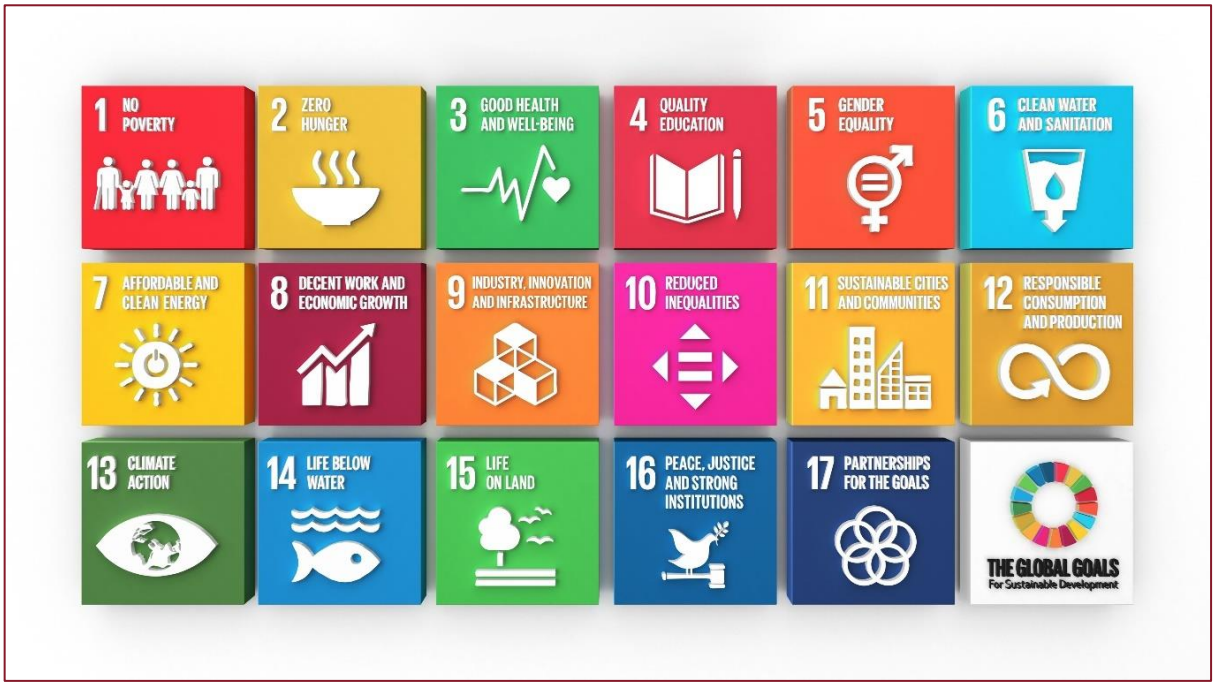
2022:02

SweNanoSafe

Swedish National Platform for Nanosafety



Nanosafety, the Sustainable Development Goals and meeting EU policy ambitions

Foreword

SweNanoSafe maintains a national platform for the safe handling of nanomaterials, commissioned by the Swedish Ministry of Environment and the Swedish Chemicals Agency. The main objective of the platform is to contribute to the achievement of the environmental quality goal of a *non-toxic environment* and to protect human health. The platform aims to disseminate knowledge and provide advice and support to authorities on issues related to the safe handling and use of nanomaterials. SweNanoSafe brings together academia, authorities, industry, and organisations in a joint dialogue on nanosafety. This also includes identifying needs for the safe handling of nanomaterials and contributing to solutions and concrete measures that meet the needs, as well as actively promoting improved nanosafety.

SweNanoSafe began its activities 2016, and since 2019 the platform has been hosted by the Institute of Environmental Medicine (IMM) at Karolinska Institutet (KI). The platform is comprised of a Steering Board, Operations Coordination Group, Scientific Expert Panel, a Council of Government Agencies, Research Network, and Education Network, and conducts activities such as workshops and meetings, writes/commissions reports and maintains communication via a website (www.swenanosafe.se). SweNanoSafe welcomes questions, comments, and proposals regarding nanosafety, through swenanosafe@swenanosafe.se.

This scoping report identifies and outlines the synergies between the United Nations (UN) Sustainable Development Goals (SDGs), EU policy ambitions and the objective of SweNanoSafe. The report was drafted by Marietta Athanasiou and Penny Nymark (SweNanoSafe/KI) and reviewed by Lya Soeteman-Hernandez (Lead expert of the OECD Steering Group for Safe Innovation Approach and Senior risk assessor at the Dutch National Institute for Public Health and the Environment), and Urban Boije af Gennäs, Stefan Gabring and Gregory Moore at the Swedish Chemicals Agency (KemI).

SweNanoSafe

Stockholm, May 10th, 2022

SweNanoSafe

Swedish National Platform for Nanosafety

Institute of Environmental Medicine, Karolinska Institutet

Address:

Box 210, SE-171 77 Stockholm

Karolinska Institutet

Cover image:

Adobe Stock

This report can be downloaded from www.swenanosafe.se

Stockholm, May 2022

Contents

Abbreviations

EU	European Union
EURL/ECVAM	European Union Reference Laboratory for Alternatives to Animal Testing
FAIR	Findable, Accessible, Interoperable and Reusable
IMM	Institute of Environmental Medicine
JRC	Joint Research Centre
KI	Karolinska Institutet
NAMs	New Approach Methodologies
OECD	Organization for Economic Cooperation and Development
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RRI	Responsible Research & Innovation
SbD	Safe-by-Design
SSbD	Safe and Sustainable-by-Design
SIA	Safe(r) Innovation Approach
SCB	Statistics Sweden
SDGs	Sustainable Development Goals
SDI	Sustainable Development Index
UN	United Nations
WHO	World Health Organization

Summary

The SweNanoSafe focus areas include sustainable development of nanotechnology and the platforms recently organized a workshop titled "*Safe and Sustainable by Design: a prerequisite for achieving a circular economy*" and published a workshop report describing the presentations and discussions that took place.[1] In addition, a report describing stakeholder views on safe and sustainable nanotechnology innovation was recently published.[2] Following these initial activities within the focus area of sustainable development, this report aims to describe the alignment between the UN Sustainable Development Goals (SDGs)[3] and the SweNanoSafe objective and activities. In addition, the report includes reference to how the SweNanoSafe activities contribute to the new European Union (EU) policy ambitions, including the EU Green Deal[4] and Chemicals Strategy for Sustainability.[5]

The report initially provides an overview of the expected key-enabling opportunities that nanotechnology provides for sustainable development, while at the same time challenging the current health risk assessment frameworks and legislations, which are not agile enough to handle the vast number of complex nanomaterials considered in technological innovation. An overview of the status of sustainable development in Sweden is also provided followed by a short description of the concept of nanosafety and the six overarching SweNanoSafe activities.

The main part of the report details the synergies between 12 of the 17 SDGs and the SweNanoSafe objective, providing examples of stakeholder-engaging activities where relevant. An overview of the synergies is provided in **Table 1**.

Table 1. Overview of synergies between the UN Sustainable Development Goals (SDGs) and SweNanoSafe activities.

SweNanoSafe's ambition	**SDG**	**SweNanoSafe activities towards meeting SDG goal**
From responsible production to climate action	SDG 12 Ensure sustainable consumption and production patterns	Support development of an engaging system of societal, environmental and economic accounting linking chains from production to consumption and end of life of nanomaterials.
	SDG 9 Industry, Innovation and Infrastructure	Build a resilient infrastructure for communication and dialogue among stakeholders to promote inclusive and sustainable industrialization and foster innovation within nanotechnology.
	SDG 8 Decent work and economic growth	Encourage incorporation of nanosafety aspects to support decent work and economic growth.
	SDG 13 Climate action	Actively contribute to the implementation of Climate Action by fostering sustainable consumption and production of nanotechnology, and by creating awareness and providing education towards safe and sustainable nanotechnology innovations.
Towards a healthy environment	SDG 3 Ensure healthy lives and promote well-being for all at all ages	Impact the overall aim to reduce mortality from non-communicable diseases and the number of deaths and illnesses from exposure to hazardous nanomaterials in air, water and soil pollution and contamination.

