al., 2017))
- Nanomaterials Market by Type - Global Opportunity Analysis and Industry Forecast, 2014-2022, Allied Market Research (study identified as an "optimistic view" by (Inshakova, et al., 2017))

When comparing approach and data in detail, the comparison of these three central market studies allow an identification of all these elements developed and applied in these studies that should be combined for an optimal new market study on nanomaterials. It seems appropriate not only to estimate central values as point estimates but also upper and lower bounds of a scenario, defined by the respective assumptions and data sources. The central estimates can then be the basis of a business-as-usual scenario, compared to e.g. scenarios with additional regulatory action on the EU level.

The analysis of these three central studies should at least be complemented by an update of relevant scientific articles (by keyword search) and databases, since these existing studies are not yet at the latest stage of development in this market. Primary and secondary research should also be combined in a circular process, e.g. by asking the relevant experts which secondary data sources but also which parameters they evaluate as the most relevant ones.

4.4.2 Selection of parameters and factors to be considered for the new market study on nanomaterials

Considering the combination of parameters for producing market studies listed in Section 4.3 , the new market study on nanomaterials should consider:

- As basic parameters:
 - Market analysis by segmentation (geographical region and/or country, key players, applications, end-uses or type of nanomaterial). Furthermore, specific focus should be done on European region in comparison with global market.
 - Market forecasts and growth rate (CAGR)
 - Market share by region, country or company
 - Market trends (e.g. consumption, demand, etc.)
 - Competitive scenario and product portfolio of key vendors
- As additional parameters:
 - Porter's Five Forces model
 - Value Chain Analysis
 - Imports and exports (from an EU perspective)
 - PESTEL
 - SWOT analysis

Basic parameters would be the minimum parameters required to produce a new market study on nanomaterials. In addition, the additional parameters can be considered in addition for producing a more fine-tuned market study with a larger degree of variables and interactions.

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6. Annex: Inventory of relevant data sources

6.1 EU data sources

6.1.1 EU definition data sources

Table 18: Commission Recommendation of 18 October 2011 on the definition of nanomaterial

Commission Recommendation of 18 October 2011 on the definition of nanomaterial (European Commission, 2011)	
Purpose of the study:	The European Commission's Recommendation for a definition of "nanomaterials". The purpose for the definition is described: "The definition in this Recommendation should be used as a reference for determining whether a material should be considered as a 'nanomaterial' for legislative and policy purposes in the Union."
Scope and disaggregation in spatial terms:	The European Union.
Time horizon and time steps:	As of 2011.
Aggregation level with regard to production and different uses:	Not applicable.
Documentation:	Properly documented in an easy to trace format.
Sources used:	European Commission studies and the International Organization for Standardization.
Additional verification of assumptions:	Not applicable.
Further elements:	Not applicable.
Discussion:	The Recommendation calls for a future review and potential revision of the definition. See the summary of each part in the three-part series "Towards a review of the EC Recommendation for a definition of the term nanomaterial" for this review.

The definition for nanomaterial according to (European Commission, 2011) can be summarised in the following way:

"A natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm.

In specific cases and where warranted by concerns for the environment, health, safety or competitiveness the number size distribution threshold of 50 % may be replaced by a threshold between 1 and 50 %.

By derogation from the above, fullerenes, graphene flakes and single wall carbon nanotubes with one or more external dimensions below 1 nm should be considered as nanomaterials.” (European Commission, 2011).

The Recommendation further defines:

“(a) ‘particle’ means a minute piece of matter with defined physical boundaries;

(b) ‘agglomerate’ means a collection of weakly bound particles or aggregates where the resulting external surface area is similar to the sum of the surface areas of the individual components;

(c) ‘aggregate’ means a particle comprising of strongly bound or fused particles.” (European Commission, 2011).

Table 19: Towards a Review of the EC Recommendation for a Definition of the Term Nanomaterial: Part 1.

Towards a review of the EC Recommendation for a definition of the term nanomaterial.	
Part 1: Compilation of the information concerning the experience with the definition (Rauscher, et al., 2014)	
Purpose of the study:	As part of the Recommendation, the European Commission also specified that the definition would be reviewed in 2014. The Joint Research Centre of the European Commission (JRC) completed three scientific/technical reports in a series, with the purpose of reviewing the definition proposed in 2011. Part 1 of this series focused on the collection of information regarding issues experienced when applying the EC definition of nanomaterials, including a survey of stakeholders’ experiences, issues and concerns.
Scope and disaggregation in spatial terms:	This series is focused on the interpretation of the EC Recommendation for a definition of the term “nanomaterial” within the European Union. Consideration for international consistency is also considered.
Time horizon and time steps:	From 2014 onward.
Aggregation level with regard to production and different uses:	Not applicable.
Documentation:	Sources are well documented and easy to trace.
Sources used:	Public sources and stakeholder feedback.
Additional verification of assumptions:	Not any.

Further elements:

- Non-EC definitions (e.g. ISO) and in which context the definitions are used
- Stakeholder survey results
- Compilation of resources for the quantification nanomaterials and their constituents
- Alternative measurement approaches and their limitations
- Manufacturing techniques for different nanomaterials in the context of measurement metrics
- Discussion of nanostructured materials (not covered by the EC definition) and their characteristics
- Challenges in distinguishing natural/incidental nanomaterials from manufactured nanomaterials

Discussion:

This purpose of the first study in the three-part series is to provide background and data for analysis and conclusions in the next parts. Please see the summary of the next two studies in the series.

Table 20: Towards a review of the EC Recommendation for a definition of the term nanomaterial: Part 2.

Towards a review of the EC Recommendation for a definition of the term nanomaterial.

Part 2: Assessment of collected information concerning the experience with the definition (Roebben, et al., 2014)

Purpose of the study:

As part of the Recommendation, the European Commission also specified that the definition would be reviewed in 2014. The Joint Research Centre of the European Commission (JRC) completed three scientific/technical reports in a series, with the purpose of reviewing the definition proposed in 2011. Part 2 of this series assessed the information collected in Part 1 of the series. Part 2 of the JRC series focuses primarily on predominant issues with the implementation of the definition, including the misunderstandings on the purpose and scope of the EC nanomaterial definition.

Scope and disaggregation in spatial terms:

This series is focused on the interpretation of the EC Recommendation for a definition of the term "nanomaterial" within the European Union. Consideration for international consistency is also considered.

Time horizon and time steps:

From 2014 onward.

Aggregation level with regard to production and different uses:

This series is focused on the interpretation of the EC Recommendation for a definition of the term "nanomaterial" within the European Union. Consideration for international consistency is also considered.

Documentation:

Sources are well documented and easy to trace.

Sources used:

Data from Part 1 (which comes from public sources, as well as stakeholder feedback).

Additional verification of assumptions:

Not any.

<p>Further elements: Not any.</p>
<p>Discussion:</p> <ul style="list-style-type: none"> • Part 2 in this series reviews the collected responses and public data, and provides the following: • Identification of the primary terms in the Recommendation that cause confusion • Discussion of and proposals to solve challenges when implementing the definition for nanomaterials • Several sections regarding the commonly reported challenge of implementation of the definition through measurements: <ul style="list-style-type: none"> Measurement uncertainty & proposed methods for measurement for the comparison of results Discussion of measuring the constituent particle sizes of aggregates Alternatives to the direct implementation of the definition <p>The study also reviews methods the detection/identification of specific materials that do not meet the generic definition (particle size distribution) are specifically included in the definition (graphene, fullerenes and single-wall carbon nanotubes).</p>

Table 21: Towards a review of the EC Recommendation for a definition of the term nanomaterial: Part 3.

<p>Towards a review of the EC Recommendation for a definition of the term nanomaterial.</p> <p>Part 3: Scientific-technical evaluation of options to clarify the definition and to facilitate its implementation (Rauscher, et al., 2015)</p>
<p>Purpose of the study: As part of the Recommendation, the European Commission also specified that the definition would be reviewed in 2014. The Joint Research Centre of the European Commission (JRC) completed three scientific/technical reports in a series, with the purpose of reviewing the definition proposed in 2011. Part 3 of this series concludes on the most prominent and plausible issues identified in Part 2 of the series, as well as options as solutions and potential implications of each option.</p>
<p>Scope and disaggregation in spatial terms: This series is focused on the interpretation of the EC Recommendation for a definition of the term “nanomaterial” within the European Union. Consideration for international consistency is also considered.</p>
<p>Time horizon and time steps: From 2014 onward.</p>
<p>Aggregation level with regard to production and different uses: This series is focused on the interpretation of the EC Recommendation for a definition of the term “nanomaterial” within the European Union. Consideration for international consistency is also considered.</p>
<p>Documentation: Sources are well documented and easy to trace.</p>
<p>Sources used: Info from parts 1 & 2 (which comes from public sources, as well as stakeholder feedback).</p>

