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Integrating "Green Chemistry" into the Regulatory Framework of European Chemicals Policy

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with support from
Rebecca Niebler

Darmstadt, 25.07.2019

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Study on behalf of the
Austrian Federal Ministry for Sustainability and Tourism

Sonderforschungsgruppe
interdisziplinäre Institutionenanalyse e.V. (sofia)
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Abbreviations and Glossary

The study uses the following terms and abbreviations. As long as not indicated otherwise the text refers also to the definitions of the regulatory frameworks discussed in the respective sections.

10YFP	United Nations 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns
AfA	Applications for Authorisation (under REACH)
BAT	Best available techniques (under IE- and Seveso-Directive)
BREF	Best available techniques Reference document (under the → IED)
CEN	Comité Européen de Normalisation
CENELEC	European Committee for Electrotechnical Standardization
Chemical(s)	The term is used in the sense of "industrial chemical substances" being produced and/or used in industrial processes (the scope is thus narrower compared to the definition of "substance" pursuant to Art. 3(1) REACH). Depending on the context the term often refers to → "problematic" chemical substances thus indicating "problematic properties")
CJEU	European Court of Justice
CLH	Harmonised Classification and Labelling of Substances
EAP	Environmental Action Programme (of the EU)
ED	Ecodesign Directive (2009/125/EC)
EEB	European Environmental Bureau, Brussels
EGC	European General Court (of first instance)
ELR	Ecolabel Regulation (66/2010)
FMD	Full Material Declaration
GC	Green Chemistry or Greener Chemistry, while the latter reflects that reaching for a specific substance, product or process a final and definite state of "Green" Chemistry is utterly impossible as Green Chemistry by definition aims at continuous improvement processes integrated in the (re-) design of chemical substances.
GCP(s)	Green Chemistry Principle(s)
GHS	Globally Harmonised System (for Classification and Labelling of Substances)
GPSD	General Product Safety Directive
IC&C	Information, Communication and Cooperation (obligations under REACH along the supply chain)

IED	Industrial Emissions Directive 2010/75/EU
IPP	Integrated Product Policy (on EU level)
IPPC	Integrated Pollution Prevention and Control
JRC	Joint Research Center, European Commission
LP(s)	Learning Process(es)
LPP	Learning Process Principles
MEErP	Methodology for ecodesign of energy-related products (in the context of the → ED)
MSCA	Member State Competent Authority (for REACH)
NTE	Non-toxic environment (initiative on EU level)
PPORD	Process orientated research and development
PRTR	(European) Pollutant Release and Transfer Register
Problematic substance	means a chemical substance with intrinsic properties that cause or may cause damage to human health and/or the environment. Substances that meet the SVHC criteria of REACH Article 57 fall under the term as well as (other) substances classified as "hazardous" according to the CLP Regulation.
Product	Articles and mixtures according to REACH. The term includes services offered in combination with the use of products. It does not cover (chemical) substances as such (as defined in Art. 3 (1) REACH).
R&D	Research and Development
SAICM	Strategic Approach on International Chemicals Management
SiA	Substances in articles (according to REACH)
SVHC	Substance of Very High Concern (as de-fined in Art. 57 REACH)
TFEU	Treaty on the Functioning of the European Union

Preface

The authors would like to express their gratitude to all persons that contributed to the discussion process that led to the final version of the study. The team of the unit "chemicals policy and biocides" of the Austrian Federal Ministry for Sustainability and Tourisms, in particular Ing. Eva-Maria Reiss and Mag. Dr. Martin Wimmer, provided most valuable input and feedback to the previous version of the study.

The members of the Austrian stakeholder platform on REACH commented on a previous version during a meeting in Vienna in July 19, 2018. The findings of the study were presented at the "International Conference on Green Chemistry" in the course of the Austrian EU presidency in November 5 and 6, 2018, in Vienna (the conclusions of the organizers can be found under www.elni.org). The deliberations at the conference triggered enhancements of the argumentation in the study.

Further input to section 4.2 dealing with the regulative framework for industrial installations has been provided from the team dealing with the BREF process in the "European IPPC Bureau" of the JRC site in Seville and by the "Industry Working Group" of the EEB.

The study was completed in January 2019.

All conclusions drawn and all remaining errors are solely those of the authors.

With this publication the authors aim at contributing to the debate to further align the regulatory framework on European level with the objectives laid down in the treaties establishing the European Union as well as to the transposition of the Sustainable Development Goals, adopted by the General Assembly of the United Nations into binding legislation and implementation by industrial practices and consumer behaviour all over Europe.

Darmstadt, July 2019

Martin Führ *Julian Schenten* *Silke Kleihauer* *Rebecca Niebler*

1
Executive summary

20 years ago a concept of "Green Chemistry" was formulated by Paul Anastas and John Warner, aiming at an ambitious agenda to "green" chemical products and processes. Today the concept, laid down in a set of 12 principles, has found support in various arenas. This diffusion was supported by enhancements of the legislative framework; not only in the European Union. Nevertheless industry actors – whilst generally supporting the idea – still see "cost and perception remain barriers to green chemistry uptake".[1] Thus, the questions arise how additional incentives as well as measures to address the barriers and impediments can be provided.

An analysis addressing these questions has to take into account the institutional context for the relevant actors involved in the issue. And it has to reflect the problem perception of the different stakeholders. Remarkably a broad set of actors has expressed the willingness to change their attitude in the course of the year 2018: a product sustainability and regulatory compliance manager with Google under the title "Innovation in safer chemistry and product design is critical for the circular economy"[2] announced that Google has "embraced its principles of a circular economy. These are

- to design out the concept of waste;
- to rebuild natural capital; and
- to keep products, materials and molecules flowing effectively through the economy at their highest value."

At the same time consumer organisations ask for "full material disclosure" for consumer goods,[3] meanwhile a cross-sectoral initiative consisting of producers, downstream users, brands and retailers are joining their forces in a "Proactive Alliance" in order to establish a "global inter-sector standard for communication on Substances in Articles" supporting the "full material declaration" approach.[4]

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1 Patrick Harmon, BASF's industry manager in North America; , cf. https://chemicalwatch.com/66349/basf-cost-and-perception-remain-barriers-to-green-chemistry-uptake (31.10.2019); see also corresponding findings from a public consultation performed in the REFIT of chemicals legislation (excluding REACH) context, Postle et al. 2017, 55.

2 Mike Werner, Guest column to the Chemical Watch Briefing issue 109 (July 2018), 27-28.

3 Claus Jörgensen, Danish Consumer Council, Chemical Watch Briefing issue 109 (July 2018), 26.

4 CW, 14 June 2018: "Cross-sector initiative sets full materials disclosure goal - Could be key turning point for supply chain data exchange on chemicals; cf. https://chemicalwatch.com/67695/cross-sector-initiative-sets-full-mater (31.10.2019)

Against this background the supply chain into which the chemicals are distributed are of pivotal importance since they create the demand pull for chemicals designed in accordance with the "Green Chemistry Principles". Consequently, the scope of this study includes all stages in a chemical´s life-cycle, including the process of designing and producing the final products to which chemical substances contribute. For each stage the most relevant legislative acts, together establishing the regulatory framework of the "chemicals policy" in the EU are analysed.

The study acknowledges that reaching for a specific substance, product or process a final and definite state of "Green" Chemistry is utterly impossible as Green Chemistry by definition aims at continuous improvement processes integrated in the (re-) design of chemical substances. To reflect this, the report also uses the expression "Green(er) Chemistry". Besides, in order to foster the learning curve towards greener chemicals solutions in addition a procedural context is needed stipulating information, communication and cooperation mechanisms for all actors involved in the process. Mindful of these assumptions the study addresses two core questions:

1. To what extent are the existing EU policies relevant for chemicals already reflecting the elements of the Green(er) Chemistry concept?
2. How can EU policies relevant for chemicals put more emphasize on this concept, taking into account

   - the product context of the Green Chemistry Principles (GCP) as well as

   - the institutional framework fostering learning processes of the actors involved in the innovation process?

The "Green Chemistry Principles" (GCPs) serve thus as one yardstick for the analysis. Another set of "Learning Process Principles" (LPP) provides additional **assessment criteria** for the regulatory framework. Shortcomings in the framework with respect to the GCP and the LPP criteria are indicated as a "delta".

Following the introduction in chapter 2 the normative context of "Green(er) Chemistry" is summarized in chapter 3, from which assessment criteria are derived (section 3.4 with Table 1 and Table 2). The regulatory framework governing the various stages in the life cycle of a chemical substance is analysed in chapter 4; the results of the delta-analysis are summarized in tabular form in section 4.6.

Chapter 5 describes policy options addressing the identified delta. In addition to regulatory options on EU-level proposals are made to be implemented on a meso-level, e.g. by sectoral supply chain associations. Finally other institutional options supporting learning processes are presented.

Chapter 6 gives an overview on the set of policy options presented in this study.

In a nutshell the main elements of the study can be summarized as follows: Green Chemistry (GC) is the utilisation of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products. Besides, reaction efficiency, including energy efficiency, and the use of renewable resources are other motives of Green Chemistry. Putting the GC concept in a broader market context, however, it can only prevail if in the perception of the relevant actors it is linked to tangible business cases. Therefore, the study analyses the product context in which chemistry is to be applied, as well as the substance's entire life-cycle – in other words, the **six stages in product innovation processes** (cf. section 2.2):

1. Substance design,
2. Production process,
3. Interaction in the supply chain,
4. Product design,
5. Use phase and
6. After use phase of the product (towards a "circular economy").

Figure 1 illustrates the interplay of the six stages in the Green Chemistry innovation driving system.

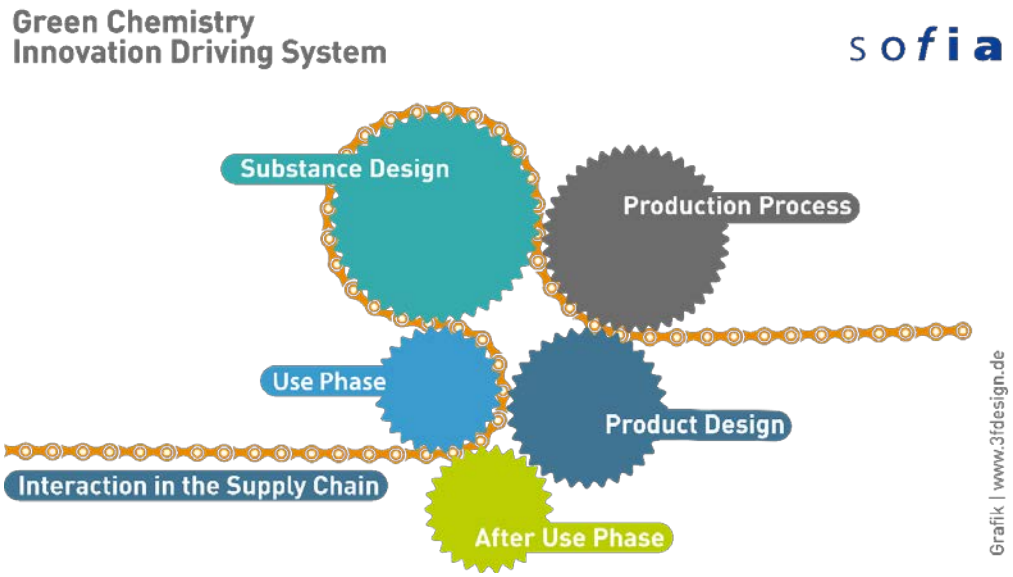

Figure 1: Green Chemistry Innovation Driving System

The report presents an overview to what extent the existing framework, i.e. legislation and the wider institutional context along the six stages, is setting incentives for actors to adequately address problematic substances and their potential impacts, including the learning processes intended to invoke creativity of various actors to solve challenges posed by these substances (cf. chapter 4). In this respect, measured against the GC and Learning Process assessment criteria, the study identified shortcomings ("delta") at each stage of product innovation (cf. section 4.6). Some criteria are covered by the regulatory framework and to a relevant extent implemented by the actors. With respect to those criteria, there is thus no priority need for further action. Other criteria are only to a certain degree covered by the regulatory framework, due to various and often interlinked reasons. For those criteria, entry points for options to strengthen or further nuance coverage of the respective principle already exist.

Most relevant are the deltas with regard to those instruments that influence the design phase; both for the chemical substance as such and for the end-product containing the substance. Due to the multi-tier supply chains, provisions fostering information, communication and cooperation of the various actors are crucial to underpin the learning processes towards the GCP.

The policy options introduced in chapter 5 aim to tackle these shortcomings in the context of the respective stage in order to support those actors who are willing to change their attitude and their business decisions towards GC. The findings are in general coherence with the strategies to foster GC identified by the Green Chemistry & Commerce Council. The following policy options comprise of EU regulatory options (macro level) as well as institutional options on the meso-level:

- Stage 1 substance design: Policy instrument: REACH Regulation
  Addressing delta: "safer design" (GCP 4), "design for degradation" (GCP 10) and "inclusive governance" (LLP 5)
  - Adaptation of REACH by introducing new Articles 14 (6a) and 37 (5a) to implement the basic obligation of "safer design" (GCP 4) and "design for degradation" (GCP 10) (find more details in section 5.1.1.1)
  - Improvement of the procedure to handle applications for authorisations (AfA) (Art. 64 REACH) by supporting third parties in AfA to provide relevant information on alternatives (section 5.1.1.2)
  - Creation of a mechanism in the AfA procedure to take into account PPORD substances in AfA alternatives assessment (Art. 64 REACH) (section 5.1.1.3)

  - Consider of a new chapter in REACH Title II implementing the REACH principle of substance responsibility in the PPORD context (section 5.1.1.3)
  - Establish a digital dashboard to address the science-policy-gap ("WikiREACH") in order to foster data quality (section 5.1.1.1)
- **Stage 2 production process:** Industrial Emission Directive (IED) Addressing delta: "prevent waste" (GCP 1), "resources efficiency" (GCP 2) "safer chemical synthesis" (GCP 3) and "increase energy efficiency" (GCP 6)
  - Explore the possibilities to enhance scope and accuracy of the BREF/BAT documents in the context of the JRC Sevilla process under the IED, regarding the above named GCP (section 5.1.2); in particular with respect to the use of less hazardous substances, resource efficiency and waste prevention
- **Stage 2 production process:** Industrial Emission Directive (IED) Addressing delta: "inclusion of GCP in research strategies and activities" (LPP 3)
  - Utilisation of the information exchange platform for the enhancement of BAT under the IED (operated by the European IPPC Bureau, JRC Sevilla) to provide specific "incentives for the inclusion of GCP in research strategies and activities" (LPP 3) (section 5.1.2)
- **Stage 2 production process:** Industrial Emission Directive (IED) Addressing delta with regard to the input streams: "prevent waste" (GCP 1) and indirectly "maximize atom economy" (GCP 2) and "use renewable feedstocks" (GCP 7)
  - Enhance the scope of the basic obligations in terms of use of renewable feedstock as well as the explicit obligation of the applicant to demonstrate that the "use of less hazardous substances" has been considered with the view of eliminating substances of concern in order to "rectify at source" the related emissions, both from the plant itself but also in later stages of the life cycle of the products that leave the plant
  - Introduction of taxes on raw materials on the IED governed input streams based on Council Consensus or national legislation (section 5.1.2)
- **Stage 3 Interaction in the supply chain:** REACH Regulation context. Addressing delta: "communicate on substances along the supply chain" (LPP 2)
  - Implementation of a full material declaration reporting in article supply chains as a meso-level approach based on a stakeholder driven

process and public support to improve the communication of information (section 5.2.1)

- Stage 3 Interaction in the supply chain: Sectoral product legislation. Addressing delta: "communicate on substances along the supply chain" (LPP 2)
  - Formulation of explicit Information, Communication & Cooperation (IC&C) requirements in sectoral product legislation to enable informed decision-making, centralized information collection and publication of information on substances in articles (alternatively implemented via "Horizontal policy approach on substances in articles"; see below) (section 5.1.3.3)
- Stage 4 Product design: Ecodesign Directive (ED)
  Addressing delta: "provide transparency on the chemical, its properties and use as well as the (possible) impacts on human health and environment" (LPP 1)
  - Modification of informal procedures and expert groups to better integrate problematic substances into ED implementation (section 5.1.3.1)
  - Adaption of ED to expand the directive's scope to not energy-related products (section 5.1.3.1)
- Stage 4 Product design: REACH Regulation
  Addressing delta: "provide transparency on the chemical etc." (LPP 1) and "communicate on substances along the supply chain" (LPP 2)
  - Specification of the information requirement on the use of substances in articles in REACH Annex VI Section 3 and Annex I Sections (e.g. 0.7, 0.8 and 5) to increase the informative value of the exposure scenarios in the registration dossiers (section 5.1.3.2)
  - Expansion of the consumer "right to know" regarding SVHC by adapting the REACH Art. 33(2) to make answers to the consumer in any case obligatory and reduce the time frame to respond (section 5.1.3.2)

- Cross-cutting issues
  - Horizontal policy approach on substances in articles addressing all actors along the product life-cycle; integrated, e.g., in the COM impact assessment in order to increase coherence (section 5.1.4)
  - Establishing a comprehensive Platform: Product design for Green Chemistry as all-embracing knowledge hub connecting all actors along the product life-cycle (section 5.2.2)
  - Additional institutional options (meso-level and beyond)

Green Chemistry is focussing on environmental impacts linked to the production of chemicals. In essence, Green Chemistry stands for a "benign by design" approach, aiming at hazard reduction and sustainable resource use in the chemical synthesis. Since chemicals are produced for specific needs and intended functions the incentives towards a "Greener Chemistry" are to a large extent provided by the design of the end-product and the culture of co-operation in the respective supply chain. This "bigger picture" offers a variety of options to enhance the innovation process towards the Green Chemistry Principles.

In the context of the "Non-toxic Environment"-Strategy - or its successors - and the efforts towards a "Circular Economy" the actors on EU Level are invited to consider the proposals developed in this study to enhance the institutional framework.

Looking at the status quo of the EU framework the legal provisions addressing the production process have reached a comprehensive level and are consolidated in the Industrial Emission Directive and its by-laws. With regard to emissions to water and air substantial progress has been reached in the last thirty years. The main area of improvement potential towards the GCP is to be identified in the product design and the related supply chain interaction triggering innovation processes towards GCP. Here a fairly fragmented patchwork of legal provisions is to be observed. A comprehensive "Product Framework Package" merging the different pieces of legislation and filling the existing gaps (as proposed above) should be considered.

In this context not only requirements formulated in public law – as analyzed in this study – should be considered: In order to promote innovation processes also the legal context in private law, such as stepwise prolonged warranty for a product and its performance, should be taken into account.

2
Introduction

This report discusses options how to further align EU policies relevant for the manufacturing and use of chemical substances with the concept of "Green Chemistry" (GC) and thus contributing to the United Nations Sustainable Development Goals (SDG´s, see section 2.1). Green Chemistry is focussing on environmental impacts linked to the production of chemicals. In essence, Green Chemistry stands for a "benign by design" approach, aiming at hazard reduction and sustainable resource use in the chemical synthesis (section 2.2).

The core questions of the study are presented in section 2.3 leading to a brief description of the analytical framework applied and the structure of the report (section 2.4).