SweNanoSafe's ambition	SDG	SweNanoSafe activities towards meeting SDG goal
	SDG 2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Advocate for safety and sustainability of nanomaterials in food and feed during food process, food packaging and labelling, as well as sustainable food production systems with the use of safe and resilient nanotechnology agricultural practices.
From clean water to conserved marine life	SDG 6 Ensure availability and sustainable management of water and sanitation for all	Promote and engage stakeholder in achieving clean water, sanitation and sustainable management of waste streams by compiling and communicating knowledge regarding the existence of nanomaterials in specific industrial sectors (such as building materials, textiles, cosmetics, food and packaging) and in the environment.
	SDG 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Support reduced marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution by increasing knowledge regarding the content and presence of nanomaterials and nanoplastics and potential risks to health and the environment associated with nanomaterial reuse, recycling, incineration and landfill sites.
A safe and sustainable key enabling technology	SDG 7 Ensure access to affordable, reliable, sustainable and modern energy for all	Enhance international cooperation among all stakeholders to facilitate knowledge dissemination and communication regarding clean, sustainable and safe nano-enabled energy research and technology innovation.

SweNanoSafe's ambition	SDG	SweNanoSafe activities towards meeting SDG goal
From strong institutions to international partnerships and equality	SDG 16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.	Stimulate cross-sectoral and international partnerships and policy coherence by providing information about existing programmes and courses regarding nanosafety through the platform's website, contributing to knowledge transfer between various stakeholders, including academia, industry, trade organizations and governmental agencies.
	SDG 17 Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.	Strengthen active collaboration with other European national nanosafety platforms and with international working groups such as the Organization for Economic Cooperation and Development (OECD) and the European Union Reference Laboratory for Alternatives to Animal Testing (EURL/ECVAM).
	SDG 10 Reduce inequalities within and among countries	Map and prioritize needs within nanosafety to support actions towards relevant measures and efficient use of resources, thereby independently contributing to the reduction of inequalities between institutions, industries and international organizations and to the strengthening of the implementation of harmonized nanosafety regulations.

Sustainable development and nanotechnology

The SDGs are a collection of 17 interrelated global goals agreed upon by the UN (**Figure 1**). The SDGs have spurred change in the policy landscape within the EU and several impressive policy ambitions have been brought forward as the *EU holistic approach to sustainable development*, including the EU Green Deal[4], the Circular Economy Action Plan[6] (and the Sustainable Products Initiative[7]), and the Chemical Strategy for Sustainability[5], all involving the central goal of achieving a *non-toxic environment*.

Figure 1: The 17 UN Sustainable Development Goals (source: *www.un.org*)

Nanotechnology has been identified as a key-enabling technology for the EU[8] and has rapidly promoted the development of a new generation of smart and innovative materials, products and processes, expected to have a significant impact on the achievement of the SDGs. Nanotechnology and the materials applied in these technologies have created a tremendous

growth potential for a wide range of applications and a large number of major industry sections such as infrastructure, energy, chemicals, healthcare, cosmetics and food.[9-11]

Nanomaterials are defined as advanced materials that are intentionally produced at a size of approximately 1 to 100 nanometres in at least one dimension (detailed definition available in[12], and reviewed further in[13,14]). Nanomaterials are referred to as nanoforms within regulatory settings such as the REACH regulation.[15] Furthermore, SweNanoSafe has recently written a post to clarify the term advanced materials in Swedish (available on the SweNanoSafe website[16]) and the European Commission has announced its support for the development of advanced materials.[17] Nanomaterials can have desirable properties that make them unique and useful for a wide range of innovative applications. However, despite the expected benefits for the market and sustainability, nanomaterial applications have also raised safety concerns regarding their possible adverse effects on human health and the environment relating to the novel functional properties[18] (as reviewed and outlined in several recent SweNanoSafe reports).[19-21] Thus, it is important to take advantage of the valuable innovation opportunities while simultaneously minimizing the potential human health and environmental risks from nanomaterials. Such harmonized action towards inclusion of so called nanosafety aspects in innovation requires efficient collaboration and communication among actors and stakeholders in the field.

Sweden and the Sustainable Development Goals

Monitoring the implementation of SDGs Agenda 2030 is carried out under the auspices of the United Nations and the progress is reported annually by each country, during the UN High-level Political Forum on Sustainable Development.[22] Each SDG is coupled to a set of specific targets, which are measurable and can be used to monitor progress through the SDG index. Statistics Sweden (SCB) is responsible for coordinating statistical monitoring in Sweden and determines how the 17 SDGs and 169 targets in Agenda 2030 are implemented in the Swedish society.

Sweden has traditionally been committed to international collaboration on global issues and is presently highly ambitious to contribute to the transformation of the world into a more socially, economically and environmentally sustainable place.[23-25] Indeed, according to the most recently published sustainable development review (2021), Sweden remains a front-runner in achieving the highest performance in implementing SDGs among the rest of the countries (dashboards.sdgindex.org/profiles/sweden). Sweden has been ranked 2nd among 165 countries in developing sustainable strategies and putting them into practice, gathering a total SDG index score of 85.6 out of 100, achieving the majority of the targets for each SDG.[22,23] Significant improvements have been seen in Sweden in several environmental, social and governance indicators, including no poverty (SDG 1), gender equality (SDG 5), the use of renewable energy sources (SGD 7), labour participation and decent work (SDG 8), innovation and infrastructure (SDG 9), peace, justice and strong institutions (SDG 16), as well as partnerships for the goals (SDG 17), as indicated by the green arrows in **Figure 2** (on track or maintaining achievement).

However, despite this strong starting position, Sweden faces several significant challenges. It is well recognized that Sweden needs to be more ambitious by focusing and implementing more sustainable consumption and production patterns (SDG 12), as well as by increasing its effort to prevent climate change (SDG 13), which still constitute major challenges (as shown by the red colour in Figure 2). Furthermore, the achievement of SDG 2 (zero hunger) in terms of achieving food and feed safety, promoting sustainable food production systems and resilient agricultural practices, and SDGs 14 and 15 (life below water and on land, respectively) seem to be hindered (as indicated by red colour and/or orange arrows in **Figure 2**). Whereas other goals including good health and well-being (SDG 3), quality education (SDG 4), clean water and sanitation (SDG 6), reduced inequalities (SDG 10) and sustainable cities and communities (SDG 11) are moderately or slowly improved (see yellow arrows in Figure 2).

Thus, it has been suggested that rich countries, such as Sweden, need to take further action to implement the SDGs with a particular focus on reducing CO_2 emissions and the overall material footprint. This is reflected in the newly proposed Sustainable Development Index (SDI), which in contrast to the SDG index, considers CO_2 emissions and material footprint calculated in per capita consumption-based terms and aligned with planetary boundaries.[26] From an SDI perspective Sweden is positioned at the bottom (146th of 165 countries), which is in striking contrast to the 2nd position based on the SDG index measuring the overall achievement of the SDGs. Overall and importantly, the burden of achieving all 17 SDGs and their targets requires strong collaboration across societal actors including governments, public authorities, industrial sector, and academia.

Description

The overall score measures a country's total progress towards achieving all 17 SDGs. The score can be interpreted as a the percentage of SDG achievement. A score of 100 indicates that all SDGs have been achieved.