<p>Additional verification of assumptions: Not any.</p>
<p>Further elements:</p> <ul style="list-style-type: none"> Suggested clarifications for the terms in the definition, and other problematic references, and the possible solutions/changes to such. Some examples of such issues include: <ul style="list-style-type: none"> A more specific definition for the term “particle” and/or more detailed guidance for interpretation Better definitions for the terms “particle size” “external dimension” and “external dimension” A definition for the term “constituent particle” Identification of problems and important considerations for specific elements of the recommended definition, including: <ul style="list-style-type: none"> Volume-specific surface area can be used to determine compliance with the definition but cannot be used to classify a substance as a non-nanomaterial. Difficulties in proving a material is not a nanomaterial, and the avoidance of unintended inclusion of materials within the definition.
<p>Discussion: The report suggests that the scope of the definition as far as regarding the origin of nanomaterials, should remain unchanged, meaning it addresses natural, incidental as well as manufactured nanomaterials. Further the report finds no evidence to support changing the size range in the definition (1 nm to 100 nm). Other problems such as the inability to prove a material is a nanomaterial based on the definition, and the unintended inclusion of certain materials and potential remedies.</p>

6.1.2 European Commission non-definition data sources

Table 22: Commission Staff Working Paper: Types and uses of nanomaterials, including safety aspects

<p>Commission Staff Working Paper: Types and uses of nanomaterials, including safety aspects (European Commission, 2012)</p>
<p>Purpose of the study: This working paper is part of communication from the Commission to the European Parliament and other governing bodies as part of the Second Regulatory Review on Nanomaterials in 2012. The report discusses challenges posed by nanomaterial aggregates and composites and details the different nanomaterials on the EU market with an overview of their properties and uses.</p>
<p>Scope and disaggregation in spatial terms: Europe</p>
<p>Time horizon and time steps: As of 2012.</p>

Aggregation level with regard to production and different uses:

This report details the primary nanomaterials on the EU market and their properties and uses:

- Synthetic amorphous silica
- Substances similar to synthetic amorphous silica
- Titanium dioxide
- Zinc oxide
- Aluminium oxide
- Aluminium hydroxides and aluminium oxo-hydroxides
- Iron oxides: Diiron trioxide & triiron tetraoxide
- Cerium dioxide
- Zirconium dioxide
- Other oxide nanomaterials
- Calcium Carbonate
- Other non-oxide inorganic non-metallic nanomaterials (e.g. aluminium nitride, silicon nitride, titanium nitride, tungsten carbide, tungsten sulphide)
- Gold
- Silver
- Platinum and palladium alloy
- Fullerenes
- Carbon nanotubes and carbon nanofibers
- Carbon black
- Graphene flakes
- Nanopolymers and dendrimers
- Quantum dots
- Nanoclays
- Nanocomposites
- Others (with limited information available)

Documentation:

Sources are well documented and simple to follow.

Sources used:

A large amount of scientific research is cited, including a large amount of public research from Member States and other countries.

Additional verification of assumptions:

Not applicable.

Further elements:

The study also discusses potential hazards of each nanomaterial.

Discussion:

The study has a strong emphasis on the hazards and safety of nanomaterials and discusses the lack of data and other related info.

This study details the primary uses of nanomaterials available in the EU, however, it is relatively dated for this industry and therefore cannot be considered as an exhaustive list.

Table 23: Examination and assessment of consequences for industry, consumer, human health and the environment of possible options for changing the REACH requirements for nanomaterials

Examination and assessment of consequences for industry, consumer, human health and the environment of possible options for changing the REACH requirements for nanomaterials (BiPRO, Öko-Institut e.V., 2013)
<p>Purpose of the study: This study was completed by BiPRO and Öko-Institut e.V., 2013, on behalf of the European Commission. This study focuses on consequences of nanomaterial policy options to REACH, specifically to industry, consumers, human health and the environment.</p>
<p>Scope and disaggregation in spatial terms: Development of a baseline and an option scenario with an implemented set of options.</p>
<p>Time horizon and time steps: 10 years from 2012 (baseline year) up to 2022. Relevant REACH actions and registration deadlines 2013 and 2018 within this time frame have been taken into respect but no explicit (e.g. annual) time steps have been modelled; overall estimation of one-off costs.</p>
<p>Aggregation level with regard to production and different uses: Market for nanomaterials in the EU-27, not disaggregated according to Member States or production versus import. Case studies examined in detail: <ul style="list-style-type: none"> • Nano TiO₂ • Nano ZnO • Nano diamond Additional nanomaterials examined: <ul style="list-style-type: none"> • Synthetic Amorphous Silica (SAS) • Carbon black • Carbon Nano Tubes (CNTs) • Fullerene • Nano silver • Nano copper • Quantum dots (e.g. Cadmium sulphide) Extrapolation of data to the total EU market of 500 – 2,000 nanomaterials</p>
<p>Documentation: Final Report with detailed information on the analysis provided and documented in five annexes.</p>
<p>Sources used: NANO SUPPORT Project – Scientific technical support on assessment of nanomaterials in REACH registration dossier and adequacy of available information (Task I and Task II step 1) as input; REACH data, in particular registration dossiers (tonnage bands, number of expected registrants), literature review on the market, information provided by steering group.</p>
<p>Additional verification of assumptions: Detailed discussion and review process by the steering group (consisting of the JRC, Institute for Health and Consumer Protection, DG Environment, DG Enterprise and Industry and ECHA) and the CASG-Nano group (CARACAL Subgroup on Nanomaterials), including Member State and stakeholder representatives during the whole duration of the project.</p>
<p>Further elements: Limitations on information on the European market for nanomaterials explicitly addressed.</p>

Discussion:

The study indicates current and expected future applications of nanomaterials, indicating expected registration tonnage bands for single substances; information on companies manufacturing and/or importing substances with nanoforms; trends in registration updates and new registrations, existence of 'learning curves' and that knowledge on nanosafety is rapidly developing, expected changes in other relevant legislation/regulation that could affect the uses and thus the amount of nanomaterials produced in or imported into the EU, actions and legislation already decided or proposed, and impacts of these actions.

Table 24: Study to assess the impact of possible legislation to increase transparency on nanomaterials

Study to assess the impact of possible legislation to increase transparency on nanomaterials on the market (Risk & Policy Analysts Ltd., BiPRO, 2015)

Purpose of the study:

The evaluation report, building blocks report and options assessment report we completed on behalf of the European Commission by Risk & Policy Analysts Ltd. and BiPRO in April 2015. The overall aim of this study was to provide support to the European Commission in the preparation of an impact assessment to identify and develop the most adequate way to increase transparency and ensure regulatory oversight for nanomaterials. The tasks were:

- to gather relevant information on the experience from other nanomaterials register-like schemes, in particular the French scheme;
- to provide information on health and safety, markets and research trends of nanomaterials for the better definition of the policy options to be assessed; and
- to support the impact assessment of the policy options.

Scope and disaggregation in spatial terms:

Global.

Time horizon and time steps:

2015

Aggregation level with regard to production and different uses:

Some information about the production and use of nanomaterial but not a lot about products and consumption.

Documentation:

Good-moderate: mostly health and safety around nanomaterial; solubility, pathways and limitation values.

Sources used:

For information on nanomaterials on the market, in particular an overview and comparison of all data sources used, see in detail Chapter 6.2 (Camboni et al. (2014), pp. 83 ff.) and Annex III (pp. 122 ff.).

Additional verification of assumptions:

Steering group accompanying the project; Key stakeholder meeting; online review of company views; questionnaires to French authorities and DG SANCO, validation workshop with presentation of preliminary results and feedback from industry, authorities and NGOs.

Further elements:

Three case studies for different types of actors. The additional "building blocks report" provides detailed information on risks and hazards, growth and innovation (R&D spending, patents, future market trends, emerging nanomaterials), indicators on fitness-for-purpose.

Discussion:

The report was one of several outcomes of a study on transparency measures on nanomaterials within the EU. To date, two relevant register-like schemes – both concerning nanomaterials and operating within the EU – have been established: the French Notification System (FNS) and the Cosmetic Products Notification Portal (CPNP). Other transparency measures have been established or proposed by EU states. From these measures lessons can be learned; the report aimed to evaluate their pros and cons, successes and failures, and to ensure that this information is fully utilised in the future identification and development of any EU wide solution. The report contains:

- A review of the legislation underpinning transparency measures in the European Union
- Findings from a key stakeholder meeting as an element of the project
- Analysis of publicly available information about the FNS (with support from Cefic, the NIA and their members) – including analysis of the substances for which notifications to the FNS were made and comparison of the list with the ECHA registered substances database and the Classification and Labelling Inventory;
- The results of an online survey as an element of the project, of company views on the financial and administrative burdens associated with notification;
- Information from questionnaires sent to the French authorities and DG SANCO;
- Analysis of the debate in France concerning the notification system; and Feedback from stakeholders (industry, authorities and NGOs) on the preliminary results of the study.