2.1
Motivation and normative context

The Austrian Federal Ministry for Sustainability and Tourism commissioned the present study in the context of the second "REACH Review" by the European Commission (as foreseen in Art. 117(2) REACH). By mid-2018, the last deadline for the registration of chemicals by companies was arrived. Thus a huge number of chemical substances have been registered by companies under the REACH Regulation.[5] Depending on the tonnage band the registration dossier covers information on the properties of the substance and – above a market volume of 10 tonnes per year – also a chemical safety assessment. In cases where "problematic" properties are identified (Art. 14(4) REACH) exposure scenarios offer additional data in order to demonstrate measures "to adequately control the risks identified" (Art. 14(6) REACH) covering the entire life-cycle of the respective chemical. The regulative approach of REACH thus addresses substances, mixtures of substances and articles containing substances, i.e. also products generated at a later stage of the supply chain as well as the use phase and the subsequent fate of the substance under the water or waste management regimes.

In practice, however, the use descriptions presented in the registration dossiers are in most cases very broad and unspecific. Hence, the exposure scenarios rarely provide enlightening and reliable insight in the actual fate of a substance in its life-cycle. On the other hand, the resource input and the waste generated in the production process of the substance as such are not covered at all by the scope of REACH.

[5] As of September 14th 2018 the ECHA databases lists registration dossiers 21.343 on chemical substances. For up to date details see https://echa.europa.eu/de/regulations/reach/registration/registration-statistics.

Against this background the assumption is plausible that chemical innovation is to a large extent driven by technical feasibility and economic viability (push factors),[6] rather than by specific functional needs (pull) defined by the customers. Thus, the environmental impacts of the use and after use phases are often not in the scope of the innovation process. In addition to these limitations in the innovation activities, the society has to cope with the huge environmental legacy associated with the existing chemical portfolio as the "chemical industry releases more hazardous waste to the environment than any other industry sector".[7] However, the most relevant emission to the environment is caused by the products transported through the gates of chemical factories (and not their direct waste):[8] Of the over 100,000 chemicals estimated to be on the EU market today – estimated 35,000 chemicals of which in volumes above 1 tonne per year – over 60% by tonnage are considered hazardous to human health and/or to the environment.[9]

The question how to align the EU policies with the Green Chemistry concept thus has to be put in a broader perspective, taking into account that chemical products are linked to an estimated 90% of all globally manufactured goods.[10] Consequently, the international normative context as formulated in the UN Sustainable Development Goals (SDGs), in particular SDG 12 and 12.4 is tackling the issue in a more holistic way (see section 3.1). The same is true for the EU primary law, aiming at "a high level of protection and improvement of the quality of the environment" (Art. 3 (3) 2 TFEU). This normative objective not only is valid for the Union policy on the environment (Art. 191 TFEU) but also for the approximation of laws establishing the internal market (Art. 114 (3) TFEU). Moreover, as stipulated in Article 11 TFEU "Environmental protection requirements must be integrated into the definition and implementation of the Union policies and activities, in particular with a view to promoting sustainable development." These normative requirements are reflected, i.a., by the 7th EAP and consecutively in the recent policy initiatives addressing the environmental impact of chemicals (see section 3.2).

6 See also Warner et al. 2004, 780.

7 Warner et al. 2004.

8 As stated by manager from BASF in the 1990´s; see Führ 2000, 7.

9 Milieu Ltd et al. 2017, 11, 23.

10 GC3 2015, 6 with further references.

2.2
Green Chemistry definition and its market context

There is no globally consented or formalised definition for Green Chemistry. Yet Green Chemistry is usually linked[11] to a concept developed by Paul Anastas and John Warner. According to this concept

> "Green chemistry is the utilisation of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products."[12]

Besides, reaction efficiency, including energy efficiency and the use of renewable resources are another motive of Green Chemistry. In a nutshell, Green Chemistry is about pollution prevention."[13] Based on this definition, Anastas and Warner formulated 12 Green Chemistry Principles (GCP). Figure 2 shows how these principles refer to five main categories reaction efficiency and, reaction safety and control, low toxicity substance design, renewable resources and waste prevention.[14] Ultimately all principles and categories contribute to the reduction of negative impacts on men and environment, i.e. by reducing the exposure of men and environment towards problematic substances.

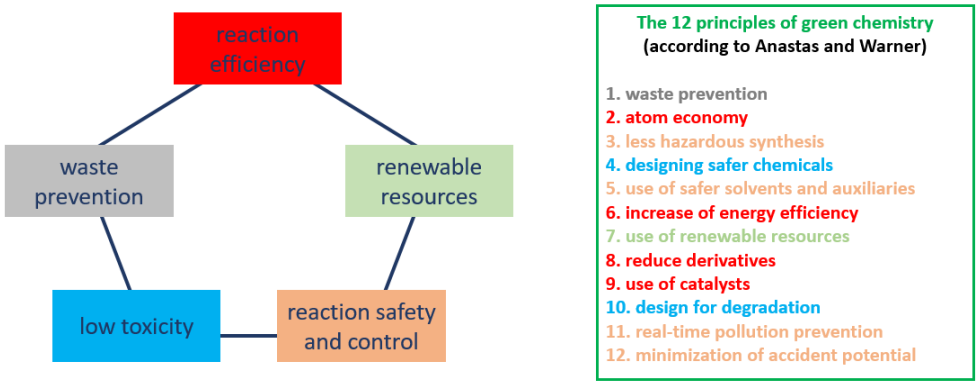

Figure 2: Green Chemistry Principles, clustered in five main categories (source Wimmer et al. 2018)

With a view to REACH, GCP 4, in particular, is paramount, calling to "design safer chemicals", i.e. "to preserve efficacy of the function while reducing toxicity". In conjunction with GCP 10 one can conclude that safer chemicals are designed for degradation. In addition, substance design has to ensure that,

11 Blum et al. 2017. See also Steinhäuser in Jakl/Wimmer/Markt (Eds.) 2011, 124 et subs.

12 Anastas and Warner 1998, 11.

13 Anastas and Warner 1998, 9.

14 Annex I provides short explanations on each principle.

generally, "toxicity and hazard is reduced to the lowest possible level".[15] In this respect, substance properties addressed by the GHS endpoints on physical, health or environmental hazards can provide guidance, complemented by environmental criteria on persistence and bioaccumulation as established, for instance, by REACH. Furthermore, problematic properties, which are not or not entirely covered by the existing frameworks, such as endocrine disrupters, neurotoxins, immunotoxins, and developmental toxins,[16] must also be considered. This follows already from the dynamic nature of Green Chemistry, according to which the criteria for problematic substances need to be adapted according to the current state of science. To the extent legal provisions reflect the GCPs, this may imply the need for manufacturers to go "beyond compliance" insofar as the legal requirements stay behind current developments of Green Chemistry.

The definition of Green Chemistry implies that the concept aims at preventing rather than managing risk.[17] To this end, hazard prevention in the sense of "low toxicity"[18] is the key element linked with controlled conditions to ensure reaction safety. The production process should be efficient in terms of energy and unintended by-products, using renewable raw material and (thus) avoiding the generation of waste. Addressing exclusively the design and synthesis of substances, including the "application" of substances to this end, the scope of the concept, however, is rather narrow. To this extent, Green Chemistry is also an integrated part of Sustainable Chemistry[19] (for the international context of this debate see section 3.1).

Putting the Green Chemistry concept theorized by Anastas and Warner in a broader market context, however, it can only prevail if in the perception of the relevant actors it is linked to tangible business cases. Therefore, the analysis has to include the product context in which chemistry is to be applied, as well as the substance's entire life-cycle, from design to manufacture, use, and end of life. In fact, taking into account the role of problematic substances already in product design would yield benefits not only in terms of human health and the environment, but also in terms of reducing companies' compliance costs and costs of public risk administration.[20] In the words of the Green Chemistry & Commerce Council (GC3), Green Chemistry "incorporates every element of business, from product design to feedstock selection through

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15 Anastas and Warner 1998, 36. See also Lahl/Zeschmar-Lahl 2011.

16 Milieu Ltd et al. 2017, 94.

17 Anastas and Warner 1998, 16.

18 See also the definition used by the US EPA under https://www.epa.gov/greenchemistry/basics-green-chemistry#twelve (12.9.2018).

19 Blum et al. 2017.

20 Postle et al. 2017, 84.

manufacturing to finished products, including the ways that companies manage their businesses and engage their customers throughout the supply chain."[21]

The following stages in the innovation process of products can be distinguished, each of which involving different actors and framework conditions (see chapter 4):

1. Substance design: This is the key feature within the Green Chemistry concept.
2. Production processes: The conditions under which chemicals, mixtures and articles are produced are highly relevant in terms of the Green Chemistry goals to reduce hazards and resource input. From a product perspective, different options to produce certain components have to be considered in a comparative perspective with the Green Chemistry criteria.
3. Supply chain interaction: Until the final product is for sale many actors in the product specific supply chains have to play their specific role. In order to allow a tailor fit substance design information on the desired performance features are to be communicated upstream while data on chemicals in products and processes must be submitted downstream.
4. Product design: Chemical substances are designed for use in production processes, i.e. to achieve certain functions with the overarching aim to finally support the performance of a (final) product, ranging from e.g. the surface feel to technical features. Therefore, product design is the primary driver for decisions on the use of chemicals. In fact, more than 80% of a product's environmental impacts are determined by its design.[22]
5. Use phase: The substance related environmental impacts of products are also determined by the use phase, e.g. the intended and unintended release of chemicals and the subsequent exposure of humans and the environment..
6. After use phase: The collection and recycling processes are also relevant, e.g. with regard to the obtained "secondary raw material" and its sometimes problematic composition.

Figure 1 (see page 13) illustrates the interplay of the six stages in the Green Chemistry innovation driving system.

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[21] GC3 2015, 6.

[22] SWD(2018) 20 fin [circular economy package: options to address the interface between chemical, product and waste legislation], 6 with further references.

In order to foster Green Chemistry it is not possible to establish the one "master plan" transforming the wide range of chemical processes towards the 12 Principles. Since Green Chemistry isn't a simple checklist of activities or outcomes, it can be challenging to measure what products or processes qualify as green chemistry.[23] Rather, a learning process of all actors involved has to be initiated with the aim to mobilize the creative capacities that can contribute to the necessary innovation steps towards a "greener" chemistry (GC). Hence, the study acknowledges that reaching for a specific substance, product or process a final and definite state of "Green" Chemistry is utterly impossible as Green Chemistry by definition aims at continuous improvement processes integrated in the (re-) design of chemical substances. To reflect this, the report also uses the expression "Green(er) Chemistry".

In order to contribute to the objectives of Green Chemistry, the GCPs are to be put into the "bigger picture" context of decision making processes during the six stages of the innovation process. This leads to the insight, that trade-offs have to be considered and decided upon when the GCPs are applied.

2.3
Main research questions

In the light of the foregoing considerations, the study focusses on two core research questions:

- To what extent are the existing EU policies relevant for chemicals already reflecting the elements of the Green(er) Chemistry concept?
- How can EU policies relevant for chemicals put more emphasize on this concept, taking into account
- the product context of the Green Chemistry Principles (GCPs) as well as
- the institutional framework fostering learning processes of the actors involved in the innovation process ?

2.4
Analytical approach and structure of the report

In order to develop policy recommendations the analysis of the existing legal framework is based on assessment criteria, taking into account international and EU law requirements (target state) with regard to the innovation process towards greener chemistry.

The study was commissioned in the context of the second "REACH Review" by the European Commission (as foreseen in Art. 117 (2) REACH) and the

[23] GC3 2015, 14.

parallel REFIT exercise.[24] Thus the main focus lies with the contribution of the REACH mechanisms to the GCP (see chapter 4.1). But also other pieces of relevant EU legislation are to be included in the scope of the analysis (see chapters 4.2 et subs.).

The set of criteria defined further in section 3.4 subsequently allows assessing in how far the existing framework(s) already reflect aspects of GC (actual state). To this end, the six stages in product innovation processes are considered:

1. Substance design,
2. Production process,
3. Interaction in the supply chain,
4. Product design,
5. Use phase and
6. After use phase of the product (towards a "circular economy").

The six stages of innovation towards greener chemistry provide the structure for chapter 4. Shortcomings with respect to the GCP are described as "delta" and summarized in tabular form within the conclusions to each stage (see sections 4.1.10, 4.2.5, 4.3.6, 4.4.6, 4.5.5.). Section 4.6 merges the different tables with the findings of the delta-analysis.

For the gaps identified by this analysis chapter 5 outlines policy options; both for the legislative framework (section 5.1) and other institutional arrangements (section 5.2) supplemented by institutional options supporting learning processes (section 5.3).

The overall conclusions with the policy options are summarized in chapter 6.

[24] For details and the related studies cf. http://ec.europa.eu/growth/sectors/chemicals/reach/review_en.

3
The normative context of Green(er) Chemistry

The European policy approach is strongly influenced by the developments on the international level (e.g. UNCED process with Rio 1992, Johannesburg 2002 and the adoption of the SDG´s in 2015; see section 3.1). These international debates are already partially reflected in the European legislative framework, and they play a prominent role in the ongoing policy proposals in the context of "circular economy" and "non-toxic environment" (see section 3.2).

3.1
International normative context

The Rio Declaration[25] provides the normative backbone of international policies aimed at sustainable development.[26] With regards to Green Chemistry, in particular, Rio Principle 15 concerning the "precautionary approach" gains momentum.[27] Thereafter protective measures to prevent serious or irreversible damage can be taken without full scientific certainty about the possible extent of damage, e.g. in cases where the actual hazards of a chemical substance or the conditions of its exposure are not yet fully known.[28] Besides, Rio Principle 10 and the more specific UNECE Aarhus Convention[29] throw a spotlight on transparency and participation in environmental matters. This does not only include a "right to know" for the general public regarding chemical risks it might be exposed to,[30] but also paves the way for learning processes based on inclusive governance in order to fully exploit available knowledge resources for sustainable development.[31]

With respect to Green Chemistry, the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns (10YFP)[32] and its integra-

[25] United Nations Rio Declaration on Environment and Development (13 June 1992), 31 ILM 874 (1992).

[26] Sands and Peel 2012, 42.

[27] United Nations, Plan of Implementation of the Johannesburg World Summit on Sustainable Development, UN Doc A/Conf.199/20 (2002) (Johannesburg Implementation Plan), para 23.

[28] For the relevance of Rio Principle 15 in this respect and possible constraints by WTO rules see Führ et al. 2015, 78 using the example of the European chemicals legislation REACH.

[29] UNECE Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters of 28 June 1998, 38 ILM 517 (1999).

[30] UNITAR 2004, 3.

[31] Führ and Schenten 2018.

[32] United Nations, A 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, UN Doc. A/CONF.216/5 (2012), Annex.

tion in the SDG´s are particularly relevant. Sustainable production and consumption (SPC) is adressed by SDG 12[33] of the Agenda 2030.[34] In general terms SPC aims at sustainable use of natural resources. With a view to chemistry, SDG 12 on SPC reaffirms the chemicals related Johannesburg Goal of 2002[35] as well as related calls in the 10YFP[36] and seeks to achieve, by 2020,

> "the environmentally sound management of chemicals and all wastes 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" (SDG 12.4).

Such international frameworks are established by a set of conventions aiming for a sound management of problematic chemicals, namely the Stockholm, Basel, Rotterdam and Minamata conventions.

SPC policies are meant to draw on experiences such as the Strategic Approach to International Chemicals Management (SAICM),[37] a multi-sector and multi-stakeholder approach to pursuing the sound management of chemicals.[38] SAICM also is committed to Green Chemistry[39] and reflects many of the Green Chemistry Principles.[40] Notably, SAICM promotes the "development of safer alternative products and processes, including non-chemical alternatives".[41]

3.2
EU law context

EU primary law aims at "a high level of protection and improvement of the quality of the environment" (Art. 3(3)2 TEU). This normative objective is not

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[33] Besides, there are touch points with several health and environment related Sustainable Development Goals (SDG) as defined by Agenda 2030, such as SDG 3 (ensure healthy lives and promote well-being), SDG 6 (availability and sustainable management of water and sanitation) as well as SDGs 7 and 13 (clean energy and combat climate change).

[34] United Nations (2015) UN General Assembly, Transforming our world: the 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly. 25.9.2015, A/70/L.1.

[35] Johannesburg Implementation Plan, para 23.

[36] 10YFP, para 1(b)(v).

[37] 10YFP (n 2), para 2(b).

[38] UNEP (2006).

[39] Dubai Declaration No 14: "We are determined to realize the benefits of chemistry, including Green Chemistry, for improved standards of living, public health and protection of the environment, and are resolved to continue working together to promote the safe production and use of chemicals".

[40] IPEN 2017, 6.

[41] Dubai Declaration No 17.

only valid for the Union policy on the environment (Art. 191 TFEU) but also for the approximation of laws establishing the internal market (Art. 114(3) TFEU). In order to allow for a high level of protection, environmental policies "shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay" (Art. 191(2) TFEU). Moreover, as foreseen in Art.11 TFEU "Environmental protection requirements must be integrated into the definition and implementation of the Union policies and activities, in particular with a view to promoting sustainable development."

Reflecting Rio Principle 10, Articel 15 TFEU provides for "good governance" and "participation of civil society", in the EU. This is accomplished by the EU Aarhus Regulation aiming at transparency of decision making processes on EU level. Besides, in a number of sectoral regulations and directives, including REACH and IED, elements of the Aarhus pillars are integrated.

In addition, the seventh general EU Environment Action Programme to 2020 (7th EAP)[42] provides a contemporary interpretation of the environmental objectives laid down in EU treaty law.[43] The 7th EAP calls on the European Commission to develop "by 2018 a Union strategy for a non-toxic environment that is conducive to innovation and the development of sustainable substitutes including non-chemical solutions". At the beginning of 2019 a draft for such strategy has not been presented. However, a study supporting the Commission in the process defines the core principle of the non-toxic environment (NTE) "that hazardous substances of particular concern (e.g. substances corresponding with the criteria of SVHC in REACH and equivalent) should as far as possible be phased out in uses which are not sufficiently well contained/ controlled during their life cycle".[44] While the target course obviously correlates with GC, the latter is more ambitious in substantive terms (scope as to what is considered hazardous or toxic).

The Circular Economy Action Plan is another current initiative providing guidance for development perspectives of EU chemical policies (and beyond). It aims for:

> "1) enabling recycling and improving the uptake of secondary raw materials, by limiting unnecessary burdens, and facilitating the cross-border circulation of secondary raw materials to ensure that they can be traded easily across the EU; and

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42 Annex to Decision No 1386/2013/EU, 2013 OJ L 354, p. 171.

43 Calliess 2011, Art. 191 AEUV, para. 8.

44 Milieu Ltd. et al. 2017, 20.

2) substituting substances of concern and, where this is not possible, reducing their presence and improving their tracking".[45]

Fulfilling these goals will require decision-making at the material design stage of product life cycles, which takes into account all relevant environmental impacts.[46] In this context, GC, which is focused on hazard prevention, can be seen as a mean to facilitate the circular economy.

3.3
Conclusions: the bigger picture of sustainable production and consumption

The Green Chemistry Principles as formulated by Anastas and Warner do not explicitly address the whole life cycle of chemicals in an industrialized society. Unless a chemical is a product on its own (e.g. charcoal), however, chemical substances are designed to be used in subsequent production processes, i.e. to achieve certain functions with the overarching aim to finally support the performance of a product, ranging from the visual impression over surface feeling up to technical features. Therefore, when operationalizing the Green Chemistry Principles, product design and the design of chemicals must be put into context. SDG 12 does in fact reflect this "bigger picture" in combining "sustainable production and consumption" (SDG 12.1) with "environmentally sound management of chemicals and all wastes throughout their life cycle" (SDG 12.4) while taking into account the resource perspective (SDG 12.2).