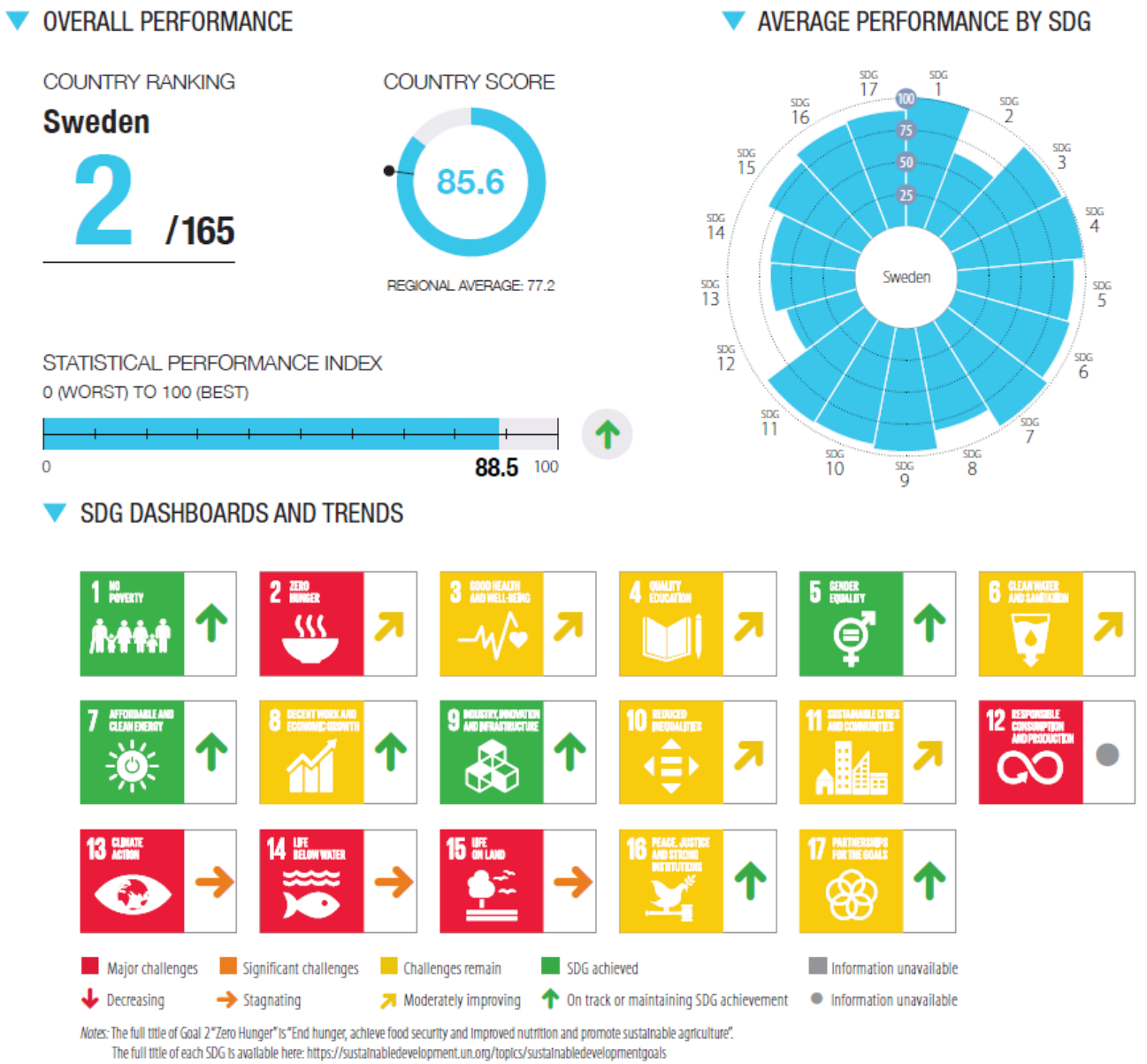


Figure 2: Sustainable Development Profile Sweden 2021 (source: dashboards.sdgindex.org/profiles/sweden)

Nanosafety and the SweNanoSafe objective and activities

The SweNanoSafe platform was created in 2016 to become a national cooperation and communication platform for safety aspects of nanomaterials, referred to as nanosafety. This direct initiative originated from the Swedish government report "*Safe development – a national action plan for the safe use and handling of nanomaterials*" (SOU 2013:70). Important aspects of the platform´s purpose constitute also addressing the relevant technological and societal challenges and the strengthening of research and innovation efforts with a specific focus on sustainable development and environmental, health and safety issues coupled to nanomaterials. This objective is in line with the current EU policy ambitions, where nanosafety involves aspects of sustainability and the overarching aim of achieving a *non-toxic environment*.[5]

With Sweden's long experience in education, training and regulation in the field of chemical safety, as well as the range and the quality of nanosafety research being conducted, the platform has provided the opportunity to lead the way towards safe handling, use and development of nanomaterials. SweNanoSafe focuses on dissemination of knowledge and provides special support to authorities in matters concerning safe handling and use of nanomaterials. SweNanoSafe also serves as a forum for collaboration between academia, authorities, businesses, and other organizations that have an interest in discussing, developing, and influencing the implementation of nanosafety in society, decision making and regulatory strategies.

The main activities of SweNanoSafe include, to:

1. *Synthetize knowledge, exchange trustworthy information and communicate* regarding the impact of nanomaterials on safety throughout the life-cycle (production-transfer-use-disposal), as well as on public health and environmental sustainability, with the overarching aim to contribute to a *non-toxic environment*.
2. Maintain a national Educational Network for nanosafety and actively contribute to education and training activities through workshops and conferences regarding the safe handling, use and development of nanomaterials in a variety of industrial sectors.
3. Maintain a national Research Network for nanosafety, with a strong presence and participation into national and international projects regarding action plans on nanosafety.
4. Provide special support to national authorities, through a Council of Government Agencies regarding regulatory needs and development in matters concerning the safe handling and use of nanomaterials.
5. Facilitate and strengthen the *collaboration* between various stakeholders in the nanosafety field, including academia, industry, trade organizations and governmental agencies, as well as the international cooperation e.g. within the EU, the OECD and the World Health Organization (WHO).
6. *Identify and highlight knowledge gaps, research needs and obstacles* to the safe handling of nanomaterials in various sectors and work as such and proposing recommendations

and practical solutions to overcome these obstacles.

To be noted, the platform does not conduct laboratory research or perform risk assessments or other tasks which are included within the responsibilities of Swedish authorities concerning nanomaterials and nanoforms.

In order for Sweden to continue to be a driving force regarding chemical policy and nanosafety issues in the EU and globally, SweNanoSafe has a significant role to play in terms of the implementation of various aspects of the SDGs either directly or indirectly, as described in the following section.

Synergies between the SDGs and the SweNanoSafe activities

SweNanoSafe's work falls within the framework of the environmental objective of the Swedish government for a *non-toxic environment* which aims to ensure that substances (chemicals, including intentionally produced nanomaterials) produced and used in society do not harm human health, environment or biodiversity.[27] This objective has recently been elaborated further through the implementation of the *non-toxic from the start* goal, (in Swedish: Giftfritt från början)[24], according to which products need to be designed as safe from the start so that they can be included in sustainable cycles with increased reuse and recycling. The SweNanoSafe activities clearly contribute to this principle and to the strategy that the Swedish Chemicals Agency has set, including (a) the phasing out of particularly hazardous substances, (b) the reduction of the total exposure and especially (c) the promotion of a non-toxic circular economy, through its objective as described above and detailed further below.[24,27]

From responsible innovation and production to climate action

SDG	SweNanoSafe activities towards meeting SDG goal
SDG 12 Ensure sustainable consumption and production patterns	Support development of an engaging system of societal, environmental and economic accounting linking chains from production to consumption and end of life of nanomaterials.
SDG 9 Industry, Innovation and Infrastructure	Build a resilient infrastructure for communication and dialogue among stakeholders to promote inclusive and sustainable industrialization and foster innovation within nanotechnology.
SDG 8 Decent work and economic growth	Encourage incorporation of nanosafety aspects to support decent work and economic growth.
SDG 13 Climate action	Actively contribute to the implementation of Climate Action by fostering sustainable consumption and production of nanotechnology, and by creating awareness and providing education towards safe and sustainable nanotechnology innovations.