6.2 Member State data sources

Table 25: Assessment of nanosilver in textiles on the Danish market

Assessment of nanosilver in textiles on the Danish market (Tønning, et al., 2012)
<p>Purpose of the study: The study is a market survey which aims to identify consumer textile products containing nanosilver and subsequently subject them to quantitative and migration analysis and washing tests. Furthermore, health and environmental risks and exposure are assessed.</p>
<p>Scope and disaggregation in spatial terms: Danish market.</p>
<p>Time horizon and time steps: 09/2011-03/2012</p>
<p>Aggregation level with regard to production and different uses: The survey was limited to include textiles referred to as:</p> <ul style="list-style-type: none"> • Containing nanosilver • Containing silver <p>With antibacterial effect 94 products from 39 different shops The registered textiles are classified in 5 categories:</p> <ul style="list-style-type: none"> • Category 1: Textiles products containing silver in nanoform • Category 2: Textiles products, containing silver ions/salts • Category 3: Textile products, containing silver threads/macrosopic silver • Category 4: Textile products, where the form of silver was not identified • Category 5: textile products which had got an antibacterial treatment

Documentation: Good: contains a lot of information concerning the effect on health and environmental assessment, differs ions and particles in effect. However, Describes only silver as nanomaterial and only cloths in Denmark
Sources used: Questionnaires sent to manufacturers, importers and retailers, shop visits, internet survey.
Additional verification of assumptions: Not available.
Further elements: It contains a list of manufacturers, importers and retailers.
Discussion: The study highlights that "is highly probable that the use of such products might be hidden and widespread than it appears from the responses".

Table 26: Supplementary Survey of Products on the Danish Market Containing Nanomaterials

Supplementary Survey of Products on the Danish Market Containing Nanomaterials (Tønning, et al., 2014)
Purpose of the study: Identification and mapping nanoproducts that are not included in the Danish Nanoproduct Register to gain knowledge of the prevalence, use and user groups as well as anticipated future prevalence of nanoproducts on the Danish market within the identified product groups.
Scope and disaggregation in spatial terms: Denmark with European and global context.
Time horizon and time steps: 01/2013-01/2014
Aggregation level with regard to production and different uses: Most often used materials, in what products those can be found, their function and amount. Food and feed, food contact materials, cosmetics (limited to nanomaterials used as colorant, UV filter or preservative), pesticides, medical devices and water treatment.
Documentation: Very good – good: describes all common used nanomaterials including data on use, no specific products or producers.
Sources used: Danish Technological Institute used literature, i.e. surveys, reports, scientific studies, etc. Previous surveys of nanoproducts, recent scientific literature/reviews on present and future use of nanomaterials and roadmaps from European Technology Platforms. Moreover, contributions from a number of Danish resource persons from various trade and industry organisations and governmental institutions. Furthermore, interviews by using a questionnaire to relevant Danish producers, importers, retailers and trade organisations.
Additional verification of assumptions: Not applicable.
Further elements: Not applicable.

Discussion:

The survey may contain products that have or not have nanomaterials because of the differences between the definitions of nanomaterials (e.g. other regulations volume- or mass-based size distribution is frequently used in other definitions).

Table 27: Nanomaterials in Commercial Aerosol Products on the Danish Market

Nanomaterials in Commercial Aerosol Products on the Danish Market (Fischer, et al., 2014)

Purpose of the study:

Description and overview of the (possible) prevalence of solid nanomaterial in aerosol products according to literature, previous surveys, etc., a mapping of aerosol products containing solid nanomaterials on the Danish market and a preliminary risk evaluation of selected products.

Scope and disaggregation in spatial terms:

Denmark.

Time horizon and time steps:

02/2014-10/2014

Aggregation level with regard to production and different uses:

The identified products have been grouped into four categories:

- Impregnation aerosol products (52 products) – Textiles: sprays for different textile types, shoes and leather – Home: sprays for tiles, concrete, metal, wood, glass and enamel – Cars: sprays for car paintwork and rims – Anti-fog: sprays for diving masks and skiing lenses
- Cleaning aerosol products (19 products) – Car cleaning – Bike cleaning – Home cleaning – Textile cleaning
- Cosmetics (1 product) – Sunscreen
- Others (6 products) – Flame retardants – Lubricants for bike chains

Moreover, a number of regular product types potentially containing nanomaterials were identified:

- Coatings – UV protection – Anti-bacterial – Impregnation
- Lubricants

Documentation:

Very good-good: describes many common used products and analyse if nanomaterials are advertised and/or included.

Sources used:

Previous surveys and recent scientific literature/reviews on aerosol products, relevant databases, including online nanodatabases such as the Woodrow Wilson database and the Nano database by the Danish Consumer Council's and the Danish Ecological Council. Furthermore, visits in a number of retail shops, Google search using combinations of a number of relevant key words. Manufacturers/importers/retailers of aerosol products, registered during shop visits and via internet pages were contacted, asking them to complete a short questionnaire.

Additional verification of assumptions:

Some assumptions are made for the exposure and risk assessment.

Further elements:

Products that campaign for nanomaterials sometimes do not use them and many products without nanomaterials in the label claims use them.

Discussion:

With the current methodology it is not possible to distinguish between the nano-form and the non-nano-form of the product.

Table 28: Survey of products with nanosized pigment

Survey of products with nanosized pigment (Sørensen, et al., 2015)	
Purpose of the study:	<p>The main focus of the study is on exempt paints, wood preservatives, glues and fillers, as well as on coloured textiles. It also addresses:</p> <ul style="list-style-type: none"> • applications of pigments for which a notification will be required (e.g. pigments in mixtures which are not specifically exempt), and • applications of pigments which are generally exempt (e.g. pigments in solid matrices from which the nanomaterial in itself will not be released)
Scope and disaggregation in spatial terms:	Global, regional (EU) and country (Denmark) level.
Time horizon and time steps:	June 2014 to November 2014.
Aggregation level with regard to production and different uses:	<p>The global market of pigments and registered pigments are segmented by application such inorganic pigments (e.g. titanium dioxide), and organic pigments. Another division is applications with intentional use of nanosized pigments which is segmented as transparent coatings, inks, transparent plastics, textiles, other applications of ultra-fine pigments. Furthermore, it is also analysed from the consumer products perspective.</p>
Documentation:	Moderate: the presence and substance-group of nanomaterials in colouring-material is described rather than nanomaterials' use, characterization or products.
Sources used:	Databases, chemical encyclopaedia, market surveys, reports from relevant organisations, EUROSTAT statistics on trade, the Danish Product Register and dialogue with companies (pigment producers and Danish importers and formulators), EU and Danish trade organisations (for pigments and downstream users of pigments), as well as other scientific institutions and green organisations. Stakeholders have been approached bilaterally, as well as via a reference group.
Additional verification of assumptions:	Not applicable.
Further elements:	Not applicable.
Discussion:	<p>The study highlights the following data gaps:</p> <ul style="list-style-type: none"> • "It remains that no common ground has been established to be used for determining the particle size distribution of pigments". • "Number particle size distributions of constituent particles (as used in the EU nano definition) are not available for commercial products".

Table 29: Carbon nanotubes

Carbon nanotubes (Jensen, et al., 2015)
<p>Purpose of the study: This study is part of the initiative “Better control of nanomaterials” (see Table 30) and provides an overview of the nanotube (CNT) types and products on the commercial market, the risk of CNT exposure and environmental release, the potential human and environmental hazard of CNT and an integrated risk assessment of the product groups identified.</p>
<p>Scope and disaggregation in spatial terms: Denmark.</p>
<p>Time horizon and time steps: Different periods.</p>
<p>Aggregation level with regard to production and different uses: It mentions the applications of CNT-based products, being most important industrial sectors automotive, energy, paint and coatings, and electronics and emerging application sectors textiles, sensor technology, diode light emitters. It classifies as follows:</p> <ul style="list-style-type: none"> • Batteries and conductive fillers (e.g. in Li-ion batteries containing 1 - 3 percent CNT by weight in the graphite electrodes and as a conducting filler in base resins and thermoplastics). • Reinforcing composite fillers (e.g. as a strength-enhancing functional filler in base resins, as reinforcing agent in advanced polymer composites used for sports equipment) • Paints and antifouling coatings (e.g. CNT-based epoxy-paints and antifouling coatings for the marine sector and CNT-based high-durability epoxy paints for other purposes and for large windmill blades). • Conductive inks and layers. (e.g. for electronic displays and touch screens) • Textiles (e.g. CNT added to textile fibres) • Other uses (e.g. field emission devices (FED) for e.g. light sources and other electronic components, non-volatile RAM memory modules for computers etc. and heat management devices for microelectronics). <p>Production volume, market size and trade value are also presented.</p>
<p>Documentation: The study documents its sources adequately.</p>
<p>Sources used: This study uses a large number of scientific sources.</p>
<p>Additional verification of assumptions: Not applicable.</p>
<p>Further elements: Preliminary risk assessment of carbon nanotubes.</p>
<p>Discussion: This study has a strong environmental and health focus; however, it provides a valuable overview of the current carbon nanotube market and its supply chain, including production volumes, costs and applications.</p>