In a product context, abstaining from problematic industrial chemicals at all is the most effective option to reduce chemical hazards.[47] To the extent that for a certain product function applying chemistry cannot be avoided, the principles of Green Chemistry provide normative guidance based on natural science evidence. Thus, mechanisms are needed to balance available design options against each other in order to determine which option contributes best to the aims of Green Chemistry – in its relevant normative context (SGD 12, Circular Economy etc.).

Thus actors in the areas of chemical design, product design as well as from the use phase etc. have to share their knowledge and creativity. Green Chemistry as a concept addresses a priori chemists. Likewise, chemists implement Green Chemistry solutions. However, whether or not a product needs a "chemical solution" depends on the product's intended functionalities. Therefore, the green chemist needs input from the product designer – and vice versa. In most cases the product consists of more than one (chemical) compo-

[45] COM(2018) 32 fin, 2.

[46] SWD(2018) 20 fin, 6.

[47] See also SWD(2018) 20 fin, 5: "*The chemicals and product policy objectives are identical from the perspective of chemical safety.*"

nent. Its function is based on an assembly of different parts added stepwise along the supply chain. Solutions towards a greener chemistry thus have to involve all industrial actors contributing to the final product.

Moreover, not only the product as such but also its impact during the use phase is relevant in the context of SDG 12. Consequently GCP 11 "analyze in real-time to prevent pollution" has to be interpreted in a way that includes pollution linked with the use of the product.

3.4
Assessment criteria

Against the background of the considerations above the subsequent assessment of the regulatory framework has to include – beside the GCPs (see Table 1) – also the institutional context that stipulates the learning process of the actors within their particular organisation. Learning steps and related change actions depend also on joint efforts along the supply chain influenced by the debate within the public at large. Thus, the capability of the regulatory framework to foster learning processes by providing transparency and inclusive governance elements is of pivotal importance in terms of the aim to gain a momentum towards a "greener" chemistry.

The assessment criteria applied in this study contain the GCP (part A.). In addition, with regard to the innovation process towards Greener Chemistry, related elements of the regulatory framework that support "learning processes" in this direction are taken into account (part B.).

A. Green Chemistry Principles	
1	prevent waste
2	maximize atom economy
3	design less hazardous chemical synthesis
4	design safer chemicals
5	use safer solvents/conditions
6	increase energy efficiency
7	use renewable feedstocks
8	avoid chemical derivatives
9	use catalysts
10	design for degradation
11	analyze in real-time to prevent pollution
12	minimize the potential for accidents

Table 1: Green Chemistry Principles

The GCP are aiming at continuous improvement processes integrated in the (re-) design of chemical substances. Hence, the different actors of the supply chain (see in section 2.2) have to interact in a way that prepares the ground for GC innovation. In the scope of this study the question arises to which extent the existing regulatory framework already contains elements supporting learning processes towards GC – and how to increase this support.

The first Learning Process (LP) element is addressing the transparency as the necessary basis for effective communication (element 2) leading to – ideally: cooperative – research strategies and activities towards GCP underpinned by respective incentives (element 3). Elements 4 and 5 are aiming at the inclusion of different perspectives by stakeholders or the public at large into the activities carried out in the context of the elements 1 to 3: Insofar as specific administrative procedures are foreseen (e.g. in applications for authorisation under REACH) formalized participation possibilities are considered (element 4). For other decision making processes and the integration of expert opinions continuous inclusive governance formats are essential to collect a wide variety of perspectives and to allow for counter-power formation contrasting the predominating view in certain professional circles (element 5).

In a longer term view the study programmes at universities[48] and in other professional training programs have to include the competences that are needed to steer innovation processes towards the GCP. Since this aspect is not covered by the scope of this study this element is listed in the table below, but it is not part of the assessment criteria applied.

B. Learning Process Principles: Regulatory elements supporting Learning Processes	
1	provide **transparency** on the chemical, its properties and use as well as the (possible) impacts on human health and environment
2	provide **incentives to communicate** information referred to in 1 to relevant supply chain partners and other stakeholders
3	provide **incentives** to include GCP in **research** strategies and activities
4	**offer formalized participation possibilities** (in administrative procedures)
5	provide elements of **continuous inclusive governance** formats
(6)	(include GCP in the **curricula of university and other professional training programs**)

Table 2: Regulatory elements supporting Learning Processes of the actors involved

The assessment of the existing EU framework is summarized in one or both (as appropriate) of the two tables introduced above. The assessment can conclude with a positive (+) or negative (-) outcome; in addition an intermediate result is possible (o) due to various and often interlinked reasons.[49] To illustrate the findings of the assessment the entries in the tables entail the following symbols:

+ Criterion is covered by the regulatory framework and at least to some extent implemented by the actors.

o Criterion is only to a certain degree covered by the regulatory framework. In this respect, three assessment findings are considered:

  (a) the level of ambition falls significantly short of the Green Chemistry Principles / Learning Process Principles and / or

[48] Illustrating examples can be found in the course "Chemistry and Sustainability" at the Carnegie Mellon University, Pittsburgh (Collins 2017) or in the master program on "Risk Assessment and Sustainability Management" (RASUM) at the Darmstadt University of Applied Sciences; c.f. https://rasum.h-da.de/.

[49] Since in most cases more than one of the characteristics described under a) b) and c) is applicable the findings are integrated into one symbol.

(b) the criterion is expressly covered but the practical implementation is (almost entirely) lacking and / or

(c) it is not explicitly covered; however the legal framework implicitly formulates the obligation to take the criterion into account.

- Criterion is not covered by the regulatory framework (e.g. because the entire stage is beyond the scope of the legislative act or the specific material or procedural aspect is not addressed).

4
Green Chemistry rooted in existing EU policies relevant for chemicals

This chapter applies the assessment criteria on the six stages in the "life cycle" of a chemical substance (see section 2.2). Section 4.6 summarizes the findings of the analysis captured in the conclusions to the five stages.

4.1
Stage 1: Substance Design for Green Chemistry under REACH

According to the REACH Regulation, manufacturers and importers of chemical substances must prior to placing those on the market collect information on the properties and uses and submit a dossier to the European Chemicals Agency (ECHA). Manufacturers with production volumes above a certain tonnage band have to prepare a chemical safety assessment, taking into account the risks associated with a substance in its entire life-cycle. REACH also stipulates (mainly information) requirements for chemicals in mixtures and articles.[50] In addition, REACH provides several risk management instruments available to public authorities. This includes, in particular, restrictions of the manufacturing and use of a certain substance as such, in a mixture or in an article or an authorisation obligation for the use of certain substances. Before authorities can impose one of these measures, they must take into account the availability of safer alternatives.

REACH puts emphasis on self-responsibility[51] of the actors. In order to achieve its protection objectives the Regulation "is based on the principle that it is for manufacturers, importers and downstream users to ensure that they manufacture, place on the market or use such substances that do not adversely affect human health or the environment".[52] In addition, according to Art. 1(3) sentence 2 the REACH[53] "provisions are underpinned by the precautionary principle".

[50] In this study, REACH provisions on articles are subject to Stage 4 on article design and are therefore assessed in section 4.4.4.

[51] Cf. *Führ* 2003, 43 et seq., *Führ* 2011, chapter 1, para. 47 et seq.

[52] First sentence of REACH Art. 1(3).

[53] All Articles, Annexes and Recitals referred to in Section 4.1 are, unless indicated otherwise, those of the REACH Regulation.

4.1.1
Largely conforming goals of REACH and Green Chemistry

According to Art. 1(1)[54] the primary goal[55] of REACH is to ensure a high level of protection of human health and the environment, including the promotion of alternative methods for assessment of hazards of substances. REACH also serves the overriding goal of a Sustainable Development (Recital 131), while emphasizing the specific context of the high level of protection (Recital 3). Accordingly, the regulation aims to contribute to the aforementioned United Nations' "Johannesburg Goal" (Recital 4) and the "SAICM" (Recital 6), highlighting the "hazard" dimension of chemicals management. To this extent, the normative goals of Green Chemistry and REACH are coherent. Natural resource considerations in terms of energy savings and waste reduction, while addressed by Green Chemistry, do not belong to the normative objectives of REACH, though.

4.1.2
Factual exemptions for substance innovations

The registration obligation is triggered by a manufacturing and/or import volume per legal entity of 1 tonne per year. Significant exemptions up to 10 years from the full registration obligation are available for substances manufactured or imported for the purposes of product and process orientated research and development (PPORD). As regards hazard information, actors desiring a PPORD exemption need to notify the Agency of the substance's classification.[56] Hazard classifications are based on the "available data" for a substance.[57] The usual source in this respect, however, is the REACH registration dossier, which the notifier does not have to generate. Whether or not the notifier provides classification data might therefore depend on the available data on structurally related substances and how he evaluates the relevance of such data.[58]

According to ECHA the PPORD exemption is "well used"; by a limited number (~ 350) of rather large companies, though. In addition, the agency anticipates

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[54] The Regulation's aim "is to ensure a high level of protection of human health and the environment, including the promotion of alternative methods for assessment of hazards of substances, as well as the free circulation of substances on the internal market while enhancing competitiveness and innovation."

[55] EGC Case T-93/10, Bilbaína de Alquitranes and others v ECHA, ECLI:EU:T:2013:106, para. 116 ("main objective"); appeal dismissed by CJEU under C-287/13 P, OJ C 261/6.

[56] Cf. Art. 9(2)(c).

[57] See e.g. Art. 5 Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures, 2008 OJ L 353, 1 (CLP Regulation).

[58] It is also questionable, whether the PPORD scheme equips the agency with sufficient information needed to decide about imposing conditions pursuant to Art. 9(4) upon the notifier.

raising notification numbers after the May 2018 registration deadline, since PPORD substances under 100 tonnes may have benefited from the expired phase-in status.[59]

Thus REACH does not directly stipulate specific provisions addressing the design phase of substances as laid down in GCP 4. With a view to Green Chemistry, the PPORD exemptions are particularly relevant, as they create a normative vacuum in the early design stage, thus missing an opportunity to guide substance innovations in the direction of Green Chemistry. However, anticipating the actual duties of manufacturers and importers after the PPORD-phase indirect incentives towards "safer chemicals" are to be expected (c.f. section 4.1.5).

4.1.3
Only indirect impulses on safer chemical synthesis

Green Chemistry aims for inherently safe chemical synthesis, i.e. manufacturing processes in terms of REACH. Notably, according to GCP 3 "synthetic methodologies should be designed […] to use substances that possess little or no toxicity". Besides, the "use of auxiliary substances (solvents, separation agents, etc.) should be made unnecessary whenever possible and, when used, innocuous" (GCP 5). Finally GCP 11 and 12 address more process related aspects.

According to the "no data no market" rule of Art. 5, substances may not be manufactured unless they comply with the registration rules imposed by REACH. However, REACH does not specify substantive requirements regarding the manufacturing process. The same applies to the Chemical safety assessments (CSA) to be prepared by registrants for substances above 10t/a.[60] While the CSA "shall address the manufacture of a substance",[61] this refers, however, only to "the exposure arising from the manufacture".[62] The chemical synthesis as such is thus outside the scope of REACH.

However, REACH takes note of the constituent substances and auxiliaries used for the creation of other substances. Art. 3(1) defines substance as "chemical element and its compounds in the natural state or obtained by any manufacturing process, including any additive necessary to preserve its stability and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition".

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59 ECHA 2016, 50.

60 Art. 14(3).

61 Annex I, Section 0.3.

62 Annex I, Section 0.5.

Consequently, substance identification during the registration process requires registrants to provide information on the composition of each substance, including (significant) main impurities as well as any additives (e.g. stabilising agents or inhibitors).[63] This is mainly relevant, as these factors can affect the classification of the substance as hazardous.[64] Thus, while not regulating the manufacturing process, REACH creates indirect incentives for manufacturers to use additives with a rather lower hazard profile.

Solvents applied during manufacturing of a substance are exempt from this substance's scope. However, solvents, as such, fall under the substance definition, too. Manufacturers of solvents may have to prepare a Safety Data Sheet (SDS) in accordance with Art. 31. In addition, downstream users must take note of conditions imposed by authorities that are limiting the use of many solvents, including candidate listing or harmonised classifications (see e.g. the group of dipolar aprotic solvents); as well as restrictions (e.g. benzene, cyclohexane, triclorobenzene, chloroform).

Finally, GCP 11 addresses analytical methodologies for in-process monitoring and control prior to the formation of hazardous substances. Such approaches are however completely out of the scope of REACH.[65] Besides, as REACH does not regulate the conditions under which substances are manufactured, it does not prescribe accident prevention measures against chemical accidents in terms of GCP 12. However, the SDS should create transparency regarding physical hazards (e.g. explosiveness, flammability) of the reactants and thus addresses at least some of the aspects that GCP 12 puts a focus on.

In conclusion, chemical synthesis as such is outside the scope of REACH and the regulation therefore creates no direct incentives towards the design of synthesis processes, which are resource efficient and apply only inherently safe auxiliaries. However, manufactures must take into account any regulatory measures regarding those auxiliaries. In addition, hazardous additives might affect a substance's classification; proactive manufacturers should consider this already in the phase of substance design. As regards chemical accident prevention, the SDS may provide relevant advice to be taken into account.

4.1.4
Natural resource and efficiency considerations largely out of scope

Some GCP are addressing natural resource considerations, i.e. waste prevention, reaction efficiency and use of renewable resources.

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[63] Cf. Annex VI, Section 3 as well as ECHA 2017, Substance Identification.

[64] Cf. Art. 10 CLP as well as ECHA 2018 (impurities) for the relevance of impurities and additives in the CLH process.

[65] To the extent that REACH promotes alternative methods for hazards assessment, this applies to strategies aimed at reduced testing on vertebrate animals, cf. Recitals 47 and 40.

As concluded in section 4.1.3, REACH does not explicitly set up process-related requirements for chemical synthesis. In particular, efficiency considerations are completely out of the regulation's scope.

As for waste prevention, likewise, REACH, does not cover the prevention of waste generated in the chemical synthesis. Only later on in the life-cycle the chemical safety assessment under REACH has to take into account the impact of the waste treatment and disposal of the substance. However, REACH does not require the minimisation of waste nor a process design targeted to a higher recyclability of the wastes.

Furthermore, GCP 7 on the use of renewable feedstocks is reflected under REACH only to the extent that certain REACH registration exemptions exist that are applicable also to specific bio-based chemicals.[66] However, REACH does not intend to foster bio-based chemicals, but these exemptions for specific substances are justified, as they do not compromise the high level of protection pursued by the Regulation. Consequently REACH does not provide any incentives for substance designers to choose renewable feedstocks rather than petro-chemical feedstocks.

4.1.5
Unfit hazard and biodegradation assessment

Green Chemistry targets the design of safer as well as more biodegradable substances (GCP 4 and 10). While REACH requires manufacturers and importers to collect information on relevant toxicological and eco-toxicological properties of substances, the scope is quite limited. For example, the standard information requirements lack specific consideration of substances like endocrine disrupters, neurotoxins, immunotoxins, and developmental toxins.[67]

Furthermore, the REACH information requirements apply to substances manufactured or imported above one tonne per year. For many substances marketed in lower quantities, such as speciality chemicals for specific purposes,[68] these requirements do thus not apply. Within the scope of REACH, according to Art. 12(1), registrants generally have to provide "all physicochemical, toxicological and ecotoxicological information that is relevant and available" to them. In addition, the (minimum) standard information requirements follow a tiered approach. Requirements for low tonnage substances (1 to 10 t/a) focus on their physico-chemical properties while a full toxicological and ecotoxicological hazard assessment is only obligatory above 1.000 tonnes. As for the

[66] Art. 2(7)(a) and (b) in conjunction with Annexes IV and V; cf. Luit and Waaijers-van der Loop 2016.

[67] Milieu Ltd et al. 2017, 94.

[68] Consider for example the low quantities of nanomaterials, cf. Schenten 2017, 14 with further references to nanomaterial quantities as reported by the economic actors.

biodegradation assessment in particular, REACH prescribes a test for ready biodegradability for substances in the first tonnage band (1 to10 tonnes) and more demanding requirements in the higher tiers.

Hence, with a view to the tiered approach, a study on behalf of the European Commission found[69] that extending the standard information requirements for substances in quantities between 1 and 10 t would yield benefits in terms of occupational health and wider public health as well as reduced environmental pollution and impacts on the ecological status of the environment.[70]

4.1.6
Practical experience on registration dossier quality

ECHA's 2017 progress report on the evaluation under REACH summarizes that, in the first 10 years after REACH's entry into force, ECHA has checked, the compliance of 1 350 dossiers in the highest tonnage band (>1 000 tn/a) and 430 (3.79 %) of the dossiers in the 100-1 000 tn/a tonnage band. In the vast majority of the cases (69 % and 77 % respectively), the compliance checks confirmed one or more data gaps and resulted in an ECHA (draft) decision.[71]

These results have to be interpreted in the light of the screening process identifying relevant dossiers. Nevertheless, the fact that about 7 out of 10 dossiers had severe deficiencies puts the entire approach of industry self-responsibility into question. Thus as a precondition for stimulating impacts from REACH towards the GCP the mechanisms to assure compliance with the data requirements in the registration regime are to be enhanced.[72] It also casts doubt on whether REACH actually provides strong incentives for manufactures to go "beyond compliance" and proactively design and apply Green Chemistry.

4.1.7
Narrow substitution focus on SVHC

Considering GCP 4 and 10, as well as the general GC objective to reduce or eliminate the use or generation of hazardous substances, the substitution focus of REACH is relevant.

In REACH, specific substitution goals and related calls for safer alternatives are predominantly linked to substances of very high concern (SVHC). According to Art. 57, eligible for SVHC status are

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[69] Footitt 2017.

[70] Milieu Ltd et al. 2017, 48 indicate that REACH information requirements burden the design of new non-toxic substances to a "comparatively low" extent.

[71] ECHA 2018, Evaluation, 15.

[72] In this respect the REACH Review results and proposals for a mandatory update requirements formulated by a number of the Member States are to be considered.

- CMRs in the category 1A or 1B,
- PBT and vPvB pursuant to REACH Annex III as well as
- other substances "for which there is scientific evidence of probable serious effects to human health or the environment which give rise to an equivalent level of concern" to the aforementioned hazards.

After formal identification (Art. 59), SVHC go the "candidate list" of substances. This listing already stimulates information requirements along the supply chain and, on request, to consumers (Art. 33).[73] A "candidate list" substance if it meets certain criteria may be included in Annex XIV. In this case, a manufacturer, importer or downstream user must not place the substance on the market or use it themselves after a certain date (sunset-date), unless he has received an authorisation from the Commission by which he is bound to certain conditions. The authorisation scheme thus establishes a use specific ban with permit reservation. These mechanisms intend to progressively replace SVHC by suitable alternative substances or technologies (Art. 55). They provide strong incentives for manufacturers of substances to avoid SVHC status by safer design approaches. In addition, the authorisation scheme creates markets for alternative solutions.

On the one hand, this corresponds to GCP 4 and 10. On the other hand, compared to the wide understanding of "hazard and toxic" in the realms of Green Chemistry, the SVHC scope is clearly too narrow. As for CMR substances, only those "known" or "presumed" to cause their respective effects may be identified as SVHC while, not least from a precautionary perspective, also substances merely "suspected" in this respect (i.e. Cat. 2)[74] could be covered. Besides, GCP 10 refers exclusively to degradation whereas, to attain SVHC status, a potential PBT substance must be persistent, bioaccumulative and toxic – cumulatively – just as a potential vPvB must show – both – (very) persistent and (very) bioaccumulative properties.[75]

From a procedural perspective, the current REACH approach focusing on the regulation of single substances bears the risk of regrettable substitution, i.e. a SVHC may be substituted by a structurally related, yet non-regulated, substance. For example, an ECHA market survey found that after the decision to restrict the SVHC Bisphenol A (BPA) for uses in thermal paper, the volume of bisphenol S (BPS), which is suspected to have many of the same adverse health effects as BPA, used as developer in thermal paper manufactured in the

[73] Section 4.3.2.