A system of societal, environmental and economic accounting

For many countries in the EU, including Sweden, **SDG 12** (Responsible consumption and production) is one of the most challenging goals to achieve.[23] SDG 12 is strongly correlated with the need for transformative change in the way the society produces, consumes and lives.[28] To identify priorities in implementing SDG 12, a system of societal, environmental and economic accounting is necessary, especially because the chains from production to consumption are largely global and are not halted by national borders. Moreover, since nanotechnologies are characterized by constant development and a growing number of novel, complex manufactured nanomaterials,[8,28] there is a lack of a coherent risk assessment system to evaluate their safety on human health and the environment precisely and effectively. Thus, the Safe(r) Innovation Approach (SIA) concept was recently introduced, aiming to mitigate these challenges and ensure the sustainable production, use and end-of-life of nanomaterials.[29]

The SIA approach constitutes a proactive system, that helps to minimize the gap between the fast pace of innovation and the pace of nano-specific risk governance and communication. SIA is an approach that combines the (a) *Safe-by-design (SbD)* concept and (b) the *Regulatory Preparedness* concept, both aiming at balancing safety, functionality and cost-efficiency in an integrated way considering all life-cycle steps.[29-31] In addition, the approach couples to the concept *Trusted Environments*, which are intended to facilitate communication and the exchange of sensitive information between innovators and authorities. The SbD concept is strongly linked with the Swedish governmental objective of products, materials and chemicals being *non-toxic from the start* at the premarketing stage, reducing uncertainties and risks related to human health and environmental safety due to the use of nanotechnology, starting as early as possible during the innovation process and covering the whole life-cycle chain from research and development phase to production, use, waste management and recycling.[24] Examples and challenges of the SbD approach within nanotechnology innovation has been discussed widely[32,33] and range from the controversies around how to handle the fibre-related hazard potential of multi-walled carbon nanotubes[34], or lack of test methods and data as exemplified by the debates around classification and risk assessment of nano-sized titanium dioxide[35], to an overall lack of basic knowledge about possible risks and their assessments among material developers and innovators.[36]

The Regulatory Preparedness concept was developed to complement the SbD concept in order for regulators to prepare accordingly the development of adaptable regulation that can keep ahead of knowledge generation and innovation of nanomaterials and nano-enabled products. Further developments of the concepts constitute inclusion of aspects relating to sustainability, which in the EU has recently been referred to as Safe and Sustainable-by-Design (SSbD).[37] At the time of writing the European Commission Joint Research Centre (JRC) is working towards establishment of an SSbD framework for both chemicals and

materials and has published a preliminary review of the safety and sustainability aspects contained in the concept.[38]

In this context, SweNanoSafe has a central and important role to support knowledge dissemination and education[39] regarding new nanomaterials/nano-enabled products and their SSbD aspects, both in the short- and long-term. For instance, the platform aims to promote and encourage companies to adopt sustainable production practices (aligned with SDG 12.6), including waste generation (SDG 12.3) and management with a life-cycle perspective (SDG 12.4). In addition, SweNanoSafe aims to raise awareness regarding sustainable and responsible lifestyle options, waste management (aligned with SDG 12.8) and novel regulatory strategies through its website, newsletters, training support and by organizing workshops and conferences. In the long term, SweNanoSafe is also in the position of evaluating the relative changes in environmental and human health risks, following the implementation of the SSbD process (for occupational, consumer and environmental safety) and estimating any residual risk in order to recommend additional risk mitigation and management measures. Furthermore, SweNanoSafe aims to support the identification of the possible barriers for the application of SSbD concepts and propose suitable approaches to adequately address them, in particular by consideration of the need for new alternative methods for toxicity testing (so called New Approach Methodologies or NAMs)[40] and estimation (e.g. grouping approaches)[41,42] that are capable of handling the diversity, complexity and volumes of materials (including both nano- and advanced materials), data management solutions (see details below),[43] infrastructures that foster communication (e.g. Trusted Environments) and diverse risk management requirements.

In line with the above, SweNanoSafe has been appointed by the Swedish Chemicals Agency to support the recently formed OECD Steering groups on Safe Innovation Approach and Advanced Materials (SG-SIA and SG-AdMa), which fall within the activities of the Working Party on Manufactured Nanomaterials (WPMN).[44,45] Overall, the platform aims to facilitate interaction between innovators and regulators to improve awareness of the latest advances in nano-enabled products and nanosafety aspects and issues. Thus, the platform can play a proactive role among industry, other stakeholders, policymakers, and regulators by creating awareness to minimize the time gap between appearance and approval of innovation and appropriate legislation. In addition, the platform spreads awareness and knowledge about the importance of digitalized FAIR (Findable, Accessible, Interoperable, Reusable) data on nanomaterials, required for industries to keep track of processes and also, to address regulatory needs and regulatory orientated guidelines in order to account for the special characteristics of nanomaterials and their safety.[43,46] This action supports recent calls for improving transparency on chemical and material use[47] and suggestions to make environmental footprint data requirements mandatory under REACH.[48] Worth mentioning is also the support that SweNanoSafe can provide for addressing the needs for achieving a society with the right chemicals/materials rather than more of them,[49] also known as *chemical*

simplification,[50] in order to meet the demands of a circular economy. This can be assumed to be a large challenge for nanomaterial/technology innovation which depends on continuous and increasing complexity of material functional properties.

A resilient infrastructure

SDG 9 (Industry, innovation, and infrastructure) is also clearly and significantly supported by the implementation of the SIA and SSbD concepts in the industry and infrastructure (aligned with SDG 9.5: enhance research and upgrade industrial technologies). Consumption and production systems involve several stakeholders in many industrial sectors, and thus, the platform can facilitate knowledge exchange regarding improved or innovative production technologies and moving towards more circular business models that include sharing, recycling, and reusing materials and products. SweNanoSafe has initiated a feasibility study regarding the presence of nanomaterials in the construction industry (2019) and published a first report (2021, in Swedish with abstract in English)[51], in order to better understand the prevalence of nanomaterials in the sector. In addition, the platform recently published a report presenting preliminary insight into the current experiences of various stakeholders on how Responsible Research and Innovation (RRI), i.e. SSbD and precautionary principles etc., is managed in practice.[2]

Work and economic growth incorporating nanosafety

Importantly, SDGs 12 and 9 are clearly correlated with **SDG 8** (Decent work and economic growth), which calls for sustained economic growth, while limiting environmental degradation and greatly increasing resource efficiency. This is in line with SweNanoSafe's recent report entitled "*Proposals for national measures for safe use, handling and development of nanomaterials*",[19] which outlines the platform's actions on ensuring that new regulations and new knowledge are implemented in the work environment measures, thereby enhancing workplace safety (aligned with SDG target 8.8). Even though coordinated supervisory measures do currently exist, there is potential for further development of the level of cooperation between responsible authorities and organizations regarding nanosafety, to ensure optimal use of information, methodology and documentation. Moreover, sustainable economic growth and productivity together with healthy long-term competitiveness can be reinforced through the promotion of the non-toxic circular economy concept, improved resource efficiency and sustainable technological upgrading and innovations (aligned with SDG 8.2 and SDG 8.4). This is especially important for the concept of non-toxic circular economy, which states that materials and products should be *non-toxic from the start*, and thus requires increased knowledge on the hazards of nanomaterials, together with information about where they are used and their exposure levels. Thus, calling for efficient implementation of the SIA and SSbD concepts and a clear alignment with the SweNanoSafe activities. It is clear from many ongoing discussions among stakeholders that one of the

largest challenges for the *non-toxic from the start* concept is the lack of data and information.[38] These aspects are being considered in the JRC-led developments of an SSbD framework and depend strongly on the advances in available (FAIR) nanosafety data.[43]