Table 30: Better control of nanomaterials

Better control of nanomaterials (Christensen, et al., 2015)	
Purpose of the study:	This report summarises the results of the initiative "Better control of nanomaterials", was intended to achieve better clarity on exposure pathways and the consequences of using nanomaterials to consumers and the environment, as well as briefly puts the work into perspective in relation to other activities taking place in the area of nanomaterials including research, surveys, standardisation and legislation.
Scope and disaggregation in spatial terms:	Denmark.
Time horizon and time steps:	Not applicable.
Aggregation level with regard to production and different uses:	<p>It mentions to roughly divide the nanomaterials into two groups:</p> <ul style="list-style-type: none"> the application intentionally exploits the nano properties of the materials used the materials fall within the definition of nanomaterials, but the applications do not intentionally make use of any special nano properties (e.g. pigments, all pigments would fall within the EU definition of nano, but the nano properties are only exploited in a fraction of pigments consumed). <p>From the consumer products perspective it lists the following:</p> <ul style="list-style-type: none"> Cosmetics (e.g. Nano-titanium dioxide applied as UV protectant, iron oxides, carbon black and aluminium hydroxide). Spray products: (e.g. nano silica, nano titanium dioxide, molybdenum, silica and borate and fluorosilane compounds). Textiles (e.g. nano silver used as an antibacterial agent in textiles). Food (e.g. titanium dioxide (E171), silicon compounds and silicates (E551 used as an anti-caking agent, anti-foaming agent, aroma carrier and thickener) and calcium carbonate (stabiliser, anti-caking agent)). Food contact materials: There is no evidence of the use of nanomaterials in food wrapping products in Denmark. Antibacterial agents: Nano silver in many other products such as kitchen equipment, refrigerators, deep freezers and coffee makers, hygienic surfaces and toothbrushes. Pigments: Pigments may be used for a wide variety of purposes such as in paints, plastics and rubber, coloured paper and cardboard and building materials. Carbon nanotubes (CNT): Carbon nanotubes are used mainly to strengthen composite materials, but also to exploit their electrical and optical properties. In consumer products the best-known applications are in sporting equipment. Water treatment: In Denmark, photocatalytic UV lamps containing titanium dioxide nanoparticles have been used successfully as catalysts in some public swimming pools. Medical devices: Currently many different medical devices containing nanomaterials are in use. <p>Nanomaterials that are found in products on the Danish market include silicates and zirconium dioxide (mechanical properties of seals, adhesives and implants), silver (antibacterial effect), copper (filters in colostomy bags), calcium alginate (carriers and moisture absorbents) and also zinc oxide, titanium dioxide and iron oxide (pigments).</p>
Documentation:	All the sources and references are well documented.

Sources used: Mostly documents from the EU Commission and Danish EPA.
Additional verification of assumptions: Not applicable.
Further elements: Not applicable.
Discussion: Not applicable.

Table 31: Mapping research and development within the nanofield in Sweden

Mapping research and development within the nanofield in Sweden (Swedish Chemicals Agency, 2012)
Purpose of the study: The objective of this survey was to map research and development activities on nanomaterials currently in progress in Sweden and to identify emerging uses of and potential exposures to nanomaterials.
Scope and disaggregation in spatial terms: Sweden.
Time horizon and time steps: 2010-2011
Aggregation level with regard to production and different uses: Regarding production the article differentiate the following types of aggregations: 82 companies also operate over several sectors; the most common were life science and medicine (21), energy and clean tech (18) and electronics (10). However, it is mention a large number of different sectors, life science and medicine, energy and clean tech, automotive, chemicals, electronics, engineering industry, electronics and others. Regarding from uses, the report listed the following based in answers from companies: Electronics, Pharmaceuticals and health products, Products for the automotive sector, Products used in construction, Packaging, Office supplies, Solar panels, Paint and glue, Textiles, Tools, Sports articles and Foodstuffs and additives.
Documentation: All the sources and references are well documented.
Sources used: bibliometric analysis, an analysis of granted research funding and a survey addressed to companies. In the survey addressed to companies the following topics were addressed: <ul style="list-style-type: none"> • Background information about the company • Confirmation regarding the company's involvement in nanotechnological research • Sector of research, if applicable. • Use and nature of nanomaterials • Nature of products, if any, on the market, level in value chain and sector
Additional verification of assumptions: Not applicable.
Further elements: Not applicable.

Discussion:

The lack of a definition of nanomaterials previous to October 2011. A tentative definition was used for the purpose of data collection for this report, which also included internal structures in the nanoscale as a criterion (e.g. nanoporous materials).

There might be a potential gap between the risk research and the development of application regarding materials in two or fewer dimensions.

An attempt to extrapolate the results from the performed company survey will by necessity be both crude and associated to a large degree of uncertainty.

Table 32: Considerations about the relationship of nanomaterial's physical-chemical properties and aquatic toxicity

Considerations about the relationship of nanomaterial's physical-chemical properties and aquatic toxicity for the purpose of grouping (Hund-Rinke, et al., 2017)

Purpose of the study:

The project aimed to develop a concept to group engineered nanomaterials considering ecotoxicological effects on algae, daphnids and fish embryos.

Scope and disaggregation in spatial terms:

Not applicable.

Time horizon and time steps:

Not applicable.

Aggregation level with regard to production and different uses:

The research provides specific information about 14 nanomaterials (different subtypes of Ag, ZnO, TiO₂ and Cu) and their influence on aquatic ecosystems.

Documentation:

Very good: specific research and explicit influence of the used NMs but only concerning a few NMs.

Sources used:

Literature (academic articles, ECHA, OECD, etc.).

Additional verification of assumptions:

Some hypothesis and assumption in order to verify some tests.

Further elements:

Not applicable.

Discussion:

Further research is needed as for example for surface modifications; substitution of the fish embryo test; adaptation of the methods for the determination of the reactivity.

Table 33: Elements from the declaration of substances in the nanoparticulate state

Éléments issus des déclarations des substances à l'état nanoparticulaire RAPPORT D'ETUDE 2017 (MTES, 2017)

Purpose of the study:

It is a fifth report over the elements on substance declarations deposited in the French national R-Nano Register.

Scope and disaggregation in spatial terms:

France.

<p>Time horizon and time steps: 2017</p>
<p>Aggregation level with regard to production and different uses: Statistics: 326 categories of nanomaterials are in use, numbers of declarations and entities of nanomaterials Mostly used: carbon, silicate, carbonate (CaCO₃), TiO₂, Mg²⁺ Used in: agriculture, silviculture, fishing, etc. Use of NACE codes for dividing sectors It aggregates the declarants into importers, producer/manufacturer, distributor, user and distributor, and repacking and distributor. It also classifies nanomaterials as inorganic nanomaterials, metals and metal alloys, carbon nanomaterials, nanopolymers, silicates and clays and others (e.g. organic nanomaterials)</p>
<p>Documentation: Moderate: does not concern production, use and consumption of nanomaterials. It provides the number of companies that declared nanomaterials in France and per some EU country.</p>
<p>Sources used: General Management of Risk Prevention.</p>
<p>Additional verification of assumptions: Not applicable.</p>
<p>Further elements: Not applicable.</p>
<p>Discussion: There is a decrease on declaration compare to previous years.</p>

Table 34: Assessment of Impacts of a European Register of Products Containing Nanomaterials

<p>Assessment of Impacts of a European Register of Products Containing Nanomaterials (Hermann, et al., 2014)</p>
<p>Purpose of the study: This study was completed on behalf of the German Umweltbundesamt, Öko-Institut e.V. and BiPRO, March 2014. The implementation of a nanoproduct register as an instrument to increase the transparency on the use of nanomaterials in the EU and to ensure the regulatory oversight on nanomaterials has been discussed in the beginning of the 2010s. In June 2012 the German Federal Environment Agency has published a "Concept of a European Register of Products Containing Nanomaterials" (ENPR). According to the concept the manufacturer and importer of nanomaterial containing products with a likely exposure of nanomaterials to human beings and the environment should notify them to a single European register. The aim of the study by Öko-Institut and BiPRO has been to analyse the impacts of such an ENPR.</p>
<p>Scope and disaggregation in spatial terms: Natural and incidental nanomaterials as well as polymers are excluded from the scope of this study. Nature is extremely prolific when it comes to nanomaterials. Adhering to the definition within Art. 3 (39) REACH of natural substances (including nanomaterials) and recognizing that natural nanomaterials are not well characterised they were omitted from the scope of this study. They cease to be natural when any change is affected that goes beyond the REACH definition of natural substances. Any other treatment than specified in Art. 3 (39) will result in the loss of the 'natural' state. By choosing this limitation a wide range of everyday products such as gardening soil, lime, coal etc. are excluded from the scope of the study. Similarly, a definition of incidental nanomaterials became necessary in the course of this study to further focus the ENPR. Without this definition, virtually every product would be included in the ENPR making data acquisition, evaluation, and application of the final dataset to specific questions unmanageable. Additionally,</p>

polymers are excluded from the scope of the study.
<p>Time horizon and time steps: Costs were compared on a 5-year basis (first year = implementation costs, then 4 years recurring costs) to assess how costs evolve over time. To this end, an estimate of the accumulated costs is provided, under the assumption that the total number of notifications does not change. The implementation year has not been fixed to a certain calendar year, but since the current market situation at the time of the study has been taken as basis and a prompt coming into force of the register has been envisaged, an overall time frame of 2014 to 2018 can be assumed.</p>
<p>Aggregation level with regard to production and different uses: Based on the criteria “high production volumes” or “wide dispersive uses” or “sufficient information on uses available from publicly accessible sources” the following nanomaterials were selected for the impact assessment: carbon black, synthetic amorphous silica, aluminium oxide, barium titanate, titanium dioxide, cerium oxide, zinc oxide, carbon nanotubes, nanosilver and fullerenes. For each material, their uses in certain applications and product groups were determined and subsequently they were grouped in the following eleven sectors or categories: substances, cosmetics, health care, food & feed, coatings & inks, cleaning & disinfection, rubber products, building & construction, textiles, paper products and complex objects & other products.</p>
<p>Documentation: Data sources and assumptions clearly described and quoted. Limitations and uncertainties explicitly addressed in a preliminary remark by UBA.</p>
<p>Sources used: Desktop research/literature, estimation and expert interviews of relevant sectors (industry associations and individual companies).</p>
<p>Additional verification of assumptions: Verification only within the scope of expert interviews.</p>
<p>Further elements: The final selection of product groups is listed in Annex 7.1 (Hermann et al. (2014), pp. 124 ff.).</p>
<p>Discussion: Sectors and companies concerned by an ENPR were identified and the number of notifiers and notifications, categories of substances, concerned mixtures and articles were estimated. Based on that result the administrative costs for notifiers and the competent authority for an ENPR were quantified and the benefits of an ENPR for public authorities, consumers and notifiers described.</p>

6.3 Commercial/research data sources

Table 35: Commercial market studies from Innovative Research and Products, Inc.