[74] Cf. See Annex I, Table 3.5.1, 3.6.1 and 3.7.1a CLP.

[75] Note that the residual clause in Art. 57(f) also does not lower the burden for SVHC identification as only substances are eligible for which scientific evidence indicates an "equivalent level of concern" compared to the other SVHC categories.

EU doubled between 2016 and 2017.[76] In this respect, recent approaches for grouping candidate substances which are structurally related or the restriction of dozens of textile chemicals hopefully mark a change of trend.

Probably mindful of these shortcomings, the Commission, ECHA and Member States plan to initiate activities intended to foster substitution of SVHC, which "*may include the promotion of capacity building and collaborative networks and promoting R&D investment (EU, Member States resources) in sustainable chemicals and technology innovations*".[77] It is also noted that in several Member State as well as beyond Europe, there are activities related to implementing Green Chemistry in the development and use of chemicals.[78] In particular, a number of platforms / networks such as SusChem and ICS3 have been established inducing and maintaining sustainable chemistry learning processes (see non-exhaustive list in Annex II).

In conclusion, while the authorisation policy established under REACH triggers continuous efforts by industry to substitute certain substances of very high concern (SVHC), the principles 4 (design for safer chemicals) and 10 (design of degradable chemicals) of Green Chemistry cover a wider scope both in terms of chemicals and of problematic properties.

4.1.8
Transparency and communication

Transparency is one of the major pillars of the whole REACH system: According to the "no data, no market" rule, manufacturers or importers of substances have to collect and generate data on the properties and uses as well as the (possible) impacts on human health and environment (section 4.1.5). They provide this data to the Agency which eventually uploads most of it[79] to an online database, free of use for everyone,[80] i.e. e.g. downstream users can compare the quality of different dossiers for (nearly) identical substances, but also researchers and other stakeholders can assess the data. Registrants have thus the incentive to document in their dossier that the substance has a low toxicity profile, or that risks can be "adequately controlled" pursuant to Art. 14.

Communication on the substance data among supply chain actors already takes place in the registration context, i.e. within the Substance Information

[76] ECHA 2018, Market Survey.

[77] COM(2018) 116 final, 7 (Action 5).

[78] Milieu Ltd. et al. 2017, 17.

[79] Only in quite limited cases the registrants can claim that data contain confidential business information.

[80] Some data not published initially may be accessed individually upon access to documents request according to Art. 118.

Exchange Forum (SIEFs), where the registration dossier is prepared,[81] but also beyond the SIEF, as manufacturers need to collect use information from downstream actors, i.a. to develop exposure scenarios. In addition, for substances classified as hazardous or identified as SVHC, and for mixtures classified as hazardous or, under certain conditions,[82] containing SVHC, manufacturers and formulators must create a SDS to be communicated to all downstream users.[83] Compared to the REACH authorisation scheme, the scope of problematic properties considered by the SDS is therefore much broader. Moreover, suppliers of articles have to communicate downstream if SVHC above a certain threshold are present in such articles (section 4.1.7).

4.1.9
Formalized participation possibilities and inclusive governance

Many elements in REACH allow for the transfer of stakeholders' (interested parties') knowledge into the REACH system.

In general, Art. 41(6) entitles third parties to pass on to the Agency the substance information available to them. In the dossier evaluation, ECHA has to take this into account.[84] In addition, ECHA and other EU agencies are currently looking into options for an online platform for mutual data exchange between the agencies.

Furthermore, public consultations are procedural parts of different risk management instruments for public authority, i.e.

- identification of SVHC,
- introducing new and amending restrictions,
- recommendation of SVHC for inclusion in Annex XIV,
- harmonized classification and labelling and
- assessment of applications for authorisation.

While all of these steps bear some meaning for Green Chemistry, the biggest potentials in this respect are probably associated with consultations in the context of the REACH authorisation. Here, third parties are encouraged to intervene and provide information on greener solutions compared to the use-scenarios of SVHC proposed by the authorisation applicant.

However, in practice, the authors of this study are not aware of any cases where due to the availability of alternative solutions the Commission did *not* gran an application for authorisation (even in cases were alternatives are well

[81] Cf. Art. 28, 29(1).

[82] Cf. Art. 31(3)(b).

[83] The chain of communication ends with the actor who integrates the substance or mixture into an article.

[84] Together with information submitted by the authorities under to Article 124.

established on the market, e.g. for lead in paints whereas in this particular case the EGC annulled the decision[85]). Rather, commitments by the European Commission to simplify "*the applications for continued use of SVHCs in legacy spare parts and further considering the case of low volume applications in 2018*" tend to rather perpetuate the status quo.[86] Besides, providing information on alternative uses in the consultation may require significant resource input from third parties. As REACH does not foresee compensation,[87] those parties may be discouraged to take part in the consultation.

In addition, public science data offer untapped potentials in terms of substance data quality. According to Art. 12 the registration dossier "shall include […] all physicochemical, toxicological and ecotoxicological information that is relevant and available to the registrant.[88] This includes industry study reports and grey literature, as well as studies published in the mostly academic peer-reviewed literature. In contrast, peer-reviewed studies are not used to the extent that they could.[89]

4.1.10 Conclusions

REACH applies to the manufacturing, import and use of chemical substances (as such or in mixtures or in articles), while the focus of this chapter lies on substances. The design process of chemical substances as such is deliberately excluded from the scope of REACH; however, some substance-related requirements could at least cause some "pre-effects" on substance design. The standard information requirements (ecotoxicological and toxicological endpoints) under REACH are incomplete. Moreover, these requirements do not apply to small volume substances (below 1 tonne), thus reinforcing the lack of governance of substances at the early stages of development and marketing. Regarding the substitution of problematic substances, the scope of REACH is limited, focussing merely on SVHC. In addition, REACH almost completely falls short of efficiency and natural resource considerations. Reflection of the Green Chemistry in REACH is thus inadequate.[90]

With a view to the overall regulatory approach of REACH, the regulation focuses on risk management rather than risk prevention. REACH also does not offer direct incentives for greener alternatives, such as e.g. a fast track for processes that provide environmental or health benefits but sets only partly ambi-

[85] EGC Case T-837/16 *Sweden v Commission*, ECLI:EU:T:2019:144.

[86] COM(2018) 116 fin, 7 („Action 6").

[87] ClientEarth and ChemSec 2018.

[88] See also Annex VII, last sentence.

[89] Ågerstrand et al. 2017.

[90] UBA 2009, 23.

tious substitution goals (SVHC). Moreover, current decision making on authorisation applications under REACH does not encourage the involvement of suppliers of benign alternative solutions. Such constellations can create a barrier to the implementation of Green Chemistry.[91] As REACH establishes transparency about substance hazards and risks, the regulation, however, to some extent creates incentives for "safer chemicals" and best practice risk assessment. In particular, downstream users can use available information to procure the chemical products causing less harm and which are therefore associated with the smallest amount of costs for occupational and environmental safety.

In addition, REACH is designed as a "learning system" in itself, at the same time initiating and steering "learning processes" of actors. To this end, REACH offers an institutional framework based on transparency, stipulating communication and cooperation of supply chain actors towards "safer (handling of) chemicals" and also involving further stakeholders through various formalized participation possibilities and inclusive governance mechanisms.

The following tables summarize the assessment by using the following symbols:
+ Criterion is covered by the regulatory framework and to a relevant extent implemented by the actors
o Criterion is only to a certain degree covered by the regulatory framework. In this respect, three assessment findings are possible: (a) the level of ambition falls short of the Green Chemistry principles / Learning Process principles and / or (b) it is expressly covered but the practical implementation is (almost entirely) lacking and / or (c) it is not explicitly covered; however the legal framework implicitly formulates the obligation to take the criterion into account
- Criterion is not covered by the regulatory framework

Table 3: Summarized explanation of the used symbols

[91] GC3 2015, 14.

Green Chemistry Principles		REACH Coverage
1	prevent waste	(-) Waste prevention not covered; however CSA is to take into account waste treatment and disposal of the substance
2	maximize atom economy	(-) Efficiency considerations not covered
3	design less hazardous chemical synthesis	(o) Chemical synthesis not covered explicitly; but information and communication requirements set incentives for safer products
4	design safer chemicals	(o) Design phase not covered; but safer design incentives from information requirements and substitution goal for SVHC; however Green Chemistry understanding of hazardous / safe would clearly go beyond; substance design/innovation largely excluded from scope; weak mid-term incentives with regard to low and medium volume substances
5	use safer solvents/conditions	(o) Chemical synthesis not covered; but solvents and auxiliaries regulated under REACH
6	increase energy efficiency	(-) Energy efficiency not covered
7	use renewable feedstocks	(-) Natural resource considerations not covered; but few (accidental) exemptions in registration context
8	avoid chemical derivatives	(-) Efficiency considerations not covered
9	use catalysts	(-) Efficiency considerations not covered
10	design for degradation	(o) Degradation endpoint in information requirements; however tied to bioaccumulation (and toxicity)
11	analyse in real-time to prevent pollution	(-) Chemical synthesis not covered
12	minimize the potential for accidents	(o) Chemical synthesis not covered, but information and communication requirements set incentives for safer processes

Table 4: Green Chemistry Principles applied to stage 1 (substance design under REACH)

Regulatory elements supporting Learning Processes		REACH Coverage
1	**provide transparency** on the chemical, its properties and use as well as the (possible) impacts on human health and environment	(+) for chemical properties (depending on tonnage threshold; limited data quality) via SDS and ECHA database (o) uses in general covered;
2	provide **incentives to communicate** information referred to in 1 to relevant supply chain partners and other stakeholders	(o) legal duty to communicate SDS and SVHC information in supply chain; however lack of practical implementation (o) implicit obligation for registrants and DU to communicate on uses
3	provide **incentives** to include GCP in **research** strategies and activities	(o) See Table 4, line GCP 4 "design safer chemicals"
4	**offer formalized participation possibilities** (in administrative procedures)	(+) in the context of SVHC identification, application procedure for authorisation and procedure to restrictions, CLH; (-) as for the registration scheme beyond Art. 41(6) for phase-in substances so far no third party input
5	provide elements of **continuous inclusive governance** formats	(o) ECHA bodies and Committees provide an institutional framework stipulating communication and cooperation of supply chain actors towards safer (handling of) chemicals by its composition and the rules of procedure. However, data quality potentials of peer-review study use not fully exploited

Table 5: Learning Processes stipulated at stage 1 (substance design under REACH)

4.2
Stage 2: Production processes

Production facilities both for chemical substances and for products containing industrial chemicals fall into the scope of Directive 2010/75/EU on industrial emissions (IED)[92]. Depending of the hazardous properties and the amount of the substances that are handled in the installation or that may occur during an accident most chemicals production sites are also subject to the Seveso-

[92] The analysis in this section was supported by valuable input form the team dealing with the BREF process in the "European IPPC Bureau" of the JRC site in Seville and by the "Industry Working Group" of the EEB. The authors thankfully acknowledge this input; all remaining errors are entirely those of the authors. https://eippcb.jrc.ec.europa.eu/ (29.10.2019)

Directive aiming at "the control of major-accident hazards involving dangerous substances" (2012/18/EU).

4.2.1
Research and Development (R&D) out of scope

Benefits from applying the GCP to a large extent rely on their inclusion in R&D-activities, i.e. the design of the final product (see stage 4 in section 4.4) and the production process towards it. According to Article 2(1) IED the directive does not apply to research activities, development activities or the testing of new products and processes. However, with regard to process oriented R&D obviously the conditions of the subsequent production of the chemical substance are of high relevance. In this respect both directives indirectly influence the scope of the R&D-activities and provide normative orientation towards the "basic obligations" (see below).

4.2.2
Reduction of hazards and resource use provided by the "basic obligations"

Art. 11 IED specifies the "general principles governing the basic obligations of the operator" of the industrial activity covered by Annex I to the IE-Directive.[93]

Principle (a) "all the appropriate preventive measures are taken against pollution" and (c) "no significant pollution is caused" are related to hazard reduction in the sense that hazard reduction is one effective strategy to avoid pollution. The term "pollution" as well as the closely linked definition of "emission" both cover impacts of industrial production processes in all environmental media ("into air, water or land"; Art. 2(2) and (4) IED); thus an interface to the "strategies against pollution of water", as provided by Art. 16 Water-Framework-Directive (2000/60/EC) is established calling for coordinated actions of the authorities in charge of implementing the different directives.[94] Moreover, the question arises whether "industrial emissions" are solely linked to emissions directly released by the installations; but also – as defined in Art. 3 (4) IED – "indirect release of substances", e.g. in the life cycle of the generated products, are be covered by the scope of the directive and thus should be considered in its implementation. [95]

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[93] IED Annex I i.a. lists all chemical production processes "on an industrial scale", being it organic (No. 4. 1 a – k)) or inorganic chemicals (No. 4.2 a – e). In addition, the production of fertilizers, plant protection products and biocides als well as pharmaceutical products (including intermediates) and explosives are listed separately.

[94] Kleihauer et al. 2015 SMART protection objectives for priority hazardous substances (EC/2008/105).

[95] This view is supported by Art. 1(1) IED asking for "integrated prevention and control of pollution arising from industrial activities" (not: industrial installations) and the definition of "pollu-

Production process oriented and resource related objectives of Green Chemistry are reflected by other basic obligations laid down in Art. 11 IED

(b) the best available techniques are applied;

(d) the generation of waste is prevented,

(e) where waste is generated, it is prepared for re-use, recycled, recovered or, where that is technically and economically impossible, it is disposed of while avoiding or reducing any impact on the environment; and

(f) energy is used efficiently;

For proper implementation and enforcement the IED general principles must be operationalised. To this end, best available techniques (BAT), "giving special consideration to" the criteria specified in Annex III IED,[96] are defined in so-called BAT reference documents (BREF) [97] on a European level. Of particular importance with respect to the GCP and its hazard reduction approach (see chapter 2.2) is IED Annex III with its criterion 2 providing to determine the BAT in a way that promotes "the use of less hazardous substances".[98]

However, BREF in terms of hazard reduction have to rely on the knowledge generated in other more specified contexts, i.e. beside the R&D efforts (section 4.2.1) of the various industrial actors and other stakeholders most likely REACH substance information will be taken into account. Hence, gaps in REACH with respect to Greener Chemistry identified above (section 4.1.5) have continued effects in the IED context.

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tion" which "means the direct or indirect introduction, as a result of human activity, of substances (…) into air, water or land which may be harmful to human health or the quality of the environment (…)"; this definition covers a broader range of emission sources than merely those released directly at the industrial installation. Consequently, the BREF´s should follow this scope and address substitution on site as well as indirect emissions outside the facilities.

[96] From the twelve criteria the following are in particular relevant in terms of the GCP:

1. the use of low-waste technology;
2. the use of less hazardous substances;
3. the furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate;

9. the consumption and nature of raw materials (including water) used in the process and energy efficiency;

11. the need to prevent accidents and to minimise the consequences for the environment.

[97] Cf. the definition in Art. 3(11) IED.

[98] The most striking example might be of the BREF for the Production of Chlor-alkali (OJ 2016 L 332/34 as of 11.12.2013) with its BAT 1 on "cell technique" which, in the view of the European IPPC Bureau in Sevilla, basically triggered a finalisation of the conversion of the remaining mercury cell plants to membrane cell plants. This technology shift completely avoids the use of the very toxic mercury, reduces mercury emissions and mercury-containing waste and moreover significantly reduces energy consumption.

Besides, the best available techniques described in a BREF are only indicative unless explicitly required in the facility specific "permit conditions" (Art. 14 IED) for which the "BAT conclusions" are – not more than[99] – "the reference" according to Art. 14(3) IED. Thus the question has been raised whether the content of BAT conclusions are specific enough with regard to the substitution, minimization, safe use and best practice to reduce the use of and emissions of hazardous chemicals throughout the life cycle.[100]

From the perspective of a "command and control"-approach as pursued in the IED and the related BREF concept it is difficult to transpose GCP into "emission levels associated with the best available techniques"[101] since the GCP do not provide a clear-cut guidance for the outcome of the process design. Consequently, the BREF´s explicitly mentioning GCP are referring to it on rather general level; both the documents published after the IED amendment in 2010[102] and the older ones.[103] An example where GCP 2 has been taken

[99] For other problematic aspects of the BREF concept, i.a. the option to "set less strict emission limit values" (Art. 15 (4) IED) see footnote 109.

[100] See HAZBREF (WP 3) 2018, section I and subs. for further details.

[101] Cf. the definition in Art. 3(12) and (13) IED.

[102] Examples can be found in the following BREFs:

- Refining of Mineral Oil and Gas (2015), 643, Solid-acid technology: "This technique was given the 'Affordable Green Chemistry Award' in 2010 from the American Chemical Society." https://eippcb.jrc.ec.europa.eu/reference/BREF/REF_BREF_2015.pdf (29.10.2019)
- Common waste water and waste gas treatment/management systems in the chemical sector (2016), 22, Section 1.3: The section describes on one page the (12) principles of green chemistry. (29.10.2019) https://eippcb.jrc.ec.europa.eu/reference/BREF/CWW_Bref_2016_published.pdf
- Food, Drink and Milk Industries, (final draft 2018), 578: "From common household white sugar, to high-tech products, the companies of the European sugar industry are active in the development of a wide range of products, all of which originate from sugar beet. These include food ingredients, animal feed, green chemistry products (replacing petroleum-based materials) and biofuels such as bio-ethanol and biogas (see Figure 15.2)." https://eippcb.jrc.ec.europa.eu/reference/BREF/FDM/FDM_02-10-2018BW.pdf (29.10.2019)

[103] The term "green chemistry" is mentioned in the following BREFs:

- Organic Fine Chemicals (2006), 90: Green chemistry is described as an approach to be considered in the determination of BAT since it aims to prevent environmental impact, i.a. by improving the process design (p. 373 and subs.); no review process indicated (as for 2018-12-31). https://eippcb.jrc.ec.europa.eu/reference/BREF/ofc_bref_0806.pdf (29.10.2019)
- Polymers (2007), xxiii, Scope: ' The present document cannot, and is not intended to replace the chemical textbooks on 'green chemistry' and indeed it gives only general guidance for the early stages of process design – but deals mainly with process modifications, plant operation and maintenance and especially with the management of unavoidable

on board is the BREF on the production of large volume organic chemicals (LVOC), where the BAT conclusion 48 reads as follows:

> In order to reduce the consumption of ethylene and emissions to air of organic compounds and CO2, BAT for new plants and major plant upgrades is to use oxygen instead of air for the direct oxidation of ethylene to ethylene oxide

With this conclusion the synthesis route that generates the least waste is indicated. Thus in principle the improvement of the atom economy (GCP 2) can be part of BAT conclusion. In this specific case, however, no practical impact is to be expected from this conclusion, since it states merely what is already "state of the art" for more than a decade.[104]

With the above mentioned limitations the basic obligations and the linked BREF processes contribute to GC principles 1, 2, 3, 5, 11 and 12.

4.2.3
Accident prevention and risk management

The basic obligation as formulated in Art. 11(g) IED ("the necessary measures are taken to prevent accidents and limit their consequences)" refers to risk management.