Climate Action by promoting sustainable nanotechnology

Overall, the above-mentioned actions by SweNanoSafe align with the implementation of **SDG 13** (Climate action) in two ways; i) by promoting sustainable consumption and production, which is one of the most efficient ways to promote better use of resources and economic development while reducing the impacts of climate change and greenhouse gas emissions (SDG 12), and ii) by improving education[39], raising awareness and ensuring safe exploitation of nanotechnology in various climate change mitigation efforts involving nanotechnology, including for example sustainable energy production and storage, lightweight materials and nanocatalysts.[52]

Towards a healthy environment

SDG	SweNanoSafe activities towards meeting SDG goal
SDG 3 Ensure healthy lives and promote well-being for all at all ages	Impact the overall aim to reduce mortality from non-communicable diseases and the number of deaths and illnesses from exposure to hazardous nanomaterials in air, water and soil pollution and contamination.
SDG 2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Advocate for safety and sustainability of nanomaterials in food and feed during food process, food packaging and labelling, as well as sustainable food production systems with the use of safe and resilient nanotechnology agricultural practices.

Reduced numbers of deaths and illnesses from exposure to hazardous nanomaterials

A prerequisite for the achievement of **SDG 3** is the availability of knowledge about the health and environmental effects of chemicals and materials, as well as exposure levels for the purpose of risk assessment. Thus, the SweNanoSafe activities support the reduction of mortality from non-communicable diseases (aligned with target 3.4) and substantial reduction in number of deaths and illnesses from exposure to hazardous nanomaterials in

air, water and soil pollution and contamination (aligned with target 3.9). Furthermore, the platform can strengthen the capacity for early warning, risk reduction and management of national and global health risks in terms of nanotechnology (aligned with target 3.9d).

In line with this goal, as previously mentioned, SweNanoSafe has recently published a report regarding the presence of nanomaterials in the construction industry (in Swedish)[51], as well as initiated feasibility studies on nanomaterials in cosmetics and food (2020) in order to support development and availability of safer products on the market. Other areas of activity at SweNanoSafe include communication about toxicity test methods for nanomaterials (including NAMs) and FAIR nanosafety data. SweNanoSafe also aims to spread and communicate knowledge and developments relating to solutions and support systems for monitoring and early warnings related to safety and sustainability of nanomaterials, such as the recently proposed Early WArning, pRioritisation and actioN (EWARN) system for advanced materials.[53]

Safety and sustainability of nanomaterials in food, feed, and agricultural practices

Nanotechnology is also applied in food and feed innovation and ongoing European activities include exploration of risk assessment development needs for innovative foods and feeds, e.g. in the One Health European Joint Programme.

In support of a healthy environment, the SweNanoSafe activities align with **SDG 2** in terms of the safety and sustainability of nanomaterials in food and feed during food process, food packaging and labelling. Through knowledge dissemination, safe and trustworthy information exchange and education[39], SweNanoSafe can contribute to the promotion of a pragmatic product-oriented RRI approach in the whole innovation chain and to balancing functionality and safety from the beginning of the manufacturing process, in line with the SIA concept. These activities also support promotion of sustainable food production systems with the use of safe and resilient nanotechnology in agricultural practices, such as nano fertilizers, nanopesticides and nanobiosensors (aligned with SDG target 2.4).

The previously mentioned pilot project (2020) on the use of nanomaterials in food and their safety, focuses on the identification of knowledge gaps regarding the food technology legislative framework, as well as providing proposals for research initiatives, with an emphasis on Swedish conditions.

From clean water to conserved marine life

SDG	SweNanoSafe activities towards meeting SDG goal
SDG 6 Ensure availability and sustainable management of water and sanitation for all	Promote and engage stakeholder in achieving clean water, sanitation and sustainable management of waste streams by compiling and communicating knowledge regarding the existence of nanomaterials in specific industrial sectors (such as building materials, textiles, cosmetics, food and packaging) and in the environment.
SDG 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Support reduced marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution by increasing knowledge regarding the content and presence of nanomaterials and nanoplastics and potential risks to health and the environment associated with nanomaterial reuse, recycling, incineration and landfill sites.

Clean water, sanitation and sustainable management of waste streams

As described in the SweNanoSafe report "*Proposals for national measures for safe use, handling and development of nanomaterials*"[19], the platform contributes to **SDG 6** to ensure clean water, sanitation and sustainable management of waste streams by compiling and communicating knowledge regarding the existence of nanomaterials in specific industrial sectors (such as building materials, textiles, cosmetics, food and packaging) and in the environment.[19,21,51] In collaboration with national authorities, companies and trade organizations, the platform can support actions such as mapping of major waste streams containing nanomaterials and contribute to the investigation of technical solutions that facilitate the safe recycling of waste containing nanomaterials, as well as prioritizing measures targeted at types of waste where large quantities of potentially harmful nanomaterials may exist.

In line with the above, SweNanoSafe recently contributed to a workshop titled "*Nanomaterials in waste – a new challenge?*" organized by the Swedish Waste Management Association and the Mistra Environmental Nanosafety Programme and aimed at increasing knowledge regarding the content and presence of nanomaterials and potential risks to health and the environment associated with nanomaterial reuse, recycling, incineration and landfill sites.[54]

Preventing or reducing marine pollution

In addition to the activities relating to waste, described above, SweNanoSafe has also initiated activities together with the Swedish Environmental Protection Agency focused on knowledge dissemination and discussion around micro- and nanoplastics in the environment and water.[55] These actions are aligned with SDG target 6.3 of improving water quality and thereby indirectly with **SDG 14** target 14.1 to prevent or reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. *Importantly, since nearly half of the targets in SDG 12 require improved management and governance of water resources and waste treatment, it is obvious that implementation of SDG 6 and SDG 14 can strongly support improved realization of SDG 12.*

A safe and sustainable key enabling technology

SDG	SweNanoSafe's Action towards meeting SDG goal
SDG 7 Ensure access to affordable, reliable, sustainable and modern energy for all	Enhance international cooperation among all stakeholders to facilitate knowledge dissemination and communication regarding clean, sustainable and safe nano-enabled energy research and technology innovation.

Clean, sustainable and safe nano-enabled energy research and technology innovation

Today, more than half of Sweden's national energy supply originates from renewable sources and the aim is to further reduce greenhouse gas emissions and become a fossil-free welfare nation.[23] Even though Sweden's performance on implementation of **SDG 7** is more than adequate, there is always room for improvement. SweNanoSafe supports the achievement of this goal indirectly by further enhancing international cooperation to facilitate knowledge dissemination and communication regarding clean, sustainable and safe nano-enabled energy research and technology innovation (see above for SDG 9), including e.g. advanced and cleaner fossil-free technology based on nanotechnology (aligned with SDG target 7.3), and investment in nano-enabled energy infrastructures (aligned with SDG target 7.2).

From strong institutions to international partnerships and equality

SDG	SweNanoSafe activities towards meeting SDG goal
SDG 16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.	Stimulate cross-sectoral and international partnerships and policy coherence by providing information about existing programmes and courses regarding nanosafety through the platform's website, contributing to knowledge transfer between various stakeholders, including academia, industry, trade organizations and governmental agencies.
SDG 17 Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.	Strengthen active collaboration with other European national nanosafety platforms and with international working groups such as the OECD and the EURL/ECVAM.
SDG 10 Reduce inequalities within and among countries	Map and prioritize needs within nanosafety to support actions towards relevant measures and efficient use of resources, thereby independently contributing to the reduction of inequalities between institutions, industries and international organizations and to the strengthening of the implementation of harmonized nanosafety regulations.