Commercial market studies from Innovative Research and Products, Inc.
T. Abraham. Nanotechnology and Nano Materials: Types, Current/Emerging Applications and Global Markets (Abraham, 2011)
Production and applications of carbon nanotubes, carbon nanofibers, fullerenes, graphene and nanodiamonds: a global technology survey and market analysis (IRAP, 2011)
<p>Purpose of the study: In the first report the global market for nanomaterials in select segments is quantified. In the second report the goal “was to perform an exhaustive look at the field of nanocarbon materials, with a focus on single wall carbon nanotubes (SWNT), multiwall carbon nanotubes (MWNT) and fullerenes, while also investigating carbon nanofiber production and technology”.</p>

<p>Scope and disaggregation in spatial terms: The scope of the first report is worldwide. The second report analyses production of carbon nanomaterials aggregated in three regions: North America, Europe and Asia including Australia. South America and Africa are excluded as it is considered that in these regions there is no significant production.</p>
<p>Time horizon and time steps: For the first report 2008-2014. For the second report 2010-2015.</p>
<p>Aggregation level with regard to production and different uses: In the first report some of the aggregations done are: packaging in the food/beverage and pharma industry, semiconductors, nanomagnetic materials and devices, nanophotonic devices, fuel cell nanotechnology, nano current and nano-enabled batteries in the second report nanomaterials are analysed as carbon nanotubes, carbon nanofibers, fullerenes, graphene & nanodiamonds.</p>
<p>Documentation: Not available.</p>
<p>Sources used: For the first report sources are not available. The second report is based on Internet searches (latest press releases on company websites, application news, company news, marketing news, product news, brochures, product literature, fuel cell and hydrogen magazines, and technical journals, as well as technical books, marketing literature, other promotional literature, annual reports, security analyst reports, and business publications) supplemented with telephone conversations and email exchanges with carbon nanotube manufacturing company representatives. Other sources of information include United Nations, U.S., European, Canadian, Chinese, Japanese, Australian, Brazilian and Indian government reports, studies, research abstracts and status reports, press releases, conference presentations, telephone and email communication.</p>
<p>Additional verification of assumptions: Not available.</p>
<p>Further elements: Not available.</p>
<p>Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.</p>

Table 36: Commercial market studies from Fredonia

<p>Commercial market studies from Fredonia: "World Nanomaterials. Study number: 2871" (Fredonia, 2012)</p>
<p>Purpose of the study: The study analyses world nanomaterial industry considering historical demand data, forecasts 2016-2021 by material and market as well as market environment factors, industry structure, market shares and industry profiles of numerous industry players</p>
<p>Scope and disaggregation in spatial terms: It analyses the global market of nanomaterials as well as at regional and country level. Regions analysed include America, Western Europe, Asia/Pacific and other regions (Eastern Europe and Africa/Middle East). At country level, it analyses the market for EEUU, Canada, Brazil, Mexico, Germany, UK, France, Italy, Japan, China, Taiwan, South Korea, Australia, India, Russia and other countries.</p>

<p>Time horizon and time steps: From 2016 to 2021. It also includes some historical demand data for the years 2001, 2006 and 2011.</p>
<p>Aggregation level with regard to production and different uses: From the production perspective, the report aggregates nanomaterials considering the material (metal oxides, chemicals & polymers, metals, nanotubes, other nanomaterials (conventional materials -clays and minerals- and new materials-fullerenes, quantum dots, dendrimers, graphene and all other-). From the uses perspective the report analyses the nanomaterials considering the markets (health care, electronics, energy generation & storage, construction and other markets- personal care products, textiles, packaging, paper & printing, machinery, motor vehicles, aerospace & defence and all other).</p>
<p>Documentation: Not available.</p>
<p>Sources used: Not available.</p>
<p>Additional verification of assumptions: Not available.</p>
<p>Further elements: Not available.</p>
<p>Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.</p>

Table 37: Commercial market studies from Transparency Market Research

<p>Commercial market studies from Transparency Market Research:</p> <p>"Nanocellulose Market – Global Industry Analysis, Forecast 2015–2023" (Transparency Market Research, 2015a)</p> <p>"Nanoclay Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2015 – 2023" (Transparency Market Research, 2015b)</p>
<p>Purpose of the study: The first report analyses the nanocellulose market by forecasting and estimating it at global, regional and country level. The second report follows the same analysis but for the nanoclay market.</p>
<p>Scope and disaggregation in spatial terms: The first report analyses nanocellulose market at global, regional and country level. Regional level includes North America, Europe, Asia Pacific, Latin America, and Middle East & Africa (MEA). Additionally, the report comprises country-level analysis (main countries U.S., Germany, Italy, the U.K., France, Spain, Japan, China, Japan, and South Africa). In the second report the nanoclay market is analysed at global and regional level. Regional level includes North America, Europe, Asia Pacific, Latin America, and Middle East & Africa.</p>
<p>Time horizon and time steps: Both reports assess the period 2014-2023</p>

<p>Aggregation level with regard to production and different uses: In the first report nanocellulose market is divided into product segments such as nanofibrillated cellulose, nanocrystalline cellulose, and bacterial nanocellulose. In terms of end-user, the global nanocellulose market is segmented into composites, paper processing, food & beverages, paints & coatings, oil & gas, personal care, and others. The second report aggregates the nanoclay market by product and by end-user. Product segmentation includes kaolinite, smectite, and others, while end-user segmentation comprises flame retardants, automotive, paints & coatings and others.</p>
<p>Documentation: Not available.</p>
<p>Sources used: The first report used sources such as company websites, financial reports, annual reports, investor presentations, broker reports, and SEC filings. Other sources used are internal and external proprietary databases, statistical databases and market reports, news articles, national government documents, and webcasts specific to companies operating in the market. Furthermore, in-depth interviews and discussions with a wide range of key opinion leaders and industry participants were also conducted. In the second report where no hard data was available, models and estimates were used. The available hard data was cross-referenced with data types (e.g. demographic data and macroeconomic indicators). It follows a top-down approach to estimate and forecast market volume by geography. Sources used were: key players' product literature, annual reports, press releases, and relevant documents for competitive analysis and market understanding. Furthermore, a search of recent trade, technical writing, Internet sources, and statistical data from government websites, trade associations, and agencies was conducted as well as in-depth interviews and discussions with key industry participants and opinion leaders.</p>
<p>Additional verification of assumptions: Not available.</p>
<p>Further elements: Not available.</p>
<p>Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.</p>

Table 38: Commercial market studies from Deloitte

<p>Advanced Manufacturing in a highly connected world (Dickson, 2015)</p>
<p>Purpose of the study: The report focuses on current market trends and future growth opportunities of nanomaterials, in industries such as paints & coatings, adhesives & sealants, healthcare, energy, electronics & consumer goods, personal care, and others.</p>
<p>Scope and disaggregation in spatial terms: Global nanomaterial market.</p>
<p>Time horizon and time steps: 2012-2019</p>
<p>Aggregation level with regard to production and different uses: Not available</p>
<p>Documentation: Moderate: presentation</p>

Sources used: Not available
Additional verification of assumptions: Not available
Further elements: Advanced Manufacturing technologies expected to double in value to \$85+ billion globally by 2019
Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents. Furthermore, only a presentation was founded on the internet search.

Table 39: Commercial market studies from BBC Research

Commercial market studies from BBC Research: The Maturing Nanotechnology Market: Products and applications (McWilliams, 2016)
Purpose of the study: The report analyses the global market for nanotechnology by applications and products and projections (CAGRs) as well as by identifying segments with greatest commercial potential and key players.
Scope and disaggregation in spatial terms: Global and regional.
Time horizon and time steps: 2015-2021
Aggregation level with regard to production and different uses: The report covers nanomaterials (nanoparticles, nanotubes, nanostructured materials and nanocomposites), nanotools (nanolithography tools and scanning probe microscopes) and nanodevices (nanosensors and nanoelectronics). Carbon black nanoparticles used to reinforce tires and other rubber products; photographic silver and dye nanoparticles; and activated carbon used for water filtration are excluded. Nanoscale semiconductors are also excluded from the study, although the tools used to create them are included.
Documentation: Not available.
Sources used: Not available.
Additional verification of assumptions: Not available.
Further elements: Not available.
Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.