According to Article 5 of the Seveso-Directive the "operator is obliged to take all necessary measures to prevent major accidents and to limit their consequences for human health and the environment."

Both directives support GCP 3, 5 and 12.

4.2.4
Learning Processes

The institutional framework provided by the two directives contains elements of transparency and participation, both as well for the public at large and the neighbourhood of the industrial installation. This offers the opportunity to introduce the knowledge and the perspectives of "third parties" into the ad-

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waste streams.'https://eippcb.jrc.ec.europa.eu/reference/BREF/pol_bref_0807.pdf (29.10.2019)

- Energy Efficiency (2009), 67 as an example how to select the process technology the "use of catalysis" is mentioned with reference to Green Chemistry (p. 316, reference 257]; no BAT conclusions are foreseen in this area as the BREF offers mainly management suggestions which are valuable but to a large extent difficult or even impossible to transpose into permit conditions. (20.10.2019) https://eippcb.jrc.ec.europa.eu/reference/BREF/ENE_Adopted_02-2009.pdf

[104] See the entry "Ethylene Oxide," in: Ullmann's Encyclopedia of Industrial Chemistry 2005, 559 et subs (table 7 on p. 566 shows that no air-based plant is running in Europe in 2005). Thus, the LVOC BREF 2017 acknowledges "the use of air has now been fully superseded by the use of oxygen in the EU-28" (see p. 363, section 7.2.1.1.1).

ministrative procedure leading to a decision on the application to receive a permit under the auspices of the directives.

As for transparency, IED data on industrial emissions are made accessible via the European Pollutant Release and Transfer Register (PRTR), a public register, intended to provide environmental information on major industrial activities. [105] In a European perspective, the BREF process with its established elements of inclusion of "interested parties" from authorities, industry actors and NGO´s offers a framework for learning processes as well (cf. Art. 13 IED).

Compared to other decision-making processes on the European level it provides a unique participatory approach that allows non-industry actors to sit at the 'negotiation table' from the beginning to the end. The most important step in the process is the final meeting of the Technical Working Group where environmental NGOs benefit from the same rights as Member States representatives and industry. As the BREF development process is based on evidence, it is – in principle – the quality of the argument that counts for decision-making. At the same time, defining and updating BREF documents[106] is a tedious process[107][108] and thus – due to the course of time – face the difficulty to keep up with the technical progress. Few examples have been identified by the authors where a BREF or the BAT conclusions triggered substantially a change process towards the GCP. The BREF´s in most cases seem to have merely a documentary ("rubber stamping") function by clarifying what is already state of the art in industry practice. Thus the learning process and its impact leaves room for improvement.

In the past the binding effect of the BREFs was rather limited. With the amendment in 2010 the BAT conclusions are – to some extent[109] – "legally

[105] The PRTR-Regulation (166/2006) implements for the European Community the UNECE (United Nations Economic Commission for Europe) PRTR Protocol to the Aarhus Convention. For details see https://prtr.eea.europa.eu/

[106] The EEB Industry working group defined as one of their main agenda topics to strengthen "NGO involvement in BREF reviews, in particular through the national BREF mirror groups"; see EEB 2017, 1.

[107] The stakeholder workshop in the context of the HAZBREF project conclude that "it would be helpful to improve the BREF review process", Workshop documentation, 4; it also formulated the following result (p. 5): "General agreement that there is a need for the frontloading process to be more systematic in the consideration of hazardous substances." and "ECHA has potentially a key role to play in helping this process by providing data, but the data extracted from ECHA database will mostly not easily match to the requirements and needs of IED activities i.e. needs more preparation, categorisation and processing."

[108] The process to set up a BREF (of typically several hundred pages) needs up to almost ten years; see the timetable shown under http://eippcb.jrc.ec.europa.eu/reference/ and the history provided in the various BREFs.

[109] Schaible 2009 points out weaknesses of the amended IED with regard to the binding effect of the BAT conclusions (cf. Art. 15(4) IED).

upgraded", which might lead to a stronger impact of the outcome of the BREF process. The question remains, however, in which way this affects the learning processes in the preparation of the BREF documents on the one hand and its transposition into binding conditions of a permit for an IED installation by the regional authorities on the other.

4.2.5
Conclusions

In general, while not literally referring to Green Chemistry, the regulatory framework established by the Directives on "industrial emissions" and on "major-accident hazards involving dangerous substances" still contributes to several GC principles. Consequently existing BREFs[110] cover production process oriented and resource related objectives of Green Chemistry. However, Green Chemistry is to be understood as a process in which the greenest solution of all available options prevails. Measured by this standard, defining and updating BREF documents is a quite tedious process, and thus – if only due to the course of time – is facing the difficulty to keep up with the technical progress and the related potential for greener chemistry.

With regard to learning processes the IED and the Seveso-Directive both offer elements of transparency and public participation. These elements, however, are not directly linked with GC. By creating additional procedural requirements for problematic substances which may lead to additional technical and organisational demands they provide a competitive advantage for less problematic substances. [111]

The process to establish or update a BREF involves a wide range of stakeholders and thus bears elements of inclusive governance. However for non-industry actors, such as environmental and health NGO´s, in practical terms there a number of impediments to actively contribute to the process since they are challenged have problems to mobilize the necessary level of technical expertise. Nevertheless, they were able to use the procedural opportunities to influence the BREF processes in some cases (e.g. output based performance levels or the substitution of creosote grade).[112]

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[110] Cf. footnotes 102 and 103.

[111] See also section 5.1.2.

[112] EEB 2017, 3 et subs.; the examples refer to the (revised/draft) BREF´s for Food, Drink and Milk Industries (FDM) https://eippcb.jrc.ec.europa.eu/reference/fdm.html and Surface Treatment Using Organic Solvents (STS). https://eippcb.jrc.ec.europa.eu/reference/sts.html (29.10.2019)

Green Chemistry Principles		IE- and Seveso-Directive Coverage
1	prevent waste	(o) Waste prevention is one "basic obligation" for industrial installations (Art. 11(d) IED); however enforcement lacks straightforward guidance due to the complexity of the various productions processes
2	maximize atom economy	(o) Resource consumption not explicitly considered, however implicitly covered by the waste reduction requirements (see also GCP 1)
3	design less hazardous chemical synthesis	(+) Potential hazards related to chemical synthesis are covered by Art. 11(g) IED and Art. 5 Seveso-Directive
4	design safer chemicals	(-) The design of the substance produced in the installation is not subject to the directives
5	use safer solvents/ conditions	(+) These aspects of chemical synthesis are covered by Art. 11(g) IED and Art. 5 Seveso-Directive
6	increase energy efficiency	(o) Energy efficiency is part of the basic obligations (Art. 11(f) IED); however it is scarcely enforced by the authorities.
7	use renewable feedstocks	(-) Not addressed by the directives
8	avoid chemical derivatives	(o) This aspect of chemical synthesis is not explicitly covered, the synthesis route, however, can be described in BREFs and laid down in BAT conclusions
9	use catalysts	(o)This aspect of chemical synthesis is not explicitly covered; it may, however, contribute to energy efficiency (Art. 11(f) IED and GCP 6); see GCP 8
10	design for degradation	(-) Degradation of the substance produced in the installation is not covered
11	analyse in real-time to prevent pollution	(o) Real-time steering of chemical processes are implicitly covered by the basic obligations of both directives; it is unclear to which extent it is incorporated into the permit conditions
12	minimize the potential for accidents	(+) Chemical synthesis and storage of substances are covered by Art. 11(g) IED and Art. 5 Seveso-Directive

Table 6: Green Chemistry Principles applied to stage 2 (production process under IE- and Seveso-Directive)

Regulatory Elements Supporting Learning Processes		IED and Seveso Coverage
1	**provide transparency** on the chemical, its properties and use as well as the (possible) impacts on human health and environment	(+) transparency about emissions for the public at large and the neighbourhood of industrial installations in the administrative procedure as well as in the operation phase of the plant (i.a. via PRTR-Regulation)
2	provide **incentives to communicate** information referred to in 1 to relevant supply chain partners and other stakeholders	(-) no supply chain communication is required, since the directives are addressing the production site only. (o) Information of the neighbourhood is required; communication is mostly limited to the licensing procedure (see point 4)
3	provide **incentives** to include GCP in **research** strategies and activities	(o) indirect effect due to additional procedural and material burden linked to substances and processes not meeting the GCP
4	**offer formalized participation possibilities** (in administrative procedures)	(+) participation in the licensing procedure offers the informed public to intervene and stipulates to some extent a "public scrutiny" whether GCP have been applied
5	provide elements of **continuous inclusive governance** formats	(+) BREF process with its established elements of inclusion of "interested parties", however for non-industry actors impediments to actively contribute to the process (-) No inclusive governance formats on local or regional levels are provided; on a voluntary basis companies established "neighbourhood circles" to enable continuous communication

Table 7: Learning Processes stipulated at stage 2 (production process under IE- and Seveso-Directive)

With respect to industrial installations the directives contain elements to inform about the actual emissions, but they do not provide a continuous interaction with the neighbourhood or the local public. Only in a situation where a new licensing procedure is taking place formal participations possibilities are foreseen. Some companies fill this gab by establishing "neighbourhood circles" on a voluntary basis to enable continuous communication with the local and or regional stakeholders. Tables 6 and 7 summarize the findings measured by the GC and LP criteria (see already table 3 for an explanation of the symbols).

4.3
Stage 3: Interaction along the supply chain

Information, communication and cooperation ("IC&C") along the supply chain is a cross-cutting issue governed by several legislative frameworks mostly in an indirect manner, since "efficient functioning of supply chain communication is necessary for economic operators to implement appropriate risk management measures and to make informed purchasing decisions".[113] Most substance and product related provisions in one way or another intend to induce interaction of supply chain actors.

4.3.1
Indirect obligations in product law

Product law (cf. the examples in sections 4.4.1 and 4.4.2) stipulates product specific rules ("safety"; certain substances must not be present, e.g. above certain thresholds) and perhaps procedural aspects to ensure compliance (analytical methods of chemical testing). Although in some cases "cooperation between producers and recyclers" is foreseen (e.g. Art. 4 WEEE), the legal framework does not elaborate on specific interactions in the supply and the redistribution chains. Waste minimization as one of the core aims of WEEE and formulated as a "producer responsibility"[114] as well as the substitution of problematic substances envisaged in RohS lack implementation due to missing incentives and insufficient information flow from the producer of the article down to the dismantling and recycling facilities.[115]

In order to make sure their products are compliant or even go beyond compliance, responsible manufacturers and distributors are, however, implicitly obliged to establish communication channels and interact with their suppliers. These interactions are typically embedded in contractual obligations.

4.3.2
Supply chain interactions in REACH

REACH establishes different mechanisms, which primarily aim at information, communication and cooperation of the economic actors.

Registrants of chemical substances have to include in their dossier all identified downstream uses and must communicate downstream the identified risk management measures. Downstream users, which do not support registrants with relevant information, might be obliged to provide a dossier on their own behalf — or stop using the substance. In addition, suppliers of i.a. classified substances or mixtures have to provide their recipients with a safety data

[113] SWD(2018) 58 final, part 1, 30.

[114] See recitals 6, 12, 22, and 23 WEEE (2012/19/EU).

[115] Führ and Roller 2008.

sheet (SDS). Enforcement by authorities shows enduring quality deficits in the SDS and implementation deficits on the side of the downstream users.[116]

As regards REACH, substance uses in articles are to be reported upstream, using very broad use descriptors, though (section 4.4.4). Besides, within the article supply chain, suppliers of articles containing SVHC above 0.1 % per weight must provide the recipients with sufficient information, available to the supplier, to allow safe use of the article including, as a minimum, the name of that substance (Art.33(1) REACH). According to ECHA, however, "there are clear indications that the information on substances is not adequately communicated in the article supply chains."[117] The European Commission concludes that it "remains difficult for actors in the supply chain to retrieve, verify and communicate information on SVHCs in articles".[118]

4.3.3
ECHA database on SVHC in supplied articles

The Art. 33(1) REACH supply chain communication requirement on SVHC in articles has been underpinned by a new provision in the amended Waste Framework Directive (WFD). According to its Art. 9(1)(i) the Member States are obliged to

> "ensure that any supplier of an article as defined in point 33 of Article 3 [REACH] provides the information pursuant to Article 33(1) of that Regulation to the European Chemicals Agency as from 5 January 2021".

ECHA has to establish the database until 5 January 2021.

Under the assumption that an article supplier acts in compliance with Art. 33 (1) REACH the additional burden is quite limited. Taking into account, however, the (almost entirely) missing implementation in most supply chains (see chapter 4.3.2) the new notification requirement reinforces the duty to retrieve and communicate the content of SVHC (above 0.1%) for each supplied article. Since the candidate list is regularly enlarged the supply chain communication has to be designed in a way that ensures manageability of the SVHC´s of today and tomorrow.

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[116] REACH-ENFORCE-1 2012, 2: „The quality of the SDS definitely needs to be improved"

[117] ECHA 2016, 136, 13: "The current legal requirement for information on substances in articles is not working well enough. A fundamental review of these obligations would be helpful and could usefully form part of work on the circular economy and the drive towards a non-toxic environment."

[118] SWD(2018) 58 final, part 1, 30.

4.3.4
Industry initiatives and additional projects

Industry initiatives with sector-specific approaches and solutions to support more interaction in the supply chains should be acknowledged. These initiatives typically organise the supply chain communication on substances in articles, imposing reporting duties on suppliers with respect to lists of substances regulated horizontally (REACH, POP-Regulation) and vertically, i.e. sector-specific (e.g. RoHS for electrical and electronics), and also individually (company lists). Companies in the automotive and electronics sectors, in particular, apply ambitious approaches, partly aimed at achieving "full material declaration" (FMD) of the substances used in articles and their supply chains. The AskREACH project, funded under the EU LIFE programme, aims to scale up such approaches by applying FMD also to additional industry sectors.[119]

Ensuring supplier commitment to provide relevant and reliable data is one key challenge for such systems. Suppliers struggle i.a. with non-coherent reporting requirements, e.g. in terms of the standards and formats used. Against this background, in 2018 a "Proactive Alliance" of various industry sectors gathered, which develops recommendations for a global cross-sector standard for communicating substances in articles information along the supply chains, whereas, in the long run, reporting shall be based on FMD.[120]

4.3.5
Learning Processes

Within the context of REACH a set of IC&C mechanisms establish a learning system, based on transparency as regards substance use and related risks, aiming to set incentives for safer alternatives. Ultimately these incentives influence the innovation processes of chemical substances and induce developments towards the GCP.

Outlined FMD initiatives have a similar effect. Besides, sector solutions sometimes involve a multi-stakeholder Steering Committee with the competence to define reporting rules; in this respect they bear inclusive governance elements.

4.3.6
Conclusions

Progress in implementing the GC principles depends to a large extent on the collaboration of the various companies along the supply chain, i.e. the respective branches and departments with the wide range of individual persons which need to be involved in the change process towards GC. The Commis-

[119] See www.askreach.eu.

[120] See the "Mission Statement" of the Proactive Alliance, at https://www.reach-helpdesk.info/fileadmin/Proactive_Alliance/PA_Mission_statement_2019-02-04.pdf.

sion main study underpinning the development of the NTE strategy concludes that "the potentially largest barriers to the development and use of new, non-toxic substances result from the challenges in the supply chain."[121] In this respect, lack of chemical ingredient disclosure in the supply chains is one particular issue.[122]

The legal framework comes to its limits when a multi-actor collaboration has to be addressed. however, the regulative framework indirectly provides incentives in that direction. The industry actors face the challenge to establish a tailor fit governance framework to support a reliable and cost-effective exchange of information. The following tables summarize the findings measured by the GC and LPP criteria (see already table 3 for an explanation of the symbols).

[121] Milieu Ltd et al. 2017, 48.

[122] GC3 2015, 12.

Green Chemistry Principles		Coverage in Supply Chain Interaction according to	
		Product law	REACH
1	prevent waste	(o) design orientated cooperation between producers and recyclers foreseen ELV and WEEE directives, however no effective incentives due to collective collection system and missing information requirements along the supply and the redistribution chain	(-)
2	maximize atom economy	(-)	(-)
3	design less hazardous chemical synthesis	(-)	(o) SDS with its risk management measures creates incentives to use less hazardous substances.
4	design safer chemicals	(-)	(o) see 3
5	use safer solvents/conditions	(-)	(o) see 3
6	increase energy efficiency	(-)	(-)
7	use renewable feedstocks	(-)	(-)
8	avoid chemical derivatives	(-)	(-)
9	use catalysts	(-)	(-)
10	design for degradation	(-)	(o) see 3
11	analyse in real-time to prevent pollution	(-)	(-)
12	minimize the potential for accidents	(-)	(-)

Table 8: Green Chemistry Principles applied to stage 3 (interaction along the supply chain)

Regulatory elements supporting Learning Processes		REACH (+ ECHA SiA database under WFD)	Product Law	Further initiatives
1	**provide transparency** on the chemical, its properties and use as well as the (possible) impacts on human health and environment	(+)Transparency regarding substance uses part of the registration process; (-) however no information which substances (other than SVHC above 0.1%) can be found in which (specific) articles	(-) no transparency mechanisms	(+) Proactive Alliance aims at establishing standard supporting article specific "full material declaration" along the supply chains (o) remaining challenge, however: data quality in the reporting systems
2	provide **incentives to communicate** information referred to in 1 to relevant supply chain partners and other stakeholders	(o) REACH: Communication on classified substances + mixtures as well as on SVHC in articles (implementation deficits in both respects) (o) underpinned by the WFD requirement to notify SiA to the ECHA database (entering into force 2021), level of implementation unclear at this point of time	(o) no communication on SiA in sectoral legislation; however, transparency on the chemical composition of components is a precondition for producers (brands, OEM´s) to be compliant.	(+) communication of available data as part of the purchasing conditions (with the view towards a full material declaration, FMD)
3	provide **incentives** to include GCP in **research** strategies and activities	(-)	(-)	(o) indirect incentive due to the "full material disclosure" approach
4	**offer formalized participation possibilities** (in administrative procedures)	(-)	(-)	not applicable
5	provide elements of **continuous inclusive governance** formats	(-)	(-)	(o) some sector solutions are more inclusive, involving e.g. a multi-stakeholder Steering Committee which define reporting rules

Table 9: Regulatory stipulated Learning Processes applied to stage 3 (interaction along the supply chain)

4.4
Stage 4: Product Design towards Greener Chemistry

Stage 4 comprises legal instruments providing incentives for actors to align their product design processes with the GCP. The scopes and regulatory approaches vary to great extent. In fact, all legislative acts that are influencing the market conditions, e.g. the (non-) contractual warranty, have impact on the design phase. This section, however, focusses on legislative acts, which are relevant with regard die GCP. Thus, it covers the general product policy and legislation (section 4.4.1) as well as sector specific legislation (4.4.2) and the definition of "technical" standards (4.4.3). The analysis is accomplished by article specific requirements under REACH (4.4.4). All mentioned regulatory efforts contribute to learning processes (4.4.5).

4.4.1
General product policy and legislation

General product legislation, together with substance-specific article rules under REACH (see section 4.4.4); establish a regulatory framework, relevant in particular for products not subject to specific legislation (e.g. textiles, furniture). This is underpinned by crosscutting policies, such as the Ecodesign Directive (section 4.4.1.1), the Ecolabel system (4.4.1.2) and general provisions on product liability (4.4.1.3).