Stimulating cross-sectoral and international partnerships and policy coherence

The SDGs cannot be achieved without cross-sectoral and international partnerships and policy coherence (**SDG 16** and **17**). SweNanoSafe provides information about existing programmes and courses regarding nanosafety through the platform's website, contributing to knowledge transfer between various stakeholders, including academia, industry, trade organizations and governmental agencies. The actions are not restricted only to the transfer of quality assured information adapted to Swedish conditions and needs, but also to the establishment of a global network, promoting international dialogue, cooperation and transparent strong institutions (aligned with SDG target 17.16 and 17.17 as well as with SDG target 16.6).

Active collaboration

In line with the goals mentioned above, SweNanoSafe has initiated collaboration between other European national nanosafety platforms[56-59], which supports broader implementation of harmonized solutions and cooperations across the world towards improved safe and sustainable nanotechnology development. Moreover, the platform supports the opportunity for Swedish researchers to be present and actively participate in several international working groups, including OECD- and the EURL/ECVAM-driven working groups, in order to ensure harmonized development and availability of definitions, test methods (preferably animal-free), guidance documents, and frameworks applicable to risk assessment of nanomaterials. Access to, for example, validated test methods and data is crucial for the work of authorities, and the OECD's internationally harmonized test methods and guidelines are directly related to relevant pieces of EU chemical regulations and the Swedish environmental objective of a non-toxic environment. In addition, new frameworks for implementation of concepts such as SIA, SSbD and definition of next-generation nano- and advanced materials are needed.[11] Thus, by offering expertise in these areas, Sweden can benefit from global networks, learn about new initiatives and developments and be a pioneer in safety evaluation, policies and risk assessment. The enhancement of multi-stakeholder partnerships is one of the most crucial roles of the SweNanoSafe platform which mobilizes and shares knowledge and expertise, as well as raises awareness of the need for reliable data and information (aligned with SDG 17.18).

Mapping and prioritizing needs within nanosafety to reduce inequalities between institutions

Strong institutions and partnerships also indirectly support **SDG 10** through equal opportunities among actors within the field of nanotechnology and ensuring its safety. Nanosafety is a multidisciplinary field requiring skills and knowledge in many different areas, such as materials science, toxicology and ecotoxicology, as well as risk assessment and regulation. SweNanoSafe brings together all relevant stakeholders, offering equal support and relevant, needs-based education and training.[39] Furthermore, SweNanoSafe's efforts to map and prioritize needs within nanosafety supports actions towards relevant measures and efficient use of resources, thereby independently contributing to the reduction of inequalities between institutions, industries and international organizations and to the strengthening of the implementation of harmonized nanosafety regulations (aligned with SDG target 10.5). Worth mentioning are also the recently described benefits of the SSbD concept, which can be expected to promote a culture of shared responsibility for ethical and sustainable outcomes in the innovation process, by promoting early dialogue, as well as the prospect of a more democratized innovation process by including civil society actors in safety decisions.[60]

Safety and sustainability in innovation go hand in hand

Even though Sweden is a global leader in the area of innovative development with a strong engagement for Agenda 2030, the country still faces important challenges with regard to sustainable development.[26] SweNanoSafe sees both these conditions as driving forces in its continued work to actively contribute by providing a sound basis for both safety and sustainability of innovation within nanotechnology to proceed hand in hand, since both safeguarding human health and the environment, and developing society are part of the same challenge[37]. Importantly, the developments within the nanosafety field, including the SIA and SSbD concepts,[31,37] provide a systems approach and infrastructure to accelerate the development of new efficient and animal-free test methods for assessment of safety which can be expected to be broadly applicable beyond nanomaterials. For example, it can be foreseen that the developed methods, principles and strategies are applicable to the next generation of advanced materials (which includes nanomaterials as per the current definition[13]), but also more broadly to the required progress within the whole chemical safety field. For example, lessons learned within the nanosafety community from the challenges of lack of data and solutions to handle the overwhelming information requirements,[43] and needs for advancing yet 'simplifying' innovation (as in *chemical simplification*), will provide support. More importantly, SweNanoSafe is an example on an efficient knowledge sharing platform bringing together academia, authorities, industry, and organisations in a joint dialogue on nanosafety and sustainability. These will have a significant impact in the operationalization of European ambitions such as the Green Deal and Chemical Strategy for Sustainability.[4,5]

Overall, as outlined in this report, it is clear that SweNanoSafe can contribute in various ways to the implementation of the SDGs. Some of the SDGs are supported indirectly, whereas others are more directly linked with the platform's actions. One example of the latter is SDG 12 (Responsible consumption and production), for which Sweden still faces major challenges as assessed in the 2021 sustainable development review (as indicated by red color in Figure 2). Of particular relevance to the SweNanoSafe activities is SDG target 12.4, which states: "*By 2030, achieve an environmentally sound management of chemicals and all wastes [including materials] throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment*". Other examples of direct support by SweNanoSafe include SDGs 2 (Zero hunger), 3 (Good health), 6 (Clean water), 8 (Decent work), 9 (Innovation), 16 (Strong institutions) and 17 (Partnerships). Another target of particular relevance to SweNanoSafe is SDG 3.9, which states: "*By 2030, substantially reduce the number of illnesses from hazardous chemicals [and materials], and air, water and soil pollution and contaminations*". The strategic direction of enhancing synergies which are supported by SweNanoSafe, including education, training, knowledge transfer, guidance for research and leveraging cooperation in nanosafety, can obviously benefit Sweden in its path towards

fulfilling the SDGs. Thus, the platform can contribute significantly to a proactive *learning-by-doing* approach to the maintenance of a major society-wide action towards sustainable development and green environmental policies.

Acknowledgements

We would like to thank Lya Soeteman-Hernandez (Dutch National Institute for Public Health and the Environment, RIVM) and Urban Boije af Gennäs, Stefan Gabring and Gregory Moore (Swedish Chemicals Agency, KemI) for the extensive and insightful comments and support provided, which has improved the impact potential of this report.

References

1 SweNanoSafe. Safe and Sustainable by Design: a prerequisite for achieving a circular economy – A report from SweNanoSafe's workshop. (SweNanoSafe, 2022), https://swenanosafe.ki.se/wp-content/uploads/sites/122/2022/03/SweNanoSafe-SSbD-Workshop-Report-Nov-2021-FINAL_pdf.pdf

2 SweNanoSafe. Toward Safe and Sustainable Nanotechnology Innovation – Executive Summary. (2021), https://swenanosafe.ki.se/wp-content/uploads/sites/122/2021/12/SweNanoSafe_2021_06.pdf

3 United Nations. The 2030 Agenda for Sustainable Development. (2015), https://sdgs.un.org/sites/default/files/publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

4 European Commission. European Green Deal. (2020), https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

5 European Commission. European Chemicals Strategy for Sustainability. (2020), https://ec.europa.eu/environment/strategy/chemicals-strategy_en

6 European Commission. *A new Circular Economy Action Plan For a cleaner and more competitive Europe*, (European Commission, 2020). https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf

7 European Commission. *Green Deal: New proposals to make sustainable products the norm and boost Europe's resource independence*, 2022, https://ec.europa.eu/commission/presscorner/detail/en/ip_22_2013

8 European Parliamentary Research Service. Key enabling technologies for Europe's technological sovereignty. (Brussels, European Union, 2021), 10.2861/24482, https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2021)697184

9 European Commission. *Nanotechnology*, https://ati.ec.europa.eu/technologies/nanotechnology

10 European Food Safety Agency. *Nanotechnology*, https://www.efsa.europa.eu/en/topics/topic/nanotechnology

11 European Commission. MATERIALS 2030 MANIFESTO. Systemic Approach of Advanced Materials for Prosperity – A 2030 Perspective. (EC, 2022), https://ec.europa.eu/info/sites/default/files/research_and_innovation/research_by_area/documents/advanced-materials-2030-manifesto.pdf

12 European Commission. Commission recommendation on the definition of nanomaterial. (European Commission, Official Journal of the European Union, 2011), https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32011H0696&from=EN

13 European Commission. An overview of concepts and terms used in the European Commission`s definition of nanomaterial. (European Commission, Luxembourg, 2019), http://doi.org/10.2760/459136,

14 Mech, A. *et al.* Nano or Not Nano? A Structured Approach for Identifying Nanomaterials According to the European Commission's Definition. **16**, 2002228, https://doi.org/10.1002/smll.202002228 (2020).