Table 40: Commercial market studies from Zion Market Research

<p>Commercial market studies from Zion Market Research:</p> <p>Nanomaterials Market (Metal Oxide, Metals, Chemicals & Polymers and Others) for Construction, Chemical Products, Packaging, Consumer Goods, Electrical and Electronics, Energy, Health Care, Transportation and Other Applications: Global Market Perspective, Comprehensive Analysis and Forecast, 2016 – 2022 (Zion Market Research, 2017)</p>
<p>Purpose of the study: Status-quo and forecast of the nanomaterial market world-wide. It also identifies opportunities, drivers and restraints.</p>
<p>Scope and disaggregation in spatial terms: Global, regional (North America, Europe, Asia Pacific, Latin America, Middle East and Africa) and country level (EEUU, UK, France, Germany, China, Japan, India and Brazil).</p>
<p>Time horizon and time steps: 2016-2022. It also provides historic data from 2014-2016.</p>
<p>Aggregation level with regard to production and different uses: This report segments the global nanomaterials market by type (metal oxides, metals, chemicals & polymers, others), by application (construction, chemical products, packaging, consumer goods, electrical and electronics, energy, health care, transportation and others).</p>
<p>Documentation: Not available.</p>
<p>Sources used: Company websites, annual reports, financial reports, broker reports, investor presentations and SEC filings IDC and other relevant magazines. Internal and external proprietary databases, and relevant patent and regulatory databases. National government documents, statistical databases and market reports. News articles, press releases and webcasts specific to companies operating in the market. Primary interviews with industry participants and commentators.</p>
<p>Additional verification of assumptions: Not available.</p>
<p>Further elements: Not applicable.</p>
<p>Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.</p>

Table 41: Commercial market studies from Research and markets

<p>Commercial market studies from Research and markets: The Global Market for Nanomaterials 2010-2027 (Research & Markets, 2017)</p>
<p>Purpose of the study: It analyses the global market of nanomaterials, producers and products. It includes the analysis of production volumes, competitive landscape, commercial prospects, applications, demand by market and region, commercialization timelines, prices and producer profiles as well as historical data from 2010 and projections to 2027.</p>
<p>Scope and disaggregation in spatial terms: Global and regional.</p>

<p>Time horizon and time steps: 2010-2027</p>
<p>Aggregation level with regard to production and different uses: The nanomaterials market is analysed as aluminium oxide nanoparticles, Antimony Tin Oxide Nanoparticles, Bismuth Oxide Nanoparticles, Carbon Nanotubes, Cerium Oxide Nanoparticles, Cobalt Oxide Nanoparticles, Copper Oxide Nanoparticles, Dendrimers, Fullerenes, Gold Nanoparticles, Graphene, Iron Oxide Nanoparticles, Magnesium Oxide Nanoparticles, Manganese Oxide Nanoparticles, Nanocellulose, Nanoclays, Nanodiamonds, Nanofibers, Nanosilver, Nanowires, Nickel Nanoparticles, Quantum Dots, Silicon Oxide Nanoparticles, Titanium Dioxide Nanoparticles, Zinc Oxide Nanoparticles, Zirconium Oxide Nanoparticles, Nanoprecipitated Calcium Carbonate, Graphene And Carbon Quantum Dots, Hydroxyapatite Nanoparticles, Palladium Nanoparticles, Yttrium Oxide Nanoparticles, Other 2D Materials.</p>
<p>Documentation: Not available.</p>
<p>Sources used: Not available.</p>
<p>Additional verification of assumptions: Not available.</p>
<p>Further elements: Not available.</p>
<p>Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.</p>

Table 42: Commercial market studies from Mordor Intelligence

<p>Commercial market studies from Mordor Intelligence:</p> <p>Nanomaterials Market-Global trends, Investment Analysis and Future scope to 2022 (Mordor Intelligence, 2017b)</p> <p>Complex-Oxide Nanomaterials Market-Analysis of growth trends and Forecast (2016-2022) (Mordor Intelligence, 2017a)</p>
<p>Purpose of the study: The aim of the first study is to analyse global nanomaterials market by value chain, CARGR (forecast) and by end-user, structure type and product type by region and well as by identifying key players. The second report focuses in the analysis of complex-oxide nanomaterials market by global and regional level, by product type and by industry as well as by identifying main players, drivers and opportunities and value chain.</p>
<p>Scope and disaggregation in spatial terms: Both reports analyse the market at global, regional (North America, Asia-Pacific, Europe and Rest of the World) and country level. At country level, market is analysed for China, India, Japan, South Korea, Rest of Asia-Pacific, EEUU, Canada, Mexico, Rest of North America, Germany, UK, Italy, France, Rest of Europe, Brazil, South Africa and others.</p>
<p>Time horizon and time steps: 2015-2022</p>

<p>Aggregation level with regard to production and different uses: In the first report, the nanomaterials market is segmented by end-user industry into Transportation, Construction, Packaging, Consumer Goods, Electrical & Electronics, Energy, Healthcare, Aerospace & Defense, Water Treatment and Others. It is further segmented into nano-particles, nano-fibers, nano-tubes, nano-clays and nano-wire. Additionally, it is divided by structure type into non-polymer organic nanomaterials and polymeric nanomaterials. In the second report, the complex-oxide nanomaterials market is divided by product type (Calcium Phosphate, Rare Earth Metal Oxide, Lithium Titanate and Silica Hydride) and by industry (Health Care, Food Industry, Cosmetics Industry, Biotechnology Industry, Fuel Cell, Lithium -Ion Battery, Personal care, Surface Coatings and Others).</p>
<p>Documentation: Not available.</p>
<p>Sources used: Not available.</p>
<p>Additional verification of assumptions: Not available.</p>
<p>Further elements: Not available.</p>
<p>Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.</p>

Table 43: Commercial market studies from Lux Research Inc.

<p>Commercial market studies from Lux Research Inc.:</p> <p>Is Graphene the Next Silicon ... Or Just the Next Carbon Nanotube? (Luxresearch, 2012)</p> <p>Nanotechnology Update (Luxresearch, 2015)</p> <p>Carbon Nanomaterials Update 2017 Edition (Luxresearch, 2018)</p>
<p>Purpose of the study: The first study focuses on carbon nanomaterials (mainly graphene and carbon nanotubes) as well as in its production and gives an outlook on the commercial future of carbon nanomaterials. The second study focuses in carbon nanotubes and graphene and forecasts graphene market in 2020.</p>
<p>Scope and disaggregation in spatial terms: Not available.</p>
<p>Time horizon and time steps: Not available.</p>
<p>Aggregation level with regard to production and different uses: Not available.</p>
<p>Documentation: Not available.</p>
<p>Sources used: Not available.</p>

Additional verification of assumptions: Not available.
Further elements: Not available.
Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.

Table 44: Commercial market studies from Fractovia

<p>Commercial market studies from Fractovia</p> <p>"North America Nanosilver Market to garner substantial proceeds over 2017-2024, biomedical applications to drive the industry growth" (Fractovia, 2017b)</p> <p>"APAC Carbon Nanotubes Market to observe highest growth rate over 2016-2024, high demand from the electronics sector to stimulate the industry growth" (Fractovia, 2017a)</p> <p>"Smart textiles to stimulate the silver nanoparticles market over 2016-2024" (Fractovia, 2016b)</p> <p>"Gold Nanoparticles market outlook: Medical & Dentistry applications to stimulate industry growth over 2016-2022" (Fractovia, 2016a)</p>
<p>Purpose of the study:</p> <p>The first report focuses in North American nanosilver market. The second report is centred on the carbon nanotubes market in Asia-Pacific and EEUU. The third report also focuses in nanosilver market but in the context of smart textiles industry. In the fourth report the scope is the gold nanoparticles market, its outlook and the growth of the market due to medical and dentistry applications.</p>
<p>Scope and disaggregation in spatial terms:</p> <p>North America for the first report and Asia-Pacific and EEUU for the second report. The third report focuses on the global market as well as EEUU, Asia-Pacific, Europe and UK. The fourth report seems to focus at regional level (Europe, North America and Asia-Pacific regions).</p>
<p>Time horizon and time steps:</p> <p>First, second and third reports evaluate the period 2013-2024. The fourth report assesses the period 2014- 2022.</p>
<p>Aggregation level with regard to production and different uses:</p> <p>In the first report the nanosilver market is aggregated by end-user as electrical & electronics, healthcare, foods & beverages, textiles, water treatment and others. However, the third report differently to the first report divide the nanosilver market by application as electronics & IT, healthcare & life sciences, food & beverages, textiles and others. The second report divides carbon nanotubes market by applications as polymers, energy, electricals & electronics and others. In the fourth report the gold nanoparticles market is divided by application as medical, electronics, catalysis and others.</p>
<p>Documentation:</p> <p>Not available for the first report. The second, third and fourth report reference Global Market Insights Inc. study.</p>
<p>Sources used:</p> <p>Not available.</p>

Additional verification of assumptions: Not available.
Further elements: Not available.
Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.