The Directive on General Product Safety (GPSD) stipulates the overall rule to be transferred into national law that products intended for or likely to be used by consumers may only be placed on the market when they are safe, meaning they do not present any risk or only the minimum risks, consistent with a high level of protection for the safety and health of persons.[123] However, with a view to chemical risk the GPSD does not provide any specific criteria on hazard identification or exposure to be taken into account by producers.[124] In addition, environmental safety and human exposure via the environment are not considered. In sum, one can therefore conclude that the GPSD most likely applies "*in simple and obvious cases of noncompliance and direct acute risks*"[125] but that it does not provide incentives for GC innovation in product design.

From GC perspective the cross-cutting EU concept Integrated Product Policy (IPP) is relevant. In 2003 the Commission adopted its Communication "Integrated Product Policy – building on environmental Life-Cycle Thinking".[126] It aims at coherent action, using the most appropriate policy tools and involving

[123] Articles 3(1), 2(a), 2(b) Directive 2001/95/EG on general product safety (GPS), 2002 OJ L 11, 4.

[124] Postle et al. 2017, 84.

[125] Reihlen 2017, 16.

[126] COM (2003) 302.

stakeholders, towards "greener" products that combine lower environmental impacts with enhanced service to consumers; furthermore it calls for continuous improvement in product manufacturing and design, and for promoting their uptake by consumers.[127] Consequently, all relevant regulatory frameworks as well as the complementary "technical" product standards[128] are to be aligned with the IPP approach. The concept, however, has obviously lost some of its momentum after 2008.[129] On the other hand, a number of recent activities, including i.a. the plastics strategy build upon the IPP approach.

4.4.1.1 Ecodesign Directive

Directive 2009/125/EC on Ecodesign (ED) establishes a framework for the setting of ecodesign requirements (implementing measures) for "energy-related" products.

The ED aims to force inefficient products off the market by setting minimum efficiency or maximum consumption requirements and related information obligations. Originally, the primary focus of ED was reduced resource use in terms of energy consumption. Art. 15(5)(b) ED however provides the general rule that implementing measures shall not adversely affect health, safety and the environment. Accordingly, implementing measures can address the entire product life cycle, including manufacturing, and all for a product group "significant environmental aspects", listed in Annex I Section 1.2 of the ED):

- consumption of materials, of energy and of other resources such as fresh water;
- emissions to air, water or soil;
- pollution through physical effects such as noise, vibration, radiation, electromagnetic fields;
- generation of waste material; and
- possibilities for re-use, recycling and recovery of materials and/or of energy.

According to Annex I, Part 1, Section 1(3) (d) ED product requirements must take into account, as appropriate, use of substances classified according to CLP as well as other "legislation on the marketing and use of specific substances". Hence, in the realms of the ED there is an open door for not energy-related requirements addressing chemicals (use bans, information obligations),

[127] COM(2009) 693, 2.

[128] Führ et al. 2006.

[129] For details see the timetable under
http://ec.europa.eu/environment/ipp/implementation.htm.

linked to, e.g., certain hazard or exposure criteria[130]. The methodology for ecodesign of energy-related products (MEErP), used in the preparatory studies for ecodesign of energy-related products to identify policy options, in fact provides indicators to include substance-related criteria, e.g. with respect to SVHC and to substances subject to RoHS.[131]

Accordingly, some implementation measures address restricted substances under RoHS in electrical and electronic equipment, e.g. mercury included in fluorescent lamps[132] or mercury and lead in televisions;[133] moreover, related information obligations[134] are under discussion.[135] Beyond this, however, a 2013 report observed that in the preparatory studies there is no systematic link to the relevant processes under REACH (substance evaluation,[136] candidate listing, Annexes XIV and XVII).[137] Reasons for this can be manifold, e.g. overall complex process with a multitude of aspects; lack of precise data (and confidentiality issues, often advocated by industry); prioritization of certain aspects (based on policy priorities, i.e. energy saving, first, and recently recycling); potential overlap with other existing legislation, namely REACH.

Indeed, the authors of the report at hand are not aware of any (planned) implementation measures addressing problematic substances in articles more broadly, e.g. by strengthening the link to the REACH Regulation. Rather, even the ecodesign standards on material efficiency, currently under development, are not focusing on the potential toxicity of certain substances in products,[138] but rather consider related communication duties, mainly to improve the qual-

[130] Cf. Schomerus and Spengler 2012, 26, who from Annex I Part 3 ED ("design solution must achieve a reasonable balance between […] environmental aspects and other relevant considerations, such as safety and health"…) conclude that implementing measures cannot address health related requirements exclusively, but that these requirements must at the same time address the environment, *ibid*, 31.

[131] Kemna et al. 2011, 112.

[132] Cf. Commission Regulation (EC) No 245/2009, Commission Regulation (EU) No 347/2010

[133] Cf. Commission Regulation (EC) No 642/2009.

[134] E.g. introduction of "Mercury free" and "Cadmium free" logos in electronic displays, cf. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32009R0642 (8.9.2018).

[135] SWD (2018) 20 fin, 11: "Option 5A: use of the Ecodesign Directive, or of other dedicated product specific legislation as appropriate (for example, WEEE or ROHS), to introduce requirements for substances of concern with the purpose of enabling recovery)"; see also the Ecodesign Working Plan 2016-2019, COM (2016) 773 fin, 8.

[136] Cf. REACH Art. 44 et seq.

[137] Cf. Reihlen et al. 2013, 10.

[138] According to the mandate; see http://ecostandard.org/work-on-material-efficiency-standards-for-ecodesign-finally-kicks-off/ (8.9.2018.)

ity of recycling and to reduce the risks of spreading these substances at the end-of-life of the products.[139]

In addition, from a procedural point of view, ecodesign "benchmarks" specified in the implementing measures to be considered by manufacturers must be identified by the Commission based on information gathered during the preparation of the measure. Hence, benchmarks are identified in a formalized and thus tedious procedure which may create barriers for innovative or state of the art solutions aiming "beyond compliance".

4.4.1.2 Ecolabel

The EU set up a voluntary ecolabel scheme (Regulation 66/2010, ELR). The "general requirements for EU Ecolabel criteria" are addressing problematic chemicals[140] in Art. 6(6) and (7). For goods containing those substances the EU Ecolabel may not be awarded. According to para 7, however, the Commission may adopt measures to grant derogations for specific categories of goods, but "only in the event that it is not technically feasible to substitute them as such, or via the use of alternative materials or designs, or in the case of products which have a significantly higher overall environment performance compared with other goods of the same category". This competence does not apply for SVHC "present in mixtures, in an article or in any homogeneous part of a complex article in concentrations higher than 0,1 % (weight by weight)."

The provision provides a link between REACH and ELR. The practical implementation, while still under consideration[141] remains to be a demanding challenge since the wording "any homogeneous part of a complex article" raises the question whether it is compatible with the definition of an "article" under REACH. In addition, the problem occurs how to deal with recycled materials which, at least for an interim period, may contain SVHC due to the contamination of the products sold in the previous decades. For a transition period – which might range up to two decades for some product categories – towards a circular economy (see section 4.5) avoiding the "riskcycle"-problem[142] this issue is of pivotal importance. In terms of implementing the GCP, however,

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[139] Cf. section 4.3.3 as regards related legal developments in the waste context.

[140] Defined in Art. 6(6) ELR as "substances or preparations/mixtures meeting the criteria for classification as toxic, hazardous to the environment, carcinogenic, mutagenic or toxic for reproduction (CMR), in accordance with Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures (and) substances referred to in Article 57 REACH".

[141] Two "Chemicals Task Force(s)" (1 and 2) have been set up at the JRC in Sevilla to discuss the issue with relevant stakeholders; as of January 2019 no solution has been endorsed by the task force.

[142] Lahl and Zeschmar-Lahl 2013.

addressing the future design of substances and products this issue is relevant insofar as recycled material is included in the material design.

4.4.1.3 Product liability

One fundamental principle of EU private law is that producers are liable for damage caused by a defect in their products, whereas in this respect all "movables" including consumer products, chemical substances as such as and all materials supplied in the supply chains are covered by the product term.[143] The respective EU directive obliges Member States to establish a comprehensive and strict basis for liability claims relevant for all activities in the substance supply chain in cases where a product "does not provide the safety which a person is entitled to expect" and is therefore defect.[144] If defects can be attributed to a violation of a company management's due diligence, even cases of personal liability could be established.[145] In general, product liability could therefore be a strong driver for GC innovation in product design, not least against the background of increasing awareness about the presence of problematic substances in articles and related risks on the part of consumers.

4.4.2
Sector specific product legislation

Sector specific legislation provides for restrictions influencing the product design, which are however rather narrow in scope. Few examples shall illustrate the regulatory mechanisms in place; the literature provides more comprehensive analyses of the legal framework for products.[146]

Directive 2011/65/EU (RoHS) on the restriction of the use of certain hazardous substances in electrical and electronic equipment (EEE) restricts the use of lead, mercury, cadmium,[147] hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) in EEE when substitution is possible from the scientific and technical point of view. In addition, following the dynamic requirement to update the list of restricted substances as soon as

[143] Articles 1, 2 Directive 85/374/EEC on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, 1985 OJ L 210, p. 29 amended by Directive 1999/34/EC, 1999 L 141, p. 20.

[144] Article 6 Directive 85/374/EEC.

[145] See e.g. Schenten and Führ 2011 on interlinks between duty of care in REACH and due diligence in German corporate law.

[146] Cf. e.g. Poulsen et al. 2010 and Reihlen 2017.

[147] In August 2018 the "Volkswagen group confirmed that it might have to recall as many as 124,000 electric and hybrid cars from its VW, Audi and Porsche brands due to poisonous cadmium"; c.f. https://electrek.co/2018/08/06/electric-hybrid-cars-vw-audi-porsche-recall-cadmium/.

new scientific evidence is available on more environmentally friendly alternatives, Directive 2015/863/EU amends RoHS to restrict four phthalates.

Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) is built around the "producer responsibility" principle and, indirectly, promotes resource efficiency[148] as well as the substitution of hazardous chemicals in EEE by making producers responsible for the collection and management of waste and hazardous waste. Art. 4 WEEE addresses the "product design" and calls on Member States to "encourage cooperation between producers and recyclers and measures to promote the design and production of EEE, notably in view of facilitating re-use, dismantling and recovery of WEEE, its components and materials". However, the established collective redistribution systems in combination with the missing information flow between the various actors dilute the economic incentives towards resource efficiency and substitution of problematic substances.[149]

In addition, a large number of legislative acts addresses specific product categories, such as toys:

"Directive 2009/48/EC on the safety of toys[150] restricts the use of substances with certain hazardous properties and encourages the replacement of dangerous substances and materials used in toys with less dangerous substances or technologies, where suitable economically and technically feasible alternatives are available"[151].

Most of the legal acts with a sector specific scope follow the "new approach", thus transferring the definition of the requirements to some extent to the standardization bodies (see the following section).

4.4.3
Addressing environmental issues in product standards

In order to establish an internal market (Art. 26(2) TFEU) an approximation of laws is foreseen (Art. 144 et subs. TFEU). In the field of product related legislation the EU is relying on the "new approach": In many cases the EU legislative acts formulate basic requirements in general terms whereas the "technical" details are defined by standardization bodies based on a mandate by the European Commission.[152] These European product standards (issued by CEN or CENELEC) are of pivotal importance for the internal market and at the same

[148] According to Art. 1 WEEE the directive aims at "reducing overall impacts of resource use and improving the efficiency of such use in accordance with Articles 1 and 4 of Directive 2008/98/EC [Waste Framework Directive], thereby contributing to sustainable development."

[149] Führ and Roller 2008.

[150] Directive 2009/48/EC of 18 June 2009 on the safety of toys, 2009 OJ L 170, 1.

[151] Cf. Milieu Ltd. et al. 2017, 40.

[152] For details see Führ 2014.

time they determine to a large extent the performance indicators of the product; consequently they influence the product design and the conditions of the productions process.

In this context the governance mechanisms of the decision making process in the standardization bodies has to be scrutinized in terms of democratic principles as well as under the rule of law,[153] since the "diffuse interests", such as consumer safety and environmental protection, tend to be underrepresented in the standardization bodies dominated by representatives of the interested companies. The situation has been improved in the last two decades, i.a. by strengthening the internal support for these aspects by the "Strategic Advisory Body on Environment" (CEN/SABE) and by establishing and financing specific organizations[154] bringing the above mentioned perspectives into the decision making process.

In addition to these procedural and organisational innovations content-related developments took place. Already in 2008 the "ISO Guide 64" has been published: "Guide for addressing environmental issues in product standards". The Guide supports the actors in standardization procedures to identify the most relevant environmental impacts of the subject at stake and directs them towards "greener" solutions. Compared with the GCP a high level of convergence can be stated as ten of the twelve principles are reflected in the ISO Guide (see Annex V).

Following the publication of the ISO Guide 64 the European standardization body CEN adopted a guidance document entitled "CEN approach on addressing environmental issues in product and service standards" (CEN GUIDE 4:2008) replacing the version of 2005. In comparison with the previous edition, the revised version of the guide proposes new features:

- a detailed step-by-step approach based on the life-cycle thinking principle (chapter 3),
- an extended environmental checklist (chapter 5, table 1),
- multiple examples of possible environmental provisions for each stage of the life-cycle, including limitations and possible choices depending on the nature of the relevant environmental impacts and the scope of the

[153] Führ et al. 1996: European Standardization Procedures: A Model for Reform, elni-Review 2/1996, 22 – 27.

[154] For the consumer perspective ANEC (European Association for the Coordination of Consumer Representation in Standardisation; www.anec.eu) and for environmental aspects ECOS (European Environmental Citizens Organisation for Standardisation; ecostandard.org). This project to develop the guide was initiated by the European Commission (DG GROW) in collaboration with CEN. It was by a project team composed of Austrian Standards (ASI), Danish Standards (DS), the Spanish Association for Standardisation and Certification (AENOR) and the European Environmental Citizens' Organisation for Standardisation (ECOS).

standard (chapter 6, examples in annex B refer both to ISO and CEN standards) and

- recommendations for developing environmental sector guides (Annex A).

This was followed in 2017 by the "Guide for addressing chemicals in standards for consumer-relevant products" (CEN GUIDE 16). The latter provides "support to Technical Committees on how to develop requirements in product standards that can contribute to minimising the use of hazardous chemicals in products, and thereby reducing health and environmental risks arising from exposure to chemicals."[155] Against the background of the General Product Safety Directive (see section 4.4.1)[156] the Guide provides assistance "in the development of normative provisions for chemicals, particularly in those areas where specific regulatory provisions (e.g. limit values) for chemicals are absent and are not envisaged to be implemented in the foreseeable future" (CEN guide 16, section 1).

The guide basically "translates" the REACH requirements for the actors in the Technical Committees (CEN guide 16, sections 5 and 6, pages 17 - 83).

4.4.4
Article specific requirements in REACH

Registrants of substances must take into account all uses in the life-cycle, including the use in (consumer) articles. In this respect, very generic information based on "use descriptors" (e.g. widespread use by professional workers or consumer use)[157] is to be provided. If not already covered by a substance registration, producers and importers of articles can be obliged to register substances in articles, provided the substance is present in those articles in quantities totalling over one tonne per actor and year and that the substance is intended to be released under normal or reasonably foreseeable conditions of use (Art. 7(1) REACH). In essence, this latter prerequisite may apply to fragrances. Unintentionally released substances such as plasticizers or solvents, or

[155] Quote from: https://www.cen.eu/work/areas/env/Pages/GuideChemicalsProducts.aspx (as of 2018-07-16)

[156] Section 1 of the guide clarifies: "Electrical and electronic equipment, and ICT products, are excluded from the scope as these products fall under the lead of CENELEC and ETSI, respectively. Food contact materials, materials used in the supply of drinking water, medical devices, and construction products are also excluded. This is because comprehensive, detailed and specific regulation on chemicals in these products is either already available or subject to consideration and debate; because specific approaches are required; or because performance requirements are supposed to be addressed at national level; or a combination of all these. Nonetheless, some of the guidance may be useful in areas excluded from the scope of the Guide."

[157] ECHA 2015.

plastic additives, the release of which to the environment occurs as a result of foreseeable abrasion, are not covered.[158]

As regards SVHC, their presence in articles above 0.1% per weight has to be notified if certain prerequisites are fulfilled (Art. 7(2) REACH). Regarding the point of reference for the 0.1% threshold Member States enforced differing interpretations of the provision[159] until the CJEU decided in September 2015 in favour of the 'once an article always an article' approach:[160] , the 0,1 % threshold applies to each article of an complex object made up of more than one article, which were joined or assembled together.[161]

In the context of the 2nd REACH Review a Commission document summarizes that

> "[t]he amount and adequacy of information in registration dossiers for the safe use of substances in articles is still very limited. Fewer than expected notifications to ECHA have been provided, […] This limits the usefulness of such information for the identification of appropriate regulatory measures".[162]

In addition, presence of SVHC in articles above 0.1% per weight triggers information requirements along the supply chain (see section 4.3) and, on request, to consumers. According to Art. 33(2) REACH suppliers addressed by consumer requests have to respond within 45 days; a time frame much too long to allow for a noteworthy impact of any given answer on the purchasing decision. Another design flaw of the consumer "right to know" is that suppliers are not obliged to report on the non-presence of SVHC above 0.1 % by weight.

Annex XIV substances may only be used in articles to the extent this use is authorised or covered by possible exemptions. This does however not apply to imported articles, which can be placed on the EEA market without need for prior authorisation.[163]

In addition, on a case-by-case basis restrictions on the use of substances in articles can be imposed. These apply irrespective of an article's origin. In its 2nd REACH Review, the Commission therefore requests ECHA "to consider systematically the preparation of a restriction dossier before the sunset date of

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158 Führ at al. 2015.

159 Bergkamp and Herbatschek 2015.

160 CJEU, Case 106/14 FCD and FMB v Ministre de l'Écologie, du Développement durable et de l'Énergie (2015) ECLI:EU:C:2015:576, para 50.

161 ECHA 2017, articles, 27. In addition, the packaging used for transport and presentation of an article is considered as a separate article under REACH and is therefore separately subject to all article related provisions.

162 SWD(2018) 58 final, part 1, 29.

163 Schenten and Führ 2016.

each substance that is subject to authorisation and present in articles in accordance with Article 69(2)".[164]

However, the restriction is only available if "there is an unacceptable risk to human health or the environment (…) which needs to be addressed on a Community-wide basis" (Art. 67 REACH). This involves a high burden of proof for authorities and consequently low numbers of restrictions adopted.[165] There is also a simplified restriction procedure for CMR Category 1 substances in consumer articles (and mixtures) (Art. 68 REACH) which the Commission so far has triggered twice, notably concerning textile articles[166], the implementation of which is however not straight forward[167].

In conclusion, the REACH approach to problematic substances in articles is merely reactive and thus too selective and the regulation thus only establishes a minimum standard as regards the safety of substances in articles.

4.4.5
Learning processes

Due to the large variety in terms of scopes and regulatory approach of legal instruments assessed in stage 4, learning processes also vary. In general terms product design is key not only to achieving greater material productivity through recycling and waste prevention[168] but also in respect to the other elements of GCP. Product design in itself contains learning processes of the actors involved in the design process.

First off, relevant processes in the context of GPSD and product liability could not be identified. As regards REACH, information provided in stage 1 (section 4.1), focussing on inclusive governance in the context of authorisation (and restriction), applies accordingly.

In sector specific legislation e.g. RoHS provides, compared to REACH, a similar but yet more inclusive learning process when it comes to amendment of the annexes in restrictions of hazardous substances and related exceptions.[169] Before amendments of the Annexes are possible, the Commission, technically

[164] COM(2018) 116 fin, 9 („Action 11").