15 European Chemicals Agency. *Appendix R.6-1 for nanoforms applicable to the Guidance on QSARs and Grouping of Chemicals*, (European Chemicals Agency, 2019). https://echa.europa.eu/documents/10162/23036412/appendix_r6_nanomaterials_en.pdf/71ad76f0-ab4c-fb04-acba-074cf045eaaa

16 SweNanoSafe. *Avancerade material*, 2021, https://swenanosafe.ki.se/2021/04/19/avancerade-material/

17 European Commission. *Advanced materials and chemicals. Why the EU supports this area, sustainability by design, responsible development of nanotechnologies, related documents and links.*, 2022, https://ec.europa.eu/info/research-and-innovation/research-area/industrial-research-and-innovation/key-enabling-technologies/advanced-materials-and-chemicals_en

18 EU Science Hub. *Nanotechnology*, https://ec.europa.eu/jrc/en/research-topic/nanotechnology

19 SweNanoSafe. Proposals for national measures for safe use, handling and development of nanomaterials. (2019), https://swenanosafe.ki.se/wp-content/uploads/sites/122/2020/07/SweNanoSafe_report_hindrances_and_proposals_FINAL.pdf

20 SweNanoSafe. Nanosäkerhet vid kemikaliehantering och i arbetsmiljö. (2021), https://swenanosafe.ki.se/wp-content/uploads/sites/122/2021/08/SweNanoSafe_2121_04.pdf

21 SweNanoSafe. Nanomaterials in the environment – an overview of the current state of knowledge and the knowledge gaps today. (2021), https://swenanosafe.ki.se/wp-content/uploads/sites/122/2021/12/SweNanoSafe-Report_2021.3_Nanomaterials_in_the_environment.pdf

22 United Nations. Resolution adopted by the General Assembly on 25 September 2015 (United Nations, 2015), https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf

23 Bongaarts, J. J. Sachs, G. Schmidt-Traub, C. Kroll, G. Lafortune, G. Fuller, F. Woelm The Sustainable Development Goals and COVID-19. Sustainable Development Report 2020 Cambridge University Press, 2020. 510 p. **46**, 630-631, https://doi.org/10.1111/padr.12366 (2020).

24 Swedish Chemicals Agency (KemI). Giftfritt från början. (Swedish Chemicals Agency, 2020),

https://www.kemi.se/download/18.60cca3b41708a8aecdbdad64/1587564686708/rapport-1-2020-giftfritt-fran-borjan.pdf

25 Swedish Government. Sveriges genomförande av Agenda 2030 för hållbar utveckling (2021), https://www.regeringen.se/rapporter/2021/06/2021---sveriges-genomforande-av-agenda-2030-for-hallbar-utveckling/

26 Hickel, J. The sustainable development index: Measuring the ecological efficiency of human development in the anthropocene. *Ecological Economics* **167**, 106331, https://doi.org/10.1016/j.ecolecon.2019.05.011 (2020).

27 Swedish Chemicals Agency (KemI). Fördjupad utvärdering av Giftfri miljö 2019. (Swedish Chemicals Agency (KemI), 2019), https://www.kemi.se/download/18.60cca3b41708a8aecdbc324b/1587049628882/rapport-2-19-fordjupad-utvardering-av-giftfri-miljo-2019.pdf

28 Persson, L. *et al.* Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. *Environmental Science & Technology* **56**, 1510-1521, http://doi.org/10.1021/acs.est.1c04158 (2022).

29 Soeteman-Hernandez, L. G. *et al.* Safe innovation approach: Towards an agile system for dealing with innovations. *Materials Today Communications* **20**, 100548, http://doi.org/10.1016/j.mtcomm.2019.100548 (2019).

30 van de Poel, I. & Robaey, Z. Safe-by-Design: from Safety to Responsibility. *NanoEthics* **11**, 297-306, http://doi.org/10.1007/s11569-017-0301-x (2017).

31 Organisation for Economic Cooperation and Development. Moving Towards a Safe(r) Innovation Approach (SIA) for More Sustainable Nanomaterials and Nano-enabled Products. (2020), https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono(2020)36/REV1&doclanguage=en

32 Kraegeloh, A., Suarez-Merino, B., Sluijters, T. & Micheletti, C. Implementation of Safe-by-Design for Nanomaterial Development and Safe Innovation: Why We Need a Comprehensive Approach. *Nanomaterials (Basel)* **8**, https://doi.org/10.3390/nano8040239 (2018).

33 Gulumian, M. & Cassee, F. R. Safe by design (SbD) and nanotechnology: a much-discussed topic with a prudence? *Part Fibre Toxicol* **18**, 32, http://doi.org/10.1186/s12989-021-00423-0 (2021).

34 Fadeel, B. & Kostarelos, K. Grouping all carbon nanotubes into a single substance category is scientifically unjustified. *Nature Nanotechnology* **15**, 164-164, http://doi.org/10.1038/s41565-020-0654-0 (2020).

35 European Food Safety Agency. *Titanium dioxide: E171 no longer considered safe when used as a food additive*, 2021, https://www.efsa.europa.eu/en/news/titanium-dioxide-e171-no-longer-considered-safe-when-used-food-additive

36 Packroff, R. & Marx, R. Safe and Sustainable by Design—An Interdisciplinary Challenge for Future-Proof Chemistry. **87**, e202100534, https://doi.org/10.1002/cplu.202100534 (2022).

37 Gottardo, S. *et al.* Towards safe and sustainable innovation in nanotechnology: State-of-play for smart nanomaterials. *NanoImpact* **21**, 100297, https://doi.org/10.1016/j.impact.2021.100297 (2021).

38 European Joint Research Centre. Safe and Sustainable by Design chemicals and materials: Review of safety and sustainability dimensions, aspects, methods, indicators, and tools (EC Joint Research Centre, 2022), https://publications.jrc.ec.europa.eu/repository/handle/JRC127109

39 SweNanoSafe. Nanosafey and Education – Report from workshop series with SwenanoSafe's education network and Roadmap for 2021. (2021), https://swenanosafe.ki.se/wp-content/uploads/sites/122/2021/05/SweNanoSafe-Nanosafety-and-education_2021_1.pdf

40 Nymark, P. *et al.* Toward Rigorous Materials Production: New Approach Methodologies Have Extensive Potential to Improve Current Safety Assessment Practices. *Small* **16**, 1904749, https://doi.org/10.1002/smll.201904749 (2020).

41 Mech, A. *et al.* Insights into possibilities for grouping and read-across for nanomaterials in EU chemicals legislation. *Nanotoxicology* **13**, 119-141, http://doi.org/10.1080/17435390.2018.1513092 (2019).

42 Giusti, A. *et al.* Nanomaterial grouping: Existing approaches and future recommendations. *NanoImpact* **16**, 100182, https://doi.org/10.1016/j.impact.2019.100182 (2019).

43 Jeliazkova, N. *et al.* Towards FAIR nanosafety data. *Nature Nanotechnology* **16**, 644-654, http://doi.org/10.1038/s41565-021-00911-6 (2021).