Table 45: Commercial market studies from Global Market Insights

Commercial market studies from Global Market Insights: Silver Nanoparticles Market Size by Application, Industry Analysis Report, Regional Outlook, Growth Potential, Price Trends, Competitive Market Share & Forecast, 2016–2024 (Global Market Insights, 2017)
Purpose of the study: The purpose is to analyse silver nanoparticles market by application, region and its competitive market share.
Scope and disaggregation in spatial terms: Global, regional and country level. Regions: North America, Europe, Asia-Pacific, Latin America and Middle East. Countries: EEUU, Canada, Germany, UK, France, Italy, Spain, Russia, Poland, The Netherlands, China, India, Japan, Australia, Malaysia, Indonesia, Brazil, Argentina, Mexico, Saudi Arabia, UAE and South Africa.
Time horizon and time steps: 2013-2024
Aggregation level with regard to production and different uses: From the use perspective nanomaterials are aggregated as health care & life sciences, electronics IT, food & beverages, textiles and others.
Documentation: Not available.
Sources used: Trade magazines, technical publications, independent studies along with paid avenues such as ICIS. statistical analysis with models built around time-variance, regression and correlation analytics. Support from leadership figures such as CEOs, CSOs, VPs etc. in key companies, supply-chain participants, distributors and domain experts and key customers and B2B clients.
Additional verification of assumptions: Not available.
Further elements: Not available.
Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.

Table 46: Commercial market studies from Future Market Insights

Commercial market studies from Future Market Insights:
Nanomaterials Market: Global Industry Analysis and Opportunity Assessment 2015-2025 (Future Market Insights, 2018)
Purpose of the study: The aim of this study is to analyse the global nanomaterials market by market segmentation (material type and applications) and by region as well as by identifying key players drivers and restraints.
Scope and disaggregation in spatial terms: Global, regional (North America, Latin America, Western Europe and Eastern Europe, Asia Pacific, Middle East and Africa (GCC, S. Africa, N. Africa)) and country level. At country level the analysis is done for EEUU, Canada, Mexico, Brazil, Germany, Italy, France, U.K, Spain, Nordic countries, Belgium, Netherlands, Luxembourg, Poland, Russia, China, India, ASEAN, Australia & New Zealand and Japan.
Time horizon and time steps: 2015-2025
Aggregation level with regard to production and different uses: The nanomaterials market is divided by material type such as Metal Oxide (Silica, Aluminium Oxide/Hydroxide, Titanium Dioxide, Zinc Oxide, Iron Oxide, Other Metal Oxides), Metals, Chemicals and Polymers (Nanopharmaceuticals, Liposomes, Other Chemicals & Polymers), Nanotubes and Others (Conventional Materials and New Materials). It is also divided by applications such as Construction, Packaging, Consumer Goods, Electrical and Electronics, Energy, Health Care, Transportation and Others.
Documentation: Not available.
Sources used: first-hand information, qualitative and quantitative assessment by industry analysts, inputs from industry experts and industry participants across the value chain.
Additional verification of assumptions: Not available.
Further elements: Not available.
Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.

Table 47: Commercial market studies from Allied Market Research

Commercial markets studies from Allied Market Research:
Europe Nanomaterials Market (Allied Market Research, 2016a)
Nanomaterials Market – Global Opportunity Analysis and Industry Forecast, 2014-2022 (Allied Market Research, 2016b)
World Silver Nanomaterials as Transparent Conductor Market (Allied Market Research, 2018)

Purpose of the study:

The aim of the first report is to analyse European nanomaterials market by type of material, by end-user and by country as well as by identifying main players, opportunities, restraints and drivers.

The second report focuses on current market trends and future growth opportunities of nanomaterials, in industries such as paints & coatings, adhesives & sealants, healthcare, energy, electronics & consumer goods, personal care, and others.

The third report analyses the market of silver nanomaterials by estimating market trends as well as by identifying the drivers, restraints and opportunities.

Scope and disaggregation in spatial terms:

The first report analyses the nanomaterials market at regional (Europe) and country level (U.K., Germany, France, Spain, Italy and Rest of Europe).

The second report analyses the nanomaterial market at global level.

The third report analyses the market at global and regional level (North America, Europe, Asia-Pacific and Rest of the World).

Time horizon and time steps:

First and second report 2014-2022. The third report analyses the market from 2012 to 2020.

Aggregation level with regard to production and different uses:

In the first report nanomaterials market is segmented by type of material (carbon based nanomaterials, metal & non-metal oxides metal based nanomaterials dendrimers nanomaterials, nanoclay and nanocellulose) and by end-user (paint & coatings, adhesives & sealants, healthcare & life science, energy, electronics & consumer goods, personal care and others).

The second report lists types of nanomaterials that are commercially available in the market, namely, carbon based (carbon nanotubes, fullerenes & POSS, and graphene), metal and non-metal oxides (titanium dioxide, zinc oxide, silicon dioxide, aluminium oxide, cerium oxide, antimony tin oxide, copper oxide, bismuth oxide, cobalt oxide, iron oxide, magnesium oxide, manganese oxide, and zirconium oxide), metals (silver, gold, nickel, and quantum dots), dendrimers, nanoclay, and nanocellulose. It also analyses the current market trends of nanomaterials in different geographies and suggests the future growth opportunities by analysing government regulations & policies, which can further increase the consumer acceptance in that region.

In the third report segmentation of the market is not publicly available.

Documentation:

Good-moderate: statistics and financial forecast of the sector value, names nanomaterials and products as well as end-user markets.

Sources used:

In the first and second report the sources are not available.

The third report uses sources such as company SEC filings, annual reports, company websites, broker & financial reports and investor presentations for competitive scenario and shape of the industry, patent and regulatory databases for understanding of technical & legal developments, scientific and technical writings for product information, regional government and statistical databases for macro analysis, authentic new articles, web-casts, internal and external proprietary databases, key market indicators and relevant press releases for market estimates and forecast. Furthermore, interviews and discussion panels were conducted with Chief executives and VPs of leading corporations specific to industry, product and sales managers or country heads; channel partners and top-level distributors; banking, investments and valuation experts Key opinion leaders (KOLs).

Additional verification of assumptions:

Not any.

Further elements:

Not any.

Discussion:

Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.

Table 48: Commercial market studies from RNCOS

Global Nanotechnology Market Outlook 2024 (RNCOS, 2018)
Purpose of the study: The study identifies market dynamics and important segments with growth potential.
Scope and disaggregation in spatial terms: The report covers the global nanomaterials market as well as nanotechnologies market by region.
Time horizon and time steps: From 2017-2024.
Aggregation level with regard to production and different uses: In the report, the global market of nanotechnologies is analysed by application (electronics, energy, cosmetics, biomedical, defence and food and agriculture) and by component (nanomaterials, nanotools and nanodevices).
Documentation: Not available.
Sources used: Not available.
Additional verification of assumptions: Not available.
Further elements: Not available.
Discussion: Commercial market studies require to be purchased, thus the information that could be gathered at current stage is the one publicly available as summary, methodology or table of contents.

6.4 Databases

Table 49: The Nanodatabase

The Nanodatabase (DTU Environment, 2018)
Purpose of the study: The Nanodatabase is funded by the European Research Council through the project EnvNano - Environmental Effects and Risk Evaluation of Engineered Nanomaterials, the Danish Consumer Council and the Villum Foundation. The Nanodatabase focuses on three aspects: consumer products, waste treatment and biocidal products and treated articles.
Scope and disaggregation in spatial terms: Global.
Time horizon and time steps: 2012 – 2018
Aggregation level with regard to production and different uses: The database analysis tools allow for a wide range of queries, including production information and the uses of the nanomaterials. However, it is important to note that the database contains nanomaterial products, not nanomaterials themselves.

Documentation: Good to moderate: when available, the database links directly to exposure profiles, safety profiles, manufacture websites, etc.
Sources used: Primarily the sources are manufacturers and retailers.
Additional verification of assumptions: Not applicable.
Further elements: Not any.
Discussion: The database provides limited information relevant to the scope of this report, as it lists consumer products rather than nanomaterials themselves.

Table 50: Consumer Products Inventory

Consumer Products Inventory (of nanomaterials in consumer products) (PEN, 2018)
Purpose of the study: The database is based on crowdsourcing expertise to create a 'living' inventory for the exchange of accurate information on nano enabled consumer products. Registered users are encouraged to submit relevant data pertaining to nanoparticle function, location, properties, potential exposure pathways, toxicity and life cycle assessment. Registered users can update product information and add new products.
Scope and disaggregation in spatial terms: Global.
Time horizon and time steps: 2007-2014
Aggregation level with regard to production and different uses: The database analysis tools allow for a wide range of queries, including production information, the uses of the nanomaterials and expert opinions. It contains nanomaterial products as well as nanomaterials themselves and how well verified the information are.
Documentation: Moderate: there is a lot of relevant information, but the newest products were added in 2014.
Sources used: Websites of producers, sometimes statements of producers, customers and experts.
Additional verification of assumptions: Not applicable.
Further elements: Not any.
Discussion: Over 1,600 manufacturer-identified nanotechnology-based consumer products introduced to the market which can be browse by products, name, category, company, country and more but only until a certain date.