[165] On average four adoptions per year, according to ECHA 2016, 107.

[166] Commission Regulation (EU) 2018/1513 of 10 October 2018 as regards certain substances classified as carcinogenic, mutagenic or toxic for reproduction (CMR), category 1A or 1B; Commission Regulation (EU) No 1272/2013 of 6 December 2013 as regards polycyclic aromatic hydrocarbons.

[167] CA/102/2014, Criteria and procedure for the implementation of Article 68(2) of REACH: restriction of CMRs 1A and 1B in consumer articles
http://ec.europa.eu/DocsRoom/documents/24801/attachments/1/translations/ (3.1.2019).

[168] BIO-IZM-WI 2013, 17.

[169] Schenten and Führ 2015.

assisted by external experts (in the last years based on a framework contract with the German Öko-Institut and Fraunhofer IZM), initiates a public consultation to determine whether the exemptions are justified due to, e.g., absence of reliable substitutes. More specifically, the consultations build on a two-tier approach in which all relevant actors such as economic operators, including competitors of the applicant, environmental organisations as well as trade unions and consumer associations are notified via Email announcement about the launch of the consultation and submitted contributions. In addition, the external experts are seeking actively for evidence that alternative options to substitute the problematic substance are available.

The Ecodesign Directive in Art. 18 establishes a Consultation Forum to consult stakeholders on the implementation of the Directive, i.e. in particular defining and reviewing implementing measures and related benchmarks.[170] 30 organisations (trade, industry, consumer and environment) are participating.[171] In addition to those formalized learning systems, there are plenty of platforms and networks, both national und multinational and mostly driven by private sector initiatives, aimed at product design taking into account sustainable resource use. Among relevant initiatives are the European Network of Ecodesign Centres (ENEC) or the DesignThinkers Academy Network. However, none of those platforms and networks clearly addresses GC or even the role of problematic substances in product design (see non-exhaustive list in Annex III).

In the context of the Ecolabel Regulation learning processes in terms of GCP are supported by means of the "Chemicals Task Force".

4.4.6 Conclusions

As already seen in stage 3, there is considerable lack of communication in supply chains as regards (problematic) substances in products, whereas clear obligations in this respect only address SVHC present in such products above 0.1%. REACH provisions on the registration of substances (in articles) are not of much help. Hence, there is a general uncertainty among article producers about which problematic substances are present in their products. There are strong incentives for producers, though, that substances being subject to restrictions in REACH or RoHS are not present, or only present to the extent that is covered by any exemptions to the restrictions, in their products. Unlike REACH, RoHS only applies to electrical and electronic equipment.

[170] See http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=1798&news=1 (24.5.2018).

[171] For details, see http://ec.europa.eu/DocsRoom/documents/5363/attachments/1/translations (24.5.2018).

Regulatory elements supporting learning processes		Ecodesign Directive Coverage	REACH Coverage
1	**provide transparency** on the chemical, its properties and use as well as the (possible) impacts on human health and environment	(o) chemicals used in the production process of an article are covered by the scope; however, the practical implementation up to now does not include this issue	(o) Registration duty regarding substances in articles using very broad "use descriptors"; notification duty regarding SVHC in articles restrained by too many preconditions to be met
2	provide **incentives to communicate** information referred to in 1 to relevant supply chain partners and other stakeholders	(-) out of scope	(o) Consumer "right to know" on SVHC in articles with design flaws (cf. table 9 on supply chain communication in REACH)
3	provide **incentives** to include GCP in **research** strategies and activities	(-) out of scope	(-) out of scope
4	**offer formalized participation possibilities** (in administrative procedures)	(-) no administrative procedures	See Table 4
5	provide elements of **continuous inclusive governance** formats	(+) In the context of defining and reviewing implementing measures and related benchmarks	See Table 4

Table 10: Regulatory stipulated Learning Processes applied to stage 4 (product design)

The GPSD does require producers to take into account chemical risks, however due to lack of substance specific criteria, GPSD non-compliance in terms of chemical risk will most likely be triggered by non-compliance with relevant laws providing such criteria, i.e. e.g. REACH or RoHS, thus not adding any additional incentives to producers. The same applies to the product liability regime, though, in theory, equipped with very effective sanctions; the practical problems of the claimant to cope with the burden of proof dilute the incentives.

ED implementing measures, finally, may address energy-related products, i.e. the scope goes beyond RoHS but relevant product classes (e.g. textiles) are excluded. Besides, so far implementing measures were not concerned with the role of problematic substances though the ED framework provides instruments in this respect.

In conclusion, product designers lack knowledge on what chemicals actually are present in articles and the materials thereof. Besides, while compliance with existing restrictions most likely is a relevant factor in product design, more ambitious approaches such GC are certainly not – this is also shown by existing platforms and networks for (green) product design.

Due to the almost entirely indirect impact of the legal instruments with regard to the GCP,[172] no findings as for the substantive criteria can be formulated. The strongest incentives supporting learning processes can be found in the Ecodesign Directive and in REACH. The mechanisms covered by those frameworks are also representative for the other regulatory frameworks mentioned above, which are therefore not reflected by the table (see already table 3 for an explanation of the symbols).

4.5
Stage 5: Use phase and Stage 6: after use phase

The most relevant environmental and health impact of a product occurs in many cases during the use phase. The extent of the impact is partly depending on the consumer behaviour; e.g. the amount of washing powder inserted for a washing programme. At the same time the composition of the washing powder is decided by the producer. In addition the washing instructions on the product and the practical conditions offered by the producer (e.g. the volume of the measuring cup, the possibility to read the different volume level on the cup) are triggers for the actual use of a chemical product. Thus, the product design in combination with the use instructions determine to a high extent the contribution to the GCP in the use phase.

Of utmost importance, however, are behavioural patterns of the individuals, often perpetuated over a longer time period – in some cases from one generation to the next. One of the most challenging tasks might be seen in triggering transition processes in the use phase (section 4.5.1) as well as the proliferation of data on the chemical composition of a product towards those actors involved in the after use phase (section 4.5.2) (Stage 6; sections 4.5.3 and 4.5.4). Both stages of the life-cycle of a chemical are covered by the REACH

[172] Green Chemistry focusses on chemical design and synthesis, aspects that are out of the scope of product law. Likewise, while both Green Chemistry and (parts of) product law aim at waste prevention, waste prevention in terms of product law refers to the final product, rather than waste minimizing production of raw materials pursuant to GCP 1.

data requirements linked with exposure scenarios in the registration dossier (section 4.1.6), recently complemented by an information requirement under the amended Waste Framework Directive (section 4.3.3).

4.5.1
Use phase in the Ecodesign Directive

The vast majority of impacts during the use phase are depending on the design of the product and its (chemical) components. The Ecodesign Directive and its implementing regulations cover these aspects (see section 4.4.1.1). In principle, they are reflecting the substance related provisions in the horizontal and vertical legislations which have been enacted when the decision process of the implementing act takes place; however, as empirical evidence shows, up to now this has not been included in any derogated legal act. In addition, the emerging issues, such as future SVHC, are even more unlikely to be integrated in ecodesign requirements.

From a GCP perspective the ecodesign framework, although offering a high impact potential, is lacking practical influence on both, the product design and the consumer behaviour related to the release of chemicals in the use phase.

In addition, the wide range of problematic substances other than SVHC not subject to sectoral legislation, is not specifically regulated; neither in the use nor in the after use phase. Thus, they fall in the scope of horizontal legislative frameworks; with the view on chemicals notably in the scope of REACH (see next section).

4.5.2
Life-cycle approach under REACH

In the context of the REACH registration scheme, for substances with "problematic properties"[173] as defined in Art. 14 (4) an exposure assessment is obligatory addressing "all identified uses of the registrant". According to Section 5.0 of Annex I to REACH the exposure assessment "shall consider all stages of the life-cycle of the substance" and "cover any exposures that may relate to the hazards identified". From the perspective of the legal text it would have been justified to expect that – after the third registration deadline at June 1, 2018 – sufficient data on the fate of chemical substances are uploaded by the registrants to the ECHA database. ECHA´s Guidance on information requirements and chemical safety assessment indicates in its chapters R.17 and R.18 how to build an exposure scenario and to estimate exposures from articles and from the waste life stage. This would have facilitated all actors involved to

[173] For details see Führ 2011, chapter 8, 144 et subs.

consider measures to tackle relevant exposure in the use phase as well as riskcycle-problems[174] in the after use phase.

The progress reports on ECHA´s evaluation activities give no clear indication to which extent the exposure scenarios are addressing these issues. For plastics additives, e.g., ECHA concludes that "insufficient information on uses has been provided in REACH registrations." To tackle the issue ECHA is supporting the "use map concept". It has been "developed to improve the quality of the information on use and conditions of use communicated up the supply chain and the efficiency of this communication process."[175] The progress report 2017 [176] states that use maps are available on ECHA's website for plastic compounding and conversion. These use maps will be extended to cover article service life. ECHA advises the registrants to include data from the use maps into the chemical safety reports. For the time being obviously the data provided by the registrants on release and exposure of chemical substances during the use and after use phase do not meet the expectations laid down in the legal provisions of REACH. In this respect the findings of the European Commission in the REACH Review is highlighting improvement potential:

> Better tracking of chemicals of concern in products would facilitate recycling and improve the uptake of secondary raw materials, as part of the Circular Economy. However, this would require transfer of information on the chemical content of end of- life articles to the waste management sector. [177]

The Commission in its review concludes in proposing the "Action 4: Tracking substances of concern in the supply chain":

> The Commission will gather evidence and assess options to address the challenges related to substances of concern, as discussed in the chemical product waste communication. The assessment will consider, among others, whether and how a tracking system could contribute to improve the workability of information requirements for SVHCs in articles.[178]

4.5.3
Waste Framework Directive

The after use phase is addressed by the horizontal Waste Framework Directive 2008/98/EC, (WFD). The directive aims at minimizing the generation of waste and thus is supporting the first GCP. However, the legal provisions in this re-

[174] Lahl/Zeschmar-Lahl 2013.

[175] https://www.echa.europa.eu/csr-es-roadmap/use-maps/concept (as of 18.08.2018).

[176] ECHA 2018, 71.

[177] SWD(2018) 58 final, part 1, 30.

[178] COM(2018) 116 final, 6.

spect, namely the "extended producer responsibility" laid down in Art. 8 WFD, have merely an appellative character. They do not offer requirements which are enforceable against industrial actors in the previous stages. Thus GCP1, although covered by the aim of the directive, is not underpinned with mechanisms providing stringent incentives towards this end.

4.5.4
Waste relevant sectoral specific legislation

In addition several sectoral approaches are applicable for relevant industrial material streams, e.g. for vehicles (ELV-Directive) and for electric and electronic equipment (RoHS- and WEEE-Directives). Both sectoral approaches formulate recycling requirements. Legally speaking, the provisions are addressing the after use phase; however, the main behavioural impact is intended towards the product design (stage 4, section 4.4.2).

The sectoral approaches also restrict the use of certain substances, notably heavy metals. With this restrictions environmental and health problems in the after use phase are addressed. However, the compliance to these provisions has also to be secured in the previous stages.

4.5.5
Conclusions

The problems related to the release of substances during the use and after use phases are as manifold as the various uses. To tackle the issue in a systematic way REACH offers the appropriate approach to collect the relevant data providing the basis for an adequate response by all actors involved, including producers and importers, downstream users of chemicals as well as buyers of articles and actors involved in end of life measures. Those aspects are covered by the legal text (see section 4.1.10).

From a circular economy perspective and in the light of the GCP it is of pivotal importance that problematic substances are not introduced to the material flows. Otherwise the phenomenon of "riskcycle"[179] occurs. To avoid the contamination of the recycled materials the regulatory approaches are addressing the previous stages, namely the product design (see section 4.4). Thus the legal framework covering the after use phase does not provide relevant additional incentives towards the GCP.

The use phase provisions have been assessed in the context of stage 4 (product design; see section 4.4.6). The following Table 10 thus focusses on the provisions supporting learning processes with regard to the stages of the life cycle after the last downstream user has incorporated a substance to an article

[179] Lahl and Zeschmar-Lahl 2013.

as well as the after use phase under the Waste Framework Directive (see already table 3 for an explanation of the symbols).

Regulatory elements supporting learning processes		Use and after use phase under REACH	Waste Framework Directive
1	**provide transparency** on the chemical, its properties and use as well as the (possible) impacts on human health and environment	(o) covered by the legal text; however, the quality of the registration dossier seems to fail the legal requirements to a large extent	(+) transparency with regard to SVHC above 0,1% is supported by the obligation in Art. 9 (1) WFD to report to the ECHA database.
2	provide **incentives to communicate** information referred to in 1 to relevant supply chain partners and other stakeholders	(o) covered by the legal text with respect to SVHC in articles above 0,1%; (-) no communication mechanisms are foreseen for the end of life phase	(-) out of scope; however the communication obligation under Art. 33 (1) REACH is indirectly underpinned by Art. 9 (1) WFD
3	provide **incentives** to include GCP in **research** strategies and activities	(o) due to additional burdens for "problematic" substance an indirect incentives is provided by the REACH mechanisms	(-) out of scope; however the two findings mentioned above indirectly serves as an incentive to exclude SVHC from the material stream in the supply chain.
4	**offer formalized participation possibilities** (in administrative procedures)	(-) not for use and after use phase	(-) no administrative procedures
5	provide elements of **continuous inclusive governance** formats	(-) not for use and after use phase	(-) no inclusive governance formats are foreseen in the WFD; however the public access to the ECHA database will allow third parties to investigate the efforts in the various supply chains.

Table 11: Regulatory stipulated Learning Processes applied to stage 5 (REACH and amended Waste FD)

4.6
Delta analysis of the regulatory context

A summary of major shortcomings is provided in the conclusions to the analysis of the stages 1 to 5 (see sections 4.1.10, 4.2.5, 4.3.6, 4.4.6 and 4.5.5). The assessment can conclude with a positive (+) or negative (-) outcome; in addition an intermediate result is possible (o) due to various and often interlinked reasons.[180]

Based on these findings priority areas for improvements can be identified as policy options (see chapter 5). The delta-analysis finds that some Green Chemistry principles, and respective Learning Process principles, are already covered by the regulatory framework of European (chemicals) policy. This is indicated in the tables with the '+' symbol (for at least one framework). For those principles, there is no relevant delta and thus no priority need for further action. Other principles are marked with the '-' symbol, meaning that these are fully out of scope of the respective framework(s) and integrating them would arguably "overstrain" the normative purposes of these frameworks. In contrast, the regulatory options to be developed in chapter 5 will focus only on those principles marked with the 'o' sign, indicating that, to some extent, these principles are already covered by the framework(s) and thus offering entry points for options to strengthen or further nuance coverage of the respective principle.

4.6.1
Delta Analysis with regard to Green Chemistry Principles

The following table merges the findings with regard to the Green Chemistry Principles for the first three stages. Stages 4, 5 and 6 do not cover the GCP to a relevant extent.

Section 4.6.2 presents the findings for the regulatory elements supporting learning processes.

[180] Table 3 provides an overview of symbols used to illustrate these findings.

Table 12: Green Chemistry Principles und their coverage in stages 1 - 3

Green Chemistry Principles		Substance Design under REACH	Production process under IE- and Seveso-Directive	Supply Chain Interaction: Product Law and REACH
1	prevent waste	(-) Waste prevention not covered; however CSA is to take into account waste treatment and disposal of the substance	(o) Waste prevention is one "basic obligation" for industrial installations (Art. 11(d) IED); however implementation lacks straightforward guidance due to the complexity of the various productions processes; thus enforcement by the authorities is largely lacking	(o) Aim of ELV and WEEE; due to the collective redistribution and recycling system the incentive and missing information requirements
2	maximize atom economy	(-) Efficiency considerations not covered	(o) Resource consumption not explicitly covered (see GCP 1)	(-)
3	design less hazardous chemical synthesis	(o) Chemical synthesis not covered explicitly; but information and communication requirements set incentives for safer products	(+)Potential hazards related to chemical synthesis are covered by Art. 11(g) IED and Art. 5 Seveso-Directive	(o) SDS with its risk management measures creates incentives to use less hazardous substances.
4	design safer chemicals	(o) Design phase not covered; but safer design incentives from information requirements and substitution goal for SVHC; however GC understanding of hazardous/safe would clearly go beyond; substance design/innovation largely excluded from scope; weak incentives for low and medium volume substances.	(-) The design of the substance produced in the installation is not subject to the directives	(o) see 3
5	use safer solvents/conditions	(o) Chemical synthesis not covered; but solvents and auxiliaries regulated under REACH	(+) These aspects of chemical synthesis are covered by Art. 11(g) IED and Art. 5 Seveso-Directive	(o) see 3
6	increase energy efficiency	(-) Energy efficiency not covered	(o) Energy efficiency is part of the basic obligations (Art. 11(f) IED); however it is scarcely enforced by the authorities.	(-)

7	use renewable feedstocks	(-) Natural resource considerations not covered; but few (accidental) exemptions in registration context	(-) Not addressed by the directives	(-)
8	avoid chemical derivatives	(-) Efficiency considerations not covered	(o) This aspect of chemical synthesis is not explicitly covered, the synthesis route, however, can be described in BREFs and laid down in BAT conclusions	(-)
9	use catalysts	(-) Efficiency considerations not covered	(o) This aspect of chemical synthesis is not explicitly covered; it may, however, contribute to energy efficiency (Art. 11(f) IED and GCP 6); see GCP 8	(-)
10	design for degradation	(o) Degradation endpoint in information requirements; however tied to bioaccumulation (and toxicity)	(-) Degradation of the substance produced in the installation is not covered	(o) see 3
11	analyze in real-time to prevent pollution	(-) Chemical synthesis not covered	(o) Real-time steering of chemical processes are implicitly covered by the basic obligations; it is unclear to which extent it is incorporated into the permit conditions	(-)
12	minimize the potential for accidents	(o) Chemical synthesis not covered, but information and communication requirements provide incentives	(+) Chemical synthesis and storage of substances are covered by Art. 11(g) IED and Art. 5 Seveso-Directive	(-)

4.6.2 Delta Analysis with regard to regulatory elements supporting learning processes

Table 13: Coverage of regulatory elements supporting Learning Processes (applied to stages 1, 2 and 3); continued in table 14

B. Regulatory Elements Supporting Learning Processes		REACH Coverage	IED and Seveso Coverage	Coverage in Frameworks/Initiatives Concerning Interaction along the Supply Chain
1	**provide transparency** on the chemical, its properties and use as well as the (possible) impacts on human health and environment	(+) for chemical properties (depending on tonnage threshold; limited data quality) via SDS and ECHA database (o) uses in general covered;	(+) transparency about emissions for the public at large and the neighbourhood of industrial installations in the administrative procedure as well as in the operation phase of the plant (i.a. via PRTR-Regulation)	(+) REACH: Transparency regarding substance uses part of the registration process; (-) however no information which substances (other than SVHC above 0.1%) can be found in which (specific) articles (-) Product law: no transparency mechanisms (+) Proactive Alliance aims at establishing standard supporting article specific "full material declaration" along the supply (o) remaining challenge, however: data quality in the reporting
2	provide **incentives to communicate** information referred to in 1 to relevant supply chain partners and other stakeholders	(o) legal duty to communicate SDS and SVHC information in supply chain; however lack of practical implementation (o) implicit obligation for registrants and DU to communicate on uses	(-) no supply chain communication is required, since the directives are addressing the production site only. (o) Information of the neighbourhood is required; communication is mostly limited to the licensing procedure (see point 4)	(o) REACH: Communication on classified substances + mixtures as well as on SVHC in articles (implementation deficits in both respects) (o) underpinned by the WFD requirement to notify SiA to the ECHA database (entering into force 2021), level of implementation unclear at this point of time (o) Product law: no communication on SiA in sectoral legislation; however, transparency on the chemical composition of components is a pre-condition for producers (brands, OEM´s) to be compliant. Further initiatives: (+) communication of available data as part of the purchasing conditions (with the view towards a full material declaration, FMD)
3	provide **incentives** to include GCP in **research** strategies and activities	(o) See Table 3, line GCP 4 "design safer chemicals"	(o) indirect effect due to additional procedural and material burden linked to substances and processes not meeting the GCP	(-) REACH (-) Product law (o) indirect incentive due to the FMD approach