44 Organisation for Economic Cooperation and Development. *OECD Working Party on Manufacture Nanomaterials*, 2016, https://www.oecd.org/chemicalsafety/nanosafety/

45 Rasmussen, K. *et al.* Review of achievements of the OECD Working Party on Manufactured Nanomaterials' Testing and Assessment Programme. From exploratory testing to test guidelines. *Regulatory toxicology and pharmacology : RTP* **74**, 147-160, 10.1016/j.yrtph.2015.11.004 (2016).

46 Wilkinson, M. D. *et al.* The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data* **3**, 160018, http://doi.org/10.1038/sdata.2016.18 (2016).

47 ChemSec and seven companies. *Open letter to the Commission regarding transparency*, 2022, to:European Commission, https://chemsec.org/open-letter-to-the-commission-regarding-transparency/

48 European Commission. 44th Meeting of Competent Authorities for REACH and CLP (CARACAL): Open session on concerns regarding environmental footprint in REACH. (European Commission, 2022),

http://files.chemicalwatch.com/AP4_1_CA_18_2022_Environmental_footprint_REACH.pdf

49 Altinget. *Kemikalieinspektionen: Rätt kemikalier är viktigare än fler kemikalier*, 2022, https://www.altinget.se/miljo/artikel/kemikalieinspektionen-ratt-kemikalier-ar-viktigare-an-fler-kemikalier

50 Fenner, K. & Scheringer, M. The Need for Chemical Simplification As a Logical Consequence of Ever-Increasing Chemical Pollution. *Environmental Science & Technology* **55**, 14470-14472, http://doi.org/10.1021/acs.est.1c04903 (2021).

51 SweNanoSafe. Nanomaterial i byggbranschen – en kartläggning och inventering av kunskap och kunskapsbehov. (2021), https://swenanosafe.ki.se/wp-content/uploads/sites/122/2021/12/SweNanoSafe-Report_2021.5_Nanomaterial_i_byggbranschen.pdf

52 Subramanian, K. S., Karthika, V., Praghadeesh, M. & Lakshmanan, A. *Nanotechnology for Mitigation of Global Warming Impacts.* In: *Global Climate Change: Resilient and Smart Agriculture.* , Series (eds V. Venkatramanan, S. Shah, & R. Prasad) (Springer, 2020). http://doi.org/10.1007/978-981-32-9856-9_15.

53 National Institute for Public Health and the Environment. Towards Safe and Sustainable Advanced (Nano)materials: A proposal for an Early WArning, pRioritisation and actioN system (EWARN). (National Institute for Public Health and the Environment, 2022), 10.21945/brochure-advanced-materials, https://www.rivm.nl/sites/default/files/2022-02/Towards_safe_sustainable_advanced%20%28nano%29materials_EWARN_feb2022.pdf

54 Mistra Environmental Nanosafety. *Mistra Environmental Nanosafety Workshop: Nanomaterials in waste – a new challenge?*, 2021, https://swenanosafe.ki.se/2020/10/06/nanomaterials-in-waste-a-new-challenge/

55 SweNanoSafe. *SweNanoSafe Workshop: Utsläpp av mikroplaster – åtgärder för att minska miljöpåverkan*, 2022, https://swenanosafe.ki.se/2021/12/03/workshop-utslapp-av-mikroplaster-atgarder-for-att-minska-miljopaverkan/

56 Data and knowledge on Nanomaterials. *DaNa 2.0 - Data and knowledge on Nanomaterials - Processing of socially relevant scientific facts*, https://nanopartikel.info/en/links/

57 BioNanoNet. *BioNanoNet Association*, https://www.bnn.at/about/

58 Dutch Ministry of Infrastructure and Water Management and RIVM. *Dutch website gathering information about Safe-by-Design* https://safe-by-design-nl.nl/home+english/default.aspx

59 SweNanoSafe. *SweNanoSafe Workshop: Workshop on European, national nanosafety initiatives in collaboration* 2020, https://swenanosafe.ki.se/meeting-for-european-nanosafety-initiatives/

60 Brennan, M. E. & Valsami-Jones, E. Safe by Design for Nanomaterials—Late Lessons from Early Warnings for Sustainable Innovation. *NanoEthics* **15**, 99-103, http://doi.org/10.1007/s11569-021-00393-9 (2021).

Useful links and sources of information

Non-toxic from the start	
Swedish Chemicals Agency on non-toxic from the start	https://www.kemi.se/en/about-the-swedish-chemicals-agency/our-task/government-assignments/non-toxic-from-the-start https://www.altinget.se/miljo/artikel/kemikalieinspektionen-ratt-kemikalier-ar-viktigare-an-fler-kemikalier
Planetary boundaries	https://www.stockholmresilience.org/research/research-news/2015-01-15-planetary-boundaries---an-update.html https://chemsec.org/the-planet-cant-handle-any-more-toxic-chemicals/

The EU holistic approach to sustainable development	
EU holistic approach	https://ec.europa.eu/info/strategy/international-strategies/sustainable-development-goals/eu-holistic-approach-sustainable-development
Sustainable Development Indicators	https://ec.europa.eu/eurostat/web/sdi/overview
Sustainable Products Initiative	https://ec.europa.eu/commission/presscorner/detail/en/ip_22_2013 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0140&qid=1649112555090 https://www.endseurope.com/article/1751356/in-depth-need-know-sustainable-products-initiative?bulletin=bulletin%2Fendseuropedaily&email_hash=
SSbD to boost innovation and growth (webinar)	https://ebcd.org/events/online-event-safe-and-sustainable-by-design-a-key-tool-to-boost-innovation-and-growth/

EU JRC developments and proposal for a SSbD framework	
Stakeholder workshops	https://ec.europa.eu/environment/events/safe-and-sustainable-design-criteria-chemicals-materials-and-products-first-stakeholders-workshop-2021-03-19_en https://ec.europa.eu/environment/events/second-stakeholders-workshop-safe-and-sustainable-design-criteria-chemicals-and-materials-2022-03-22_en

	Recording available here: https://www.youtube.com/watch?v=Vz1rGpI7jIU
Review of safety and sustainability dimensions, aspects, methods, indicators, and tools	https://publications.jrc.ec.europa.eu/repository/handle/JRC127109

Definition of nanomaterials and advanced materials

Advanced materials	https://ec.europa.eu/info/research-and-innovation/research-area/industrial-research-and-innovation/key-enabling-technologies/advanced-materials-and-chemicals_en https://www.umweltbundesamt.de/publikationen/risk-governance-of-advanced-materials https://swenanosafe.ki.se/2021/09/01/temakonferenser-om-avancerade-material-bedomning-av-regleringsbehov-avseende-atgarder-inom-kemikaliesakerhet/ https://swenanosafe.ki.se/2021/04/19/avancerade-material/
Nanomaterials	https://ec.europa.eu/environment/chemicals/nanotech/faq/definition_en.htm https://zerowasteeurope.eu/library/open-letter-civil-society-concerns-and-demands-regarding-the-ec-nanomaterial-definition/

Data and transparency demands

Environmental footprint data in REACH	https://ec.europa.eu/environment/news/environmental-footprint-methods-2021-12-16_en http://files.chemicalwatch.com/AP4_1_CA_18_2022_Environmental_footprint_REACH.pdf
Industry organizations demand transparency	https://chemsec.org/chemsec-and-seven-companies-we-want-to-know-which-chemicals-are-used-in-the-supply-chain/

Early warning systems

Early WArning, pRioritisation and actioN system (EWARN)	https://www.rivm.nl/sites/default/files/2022-02/Towards_safe_sustainable_advanced%20%28nano%29materials_EWARN_feb2022.pdf

Infrastructures and platforms in support of SSbD

E-infrastructure for SSbD	https://www.h2020sunshine.eu/events/sunshine-e-infrastructure-for-safe-and-sustainable-by-design-of-advanced-multicomponent-nanomaterials https://drive.google.com/file/d/15n24MFoG4JpkfPbndRyTwptlEsTDOvoj/view