Table 51: Nanotechnology in the real world: Redeveloping the nanomaterial consumer products inventory

Nanotechnology in the real world: Redeveloping the nanomaterial consumer products inventory (Vance, et al., 2015)
Purpose of the study: The objective of this work is to redevelop the consumer product inventory by leading a research effort to increase the usefulness and reliability of this inventory.
Scope and disaggregation in spatial terms: 32 countries.
Time horizon and time steps: 2005-2013
Aggregation level with regard to production and different uses: Different uses within products: <ul style="list-style-type: none"> • Bulk: Nanomaterials sold in powder form or in liquid suspensions. • Nanostructured bulk: Products or parts that contain nanostructured features in bulk (e.g., nanoscale computer processors). • Nanostructured surface: Products or parts that contain nanostructured features on their surface (e.g., nanofilmcoated products). • Surface-bound particles: Nanoparticles added to the surface of a solid product or part (e.g., a computer keyboard coated with silver nanoparticles for antimicrobial protection). • Suspended in liquid: Nanomaterials suspended in a liquid product (e.g., disinfecting sprays, liquid supplements). • Suspended in solid: Nanomaterials suspended in a solid matrix, usually plastic or metal (e.g., composites of carbon nanotubes in a plastic matrix to confer strength).
Documentation: Information concerning the use, path and location of nanomaterial. Limited information of explicit producers and products.
Sources used: Reports and articles, some websites.
Additional verification of assumptions: Not any.
Further elements: The development of standardized methods and metrics for nanomaterial characterization and labelling in consumer products can lead to greater understanding between the key stakeholders in nanotechnology, especially consumers, researchers, regulators, and industry.
Discussion: Information of nanomaterials themselves and the quantity of use and an overview of nanomaterials in the inventory.

Table 52: Nanowerk – Nanomaterials Database

Nanowerk – Nanomaterials Database (Nanowerk, 2018)
Purpose of the study: Database that lists hundreds of worldwide suppliers of thousands of nanomaterials. Purported as

the most comprehensive online source for manufactured nanomaterials.
Scope and disaggregation in spatial terms: Global.
Time horizon and time steps: 2005-2018
Aggregation level with regard to production and different uses: Categorized in nanotubes, fullerenes, graphene, nanoparticles, quantum dots, nanofibers, nanowires
Documentation: Good: lists suppliers and their nanomaterial though not the use or product it is used in.
Sources used: User-based (suppliers) updates and administration. The US Environmental Protection Agency uses the Nanowerk Nanomaterial Database for the EPA's Nanoscale Materials Stewardship Program.
Additional verification of assumptions: Not any.
Further elements: Not any.
Discussion: The database has ~4,000 nanomaterial products listed, organised by type. Materials are listed in sub-groups with different "specifications" e.g. Chemically Modified Fullerenes with the different specifications of Halogenated C60Br24 or Halogenated C60Cl6 or Halogenated C60F36. <ul style="list-style-type: none"> • Nanotubes • Fullerenes • Graphene • Nanoparticles • Quantum dots • Nanofibers • Nanowires

Table 53: DaNa – Information about nanomaterials and their safety assessment

DaNa – Information about nanomaterials and their safety assessment (DaNa, 2018)
Purpose of the study: Detailed information on nanomaterials such as properties, use, occurrence and production, contact, risk and behaviour in the body. The project is funded by the German Federal Ministry of Education and Research and Swiss Federal Ministry of environment and Swiss Federal Ministry of health and some Swiss organisations.
Scope and disaggregation in spatial terms: Global.
Time horizon and time steps: 2006-2018

<p>Aggregation level with regard to production and different uses: The database provides a lot of information including substance and production information, the uses of the nanomaterials and applications and risks using them. It contains nanomaterials themselves and the paths of contact with the consumers. There is no list of products using nanomaterials</p>
<p>Documentation: Very good-good: website and links contain information on the combination of materials and their applications, exposure profiles, safety profiles, etc.</p>
<p>Sources used: Literature, operating instructions (Standard Operating Procedures and laboratory protocols, etc.). Furthermore, scientific publications, reports, project results (funded by the German Federal Ministry of Education and Research) and latest news on human and environmental toxicology.</p>
<p>Additional verification of assumptions: Not available.</p>
<p>Further elements: Not applicable.</p>
<p>Discussion: Not applicable.</p>

Table 54: Nanowatch (nano-product database)

<p>Nanowatch – Nanoproduktdatenbank (Nanoprodukte im Alltag) (BUND, 2018)</p>
<p>Purpose of the study: The nanoproduct database is funded by the “Bund – Friends of the Earth Germany” It focuses on all products containing nanomaterials that consumers have access to.</p>
<p>Scope and disaggregation in spatial terms: Global.</p>
<p>Time horizon and time steps: 2015-present.</p>
<p>Aggregation level with regard to production and different uses: The database analysis tools allow to search producers, product categories and subcategories as well as nanomaterials used.</p>
<p>Documentation: Moderate: information contains product name, producer, category (by these information categories information can be sorted), sale, manufacture website and date of the information.)</p>
<p>Sources used: Primary sources are the homepages of the manufacturer.</p>
<p>Additional verification of assumptions: Not applicable.</p>
<p>Further elements: Not any.</p>

Discussion:

This database does not list nanomaterials, but rather products that contain nanomaterials.

Compared to other databases reviewed, this one provides limited information on products containing nanomaterials, it allows a user to sort by product category, nanomaterial used, and other criteria.

6.5 Other data sources

Table 55: World market for nanomaterials: structure and trends

World market for nanomaterials: structure and trends (Inshakova, et al., 2017)

Purpose of the study:

This article focuses on current state and key indicators of development of the world nanomaterials market, its key drivers and restraints, modern structure, emerging trends and prospects.

Scope and disaggregation in spatial terms:

Worldwide and regions (Asia/Pacific, United States, Western Europe and others).

Time horizon and time steps:

Different time horizons that range from 2010-2024.

Aggregation level with regard to production and different uses:

Regarding production the article differentiate the following types of aggregations: carbon based, metal and non-metal oxides, metals, dendrimers, nanoclay, and nanocellulose; nanoparticles, nano-fibres, nano-tubes, nano-clays and nanowires; carbon black, carbon nanotubes, graphene, fullerene, nanofibers; silica fumes; clay; metal/alloys; ceramics; and some others
For different uses, the article mentions some sectors within which nanomaterials are used (electronics, IT, health care, beauty, food and beverages packaging industry and textiles) as well as segments (electrical and electronics industry, construction, energy storage, healthcare, consumer goods, packaging, transportation, aerospace, water filtration, and others).

Documentation:

All the sources and references are well documented.

Sources used:

The article uses and reviews mainly commercial market research data (Mordor Intelligence, Allied Market Research, Deloitte Touche Tohmatsu Limited, Lux Research, The Fredonia group, RNCOS analysts, Market Insights Inc and Transparency Market Research (TMR) and discusses statistics on relevant patents as potential indicators.

Additional verification of assumptions:

Not applicable.

Further elements:

Not applicable.

Discussion:

The article concludes that "information asymmetry, heterogeneity and even inconsistency of the information in the databases exist, thus making it difficult to obtain relevant business information both for manufacturers and consumers".

Table 56: StatNano

Status of Nano-Science Technology and Innovation (StatNano, 2016)
Purpose of the study: StatNano is a nanotech statistical database, with the purpose of monitoring nanotech globally.
Scope and disaggregation in spatial terms: Global - with a focus on country comparison.
Time horizon and time steps: 2010 – present.
Aggregation level with regard to production and different uses: Not applicable.
Documentation: General documentation for the databases, and more specific for the status report.
Sources used: Studies & articles from Web of Science, Orbit Database (patent office data from many countries).
Additional verification of assumptions: Not applicable.
Further elements: Not any.
Discussion: The most recent status report details many statistical trends comparing the development of nanotechnology and materials in different countries throughout the world. StatNano provides a nanomaterial database, and a product database, these databases lists 43 nanomaterials in 1.5 million articles and 2,599 products. The product database breaks products down into sector (automotive, agriculture, electronic, etc.) with trending data of the number of products by sector, companies and countries applicable and in some cases industrial sub-sectors.

Table 57: Manufacturing nanomaterials: from research to industry

Manufacturing nanomaterials: from research to industry (Charitidis, et al., 2014).
Purpose of the study: The article describes different processes for manufacturing nanomaterials and nanoparticles as well as application. It also identifies producers and capacity production for some nanomaterials.
Scope and disaggregation in spatial terms: Global, with an EU focus.
Time horizon and time steps: 2014
Aggregation level with regard to production and different uses: Limited examples of nanomaterials at different grades, production methods, as well as limited information regarding the current applications for some of these.
Documentation: Well documented sources.

Sources used:

Private and public scientific publications.

Additional verification of assumptions:

Not applicable.

Further elements:

Not applicable.

Discussion:

The study concludes five critical success factors for nanotechnology growth and development.

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