4	offer **formalized participation possibilities** (in administrative procedures)	(+) in the context of SVHC identification, application procedure for authorisation, procedure for restrictions, CLH; (-) as for the registration scheme beyond Art. 41(6) for phase-in substances so far no third party input	(+) participation in the licensing procedure offers the informed public to intervene and stipulates to some extent a "public scrutiny" whether GCP have been applied	(-) REACH (-) Product law Further initiatives: not applicable
5	provide elements of **continuous inclusive governance** formats	(o) ECHA bodies and Committees provide an institutional framework stipulating communication and cooperation of supply chain actors towards safer (handling of) chemicals by its composition and the rules of procedure. However, data quality potentials of peer-review study use not fully exploited	(+) BREF process with its established elements of inclusion of "interested parties" (-) No inclusive governance formats on local or regional levels are provided; on a voluntary basis companies established "neighbourhood circles" to enable continuous communication	(-) REACH (-) Product law (o) Further initiatives: some sector solutions are more inclusive, involving e.g. a multi-stakeholder Steering Committee which define reporting rules

Table 14: (table 13 continued) Coverage of regulatory elements supporting Learning Processes (applied to stages 4, 5 and 6)

	B. Regulatory elements supporting Learning Processes	Eco Design Dir. Coverage	Use and after Use Phase under REACH	Waste Framework Directive
1	**provide transparency** on the chemical, its properties and use as well as the (possible) impacts on human health and environment	(o) chemicals used in the production process of an article are covered by the scope; however, the practical implementation up to now does not include this issue	(o) covered by the legal text; however, the quality of the registration dossier seems to fail the legal requirements to a large extent	(+) transparency with regard to SVHC above 0,1% is supported by the obligation in Art. 9 (1) WFD to report to the ECHA database.
2	provide **incentives to communicate** information referred to in 1 to relevant supply chain partners and other stakeholders	(-) out of scope	(o) covered by the legal text with respect to SVHC in articles above 0,1%; (-) no communication mechanisms are foreseen for the end of life phase	(-) out of scope; however the communication obligation under Art. 33 (1) REACH is indirectly underpinned by Art. 9 (1) WFD
3	provide **incentives** to include GCP in **research** strategies and activities	(-) out of scope	(o) due to additional burdens for "problematic" substance an indirect incentives is provided by the REACH mechanisms	(-) out of scope; however the two findings mentioned above indirectly serves as an incentive to exclude SVHC from the material stream in the supply chain.
4	offer **formalized participation possibilities** (in administrative procedures)	(-) no administrative procedures	(-) not for use and after use phase	(-) no administrative procedures
5	provide elements of **continuous inclusive governance** formats	(+) In the context of defining and reviewing implementing measures and related benchmarks	(-) not for use and after use phase	(-) no inclusive governance formats are foreseen in the WFD; however the public access to the ECHA database will allow third parties to investigate the efforts in the various supply chains.

The main deficits ("delta") summarized in the tables above are addressed in the discussion of the policy option in chapter 5.

5
Policy Options

When assessing the available policy options the favourable systematic approach can be summarized as: "follow the trace of design decisions". These decisions, however, are influenced by a set of system conditions which ultimately occur as motivational factors for the individual actors. Most influential might be the predominant business routine in the respective sector reproduced by the professional "thought collectives" and the corresponding "thought-styles".[181] The organisational culture of every industrial actor involved in design decisions is coined by these factors. Hence, in order to initiate the learning process towards a "greener chemistry" it is not sufficient to shift the economic incentives. Rather, a more fundamental mind shift seems to be necessary. In this respect, all six stages of the "design cycle" have to be revisited in order to identify the most relevant motivational gaps and the related system conditions. The latter can be distinguished in the levels on which institutional adjustments can be envisaged: regulatory options on the macro level (section 5.1) and additional institutional options on a meso-level (section 5.2). The overall context finally can be influenced by other institutional options (section 5.3), such as enhancing university and other professional training programmes towards GCP.

In practice not all GCP can be fulfilled at the same times. Hence, trade-offs are to be taken into account and managed: From a legal perspective in most cases risk reduction will prevail over resource efficiency. However, different endpoints and related hazard categories are difficult to compare. Besides, it is often difficult to say whether a higher risk is at stake since this depends on the use conditions. The same is true if different resources are to be consumed in a life cycle perspective. Thus, the policy framework can only offer general normative orientation in substantive terms. The appropriate balance between the various aspects has to be found on a case by case basis. The process towards this decision, however, can be supported by a procedural framework assuring that different perspectives are included in a fair manner allowing contrast information and third parties representing diffuse interests to play a meaningful role in the process.

5.1
Regulatory options

Based on the delta analysis (cf. chapter 4, summarized in the tables in section 4.6) this section offers regulatory options to enhance the existing EU leg-

[181] Both terms are created by *Ludwig Fleck* (1983) in the course of his analysis of innovations in (natural) sciences.

islation (i.e. the macro level), as policy frameworks, including regulatory requirements, have a significant impact on companies' performance in terms of Green Chemistry.[182] The options are discussed within the given regulatory scope of the different legislative acts. The REACH registration mechanisms, e.g., focus on substances and the use by other industrial actors along the supply chain (see section 5.1.1); while the production of the substances is covered by legislation on industrial installations (5.1.2). The design of the "final" products falls within the scope of the product related framework (5.1.3), including the Ecodesign framework (5.1.3.1). In addition, crosscutting issues are discussed in section 5.1.4.

5.1.1
Substance related legislation (REACH)

The GCP address the production process of the chemical substance whilst the scope of REACH is focussing on the substance "obtained by any manufacturing process" (Art. 3(1) REACH) and the following steps in their life cycle; thus regulatory policy options addressing the production phase are to be discussed in the context of industrial installation legislation (see section 5.1.2). Options related to the requirements for articles in REACH are introduced in section 5.1.3.2.

The GCP formulate a cross-cutting approach covering the various REACH mechanisms. The visibility of the GCP concept could be supported by non-regulatory policy options (see also section 5.2). In particular the ECHA guidance documents could exemplify how to manufacture substances in accordance with the principles of Green Chemistry, underpinned with best practice examples (an option to include this approach can be an annex to the ECHA document "Part A: Introduction to the Guidance Document"[183]).

Additional incentives fostering learning processes towards the GCP may include seminars and webinars as well as problem orientated research initiatives (see section 5.3). By this means the design of safer chemicals and the GCP addressing resource efficiency can be underpinned.

5.1.1.1 Substances under the registration regime

The main focus of the registration regime in REACH can be seen – based on the information requirements in the registration process in order to overcome the "toxic ignorance" problem – in the obligation to "adequately control" the substance related risks. Addressees of this "basic obligation" (laid down in Art. 14(6) and 37(5) REACH) are manufacturers and importers as well as

[182] GC3 2015, 11.

[183] Download under: https://echa.europa.eu/guidance-documents/guidance-on-information-requirements-and-chemical-safety-assessment (30.10.2019).

downstream users. However, as a precondition that REACH stimulates innovation towards the GCP the mechanisms to assure compliance with the data requirements in the registration regime are to be enhanced. In this context the duty to update the registration dossier are to be reinforced and underpinned by adequate communication mechanisms enhancing the visibility of new data for all actors involved (see last paragraph of this section).

In the regulation as it stands no obligation in the sense of "continuous improvement" towards the GCP can be found. In particular, principles 4 "design safer chemicals" and 10 "design for degradation" would be in line with the aim laid down in Art. 1(1) REACH: the regulation aims at "enhancing competitiveness and innovation" – both in the direction of a "high level of protection of human health and the environment". Innovation towards safer chemicals would in most cases serve as a competitive advantage.

A model for such a dynamic general duty for registrants can be seen in the "basic obligations" of the operator of an industrial installation laid down in Art. 11 IED. Thus, a "safer design" provision might be inserted as para 6a to Article 14[184] REACH along the following lines:

> "Any registrant shall identify options to design substances in order to preserve efficacy of the function while reducing toxicity."

In Article 37 a new para 5a could be inserted as follows:

> "Any downstream user shall identify options to design the use[185] of substances and mixtures in order to preserve efficacy of the function while reducing toxicity."

Both basic obligations can be characterized – in a material law perspective – as guiding principle. Thus they have to be underpinned by procedural obligations; e.g. a duty to document the efforts towards a "safer design" in the registration dossier. Annex I should be aligned accordingly. Even with this procedural context the guiding principle would not directly influence the design decisions; however, an additional incentive to consider these aspects would have been introduced. Together with the other policy options discussed in this chapter, however, behavioural effects are to be expected.

These effects should be further underpinned by information flow mechanisms supporting the communication between "third parties" (under REACH) and the registrants in a way that is transparent for ECHA and the Member States competent authorities. Options in this respect include, e.g., the "WikiREACH"-approach[186], fostering use of, mostly academic, peer-reviewed

[184] This would cover substances registered in the tonnage band above 10 t/a. As a starting point to include this obligation into the registration regime this seems to be appropriate. At a later state the obligation might be enlarged to substances above 1 t/a.

[185] The wording refers to the definition in Art. 3(24) REACH.

[186] Agerstrand et al. 2017

studies for the dossier preparations and updates, or the ChemSec "Marketplace"[187]. These platforms would contribute to the data quality of the registration dossiers in general and to the new design obligation in particular. At the same time, these instruments foster continuous inclusive governance (LPP 5).

5.1.1.2 Substances under the authorisation regime

The procedure to handle applications for authorisation (AfA) offers room for improvement in terms of GCP 4 "design safer chemicals" and 10 "design for degradation". Third parties should be encouraged to provide elaborated information on available greener alternatives to the use of SVHC. Tailored support for third parties, including conducting expert studies or by granting compensation for well-structured and relevant information should be considered. In combination with proactive networking by the authorities and examples for "meaningful contributions" to the decision making process additional incentives for innovation towards GCP can be provided establishing a level playing field for the alternative assessment and for (functional) substitution in the authorisation procedure.[188]

Besides, in substantive terms, adjusting the assessment focus in the AfA context could be considered. In this respect, the main preparatory report on the "non-toxic environment" proposes (more) emphasize of the substance's specific functions (functional substitution) as this "should ensure that entirely new chemical structures, and even non-chemical solutions such as new materials or processes, are considered in the assessment".[189]

5.1.1.3 Process orientated research and development (PPORD)

An additional set of options aims to provide more normative orientation to PPORD substances, thus aligning the REACH PPORD scheme with the regulation's objective to foster innovation contributing to a high level of protection (Art. 1(1) REACH).

In short-term perspective, a mechanism in the AfA context could be established that requires consideration of PPORD substances as potential substitutes. This would increase incentives for innovators to design safe substances in terms of GCP 4 and 10. Prerequisite for such a mechanism are however additional information requirements for PPORD notifiers, related e.g. to substance functionality to allow for meaningful alternatives assessment. The

[187] For details, see https://chemsec.org/

[188] Essential part of each granted authorisation finally should be a decision on the monitoring concept to be elaborated and documented by the applicant. For a proposal for the wording of an implementing regulation cf. Führ et al. 2011.

[189] Milieu Ltd et al. 2017, 44 with reference to Fantke et al. 2015.

agency, which holds all PPORD notifications, could feed in PPORD inputs to the AfA context.

In long-term perspective, another option addresses the integration of the REACH principle of substance responsibility also in the PPORD context. For this approach, the following elements could be considered:[190]

> PPORD notifiers become applicants for a PPORD exemption, who have to submit a dossier to ECHA in which they relate to (1) uses for which the PPORD substances can be applied as substitute, (2) other substances currently applied for such uses, (3) comparison of the PPORD substance's and the other substances´ hazard potential. If the data show that the PPORD substance has a lower hazard potential, the PPORD exemption is to be granted. If, in contrast, the hazard potential of the PPORD substance is more severe or equals the hazard potential of the other substances, in order to receive an exemption, the applicant has to conduct a (focussed) socio-economic analysis aimed to establish that the benefits outweigh the toxic profile. This analysis should take into account the entire life-cycle of the PPORD substance in the pursued use(s) and could include as well other e.g. resource related criteria. RAC and SEAC could evaluate such analyses.
>
> While the REACH authorisation scheme aims to remove selected SVHC off the markets, this new PPORD mechanism aims to provide markets only for substances with low toxic profiles.

However, with respect to this option in particular, a thorough analysis of the practical impact is needed. Research questions include, whether this mechanism could "penalize" innovative behaviour and which corresponding measures[191] could attenuate such effects.

5.1.2 IE- and Seveso Directive

The analysis shows (see section 4.2.5) that the regulatory framework established by the Directives on "industrial emissions" and on "major-accident hazards involving dangerous substances" contains certain elements that contribute the GC principles. In particular, the "basic obligations" are addressing production process oriented and resource related objectives of Green Chemistry: With regard to GCP 1, on the legal level, waste prevention is one "basic obligation" for industrial installations (Art. 11(d) IED); however, implementation lacks straightforward guidance due to the complexity of the various production processes and thus the requirements are scarcely enforced by the authorities. Waste prevention regularly contributes to reduce the resources

[190] Expert interview M. Wimmer.

[191] PPORD privileges are defined vis-á-vis registration requirements. Aligning also the registration process by introducing a focussed SEA might thus show one possible way forward.

employed in the production process (GCP 2); consequently, deficits in waste minimization requirements trigger shortcomings in resource efficiency as well. Similar deficits are to be stated with regard to energy efficiency (GCP 6/Art. 11(d) IED). Of particular importance with respect to the GCP is IED Annex III with its criterion 2 providing to determine the BAT in a way that promotes "the use of less hazardous substances"

For those classes of industrial installations where BREF/BAT-documents exist they are well behind the level of ambition captured in the GCP. The development and updating BREF documents is a quite tedious process, and thus – if only due to the course of time – face the difficulty to keep up with the technical progress and the related potential for greener chemistry.

In order to close the "delta" summarized above one option might be[192] to enhance scope and accuracy of the BREF/BAT documents, in particular with regard to GCP 3 (safer chemical synthesis) und GCP 5 (safer solvents etc.). To this end, the "guidance on the collection of data and on the drawing up of BAT reference documents" [193] should be enhanced in order to cover GCP to a higher extent. As for resource efficiency (GCP 1, 2 and 6), e.g., the input/output[194]-ratio could be evaluated and, where appropriate, integrated in the BAT conclusions. Additionally more emphasis could be laid on the benefits that might be gained by using the interfaces between IED and the Water Framework Directive[195] as well as the REACH Regulation[196] and the data generated under the PRTR Regulation.[197]

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[192] The issue deserves a deeper analysis which goes beyond the limits of this study; however two examples are given, cf. footnotes 202, 203 and 204.

[193] See Commission implementing decision of 10 February 2012, C(2012) 613, OJ L 63/1 as of 2.3.20012.

[194] Output in terms of emissions, including the waste stream.

[195] For suggestions in this direction, see Kleihauer et al. 2015: SMART protection objectives for priority hazardous substances (EC/2008/105).

[196] The issue was discussed in the context of the 23rd Forum of the Industrial Emissions Directive (IED). The European Commission presented the working document on the "Reconsideration of the 'Strategy to review the chemical BREF's'" at the 36th meeting of the ECHA management board in December 2014 and agenda item 8 (based on a letter from the EEB as of December 15, 2014); cf. ECHA document MB/M/04/2014, 7:
"With regard to a letter received from the European Environment Bureau on possible synergies between EU legislation through technical work of ECHA in the area of BREFs, the Director of Risk Management confirmed that the proposal appears sensible and it would probably not constitute a significant resource investment for ECHA to carry out the suggested work, should the Commission decide to request this support from ECHA.".

[197] In this respect the input to the Workshop in the context of the REFIT process (Brussels, 4 November 2015, facilitated by Amec Foster Wheeler Environment & Infrastructure UK Limited) should be considered.

However, the speed of technological innovation is in most cases much faster than the update processes. Thus, other means of promoting "state of the art" resource efficiency are to be considered. Publicly accessible information exchange platforms, based on stringent reporting criteria[198] could serve as an intermediate source between two versions of a BREF/BAT document. Mechanical engineering companies and the operators or industrial installations as well as the regional enforcement authorities could be obliged to consult the platform on a regular basis; e.g. every second year, and consider whether an update of the production process and the authorisation conditions are adequate in the light of the "basic obligations" of the IED.

A third option might be seen in taxes laid either on the input or the output stream. Options in this direction are currently considered in the context of the second edition of the UNEP/SAICM "Global Chemistry Outlook". [199]

5.1.3
Product related legislation

Product related legislation does not address chemical design and synthesis. However, it may unfold opportunities for Green Chemistry by providing the appropriate frameworks for learning process in the direction of product design using "safer" chemicals. Following the deltas identified at Stages 3 and 4, this section introduces relevant options in the contexts of the Ecodesign Directive (5.1.3.1), REACH (5.1.3.2) and sectorial legislation (5.1.3.3).

5.1.3.1 Ecodesign Directive

As regards the Ecodesign Directive (ED), the analysis shows huge potentials for improved integration of Green Chemistry, taking into account environmental effects along the entire product life-cycle. One could also argue that the ED potentially establishes the most suitable horizontal approach to address chemical and other environmental aspects in a product context.[200] In this respect, two cumulatively applicable options appear appropriate: option (1) addresses the existing framework's implementation, i.e. without amending the Ecodesign Directive and another option (2) its extension to not energy-related products through amendments.[201]

From a legal point of view, implementation measures could make more use of the existing mandate provided by the directive to link design criteria for ener-

[198] Art. 13(2) IED and the Guidance C(2012) 613 could serve as a basis.

[199] UNEP 2019, 58 (with further references).

[200] Poulsen et al. 2010, 78.

[201] Section 4.4.1.1 identified inert benchmarking as additional challenge, which will be addressed by the institutional option in section 5.2.2.

gy-related products to legislation on the marketing and use of specific substances. To this end, option (1) comprises of three structural elements,[202] i.e.:

a) *Definition of problematic substances list*, including as a minimum SVHC from the candidate list, the (potential) presence of which in articles should become more and more transparent.[203] In addition, substances classified[204] as fulfilling the criteria of REACH Art. 57 should be considered[205] as well as substances classified as respiratory sensitizers, depending on the available article specific data.[206] When determining criteria for the substance list, deliberations by the Commission to define "Substances of Concern"[207] also should be take into account.

b) *Assessment of the list (a.) and substitution potentials in preparatory studies*, i.e. systematic consideration of whether listed substances are included in the products of the product group in question; what function these substances have in these products; how alternatives[208] (including non-chemical solutions) could achieve this functionality.

c) *Development of implementing measures* addressing the entire product (groups) or just certain components, subject to particular concern.

Option (1) thus entails merely adaptations of the procedures and non-legal framework (e.g. review MEErP, probably composition of expert groups). Potential synergies with the structures established in the context of the EU Ecolabel Regulation could support efficient allocation of resources.[209]

The ED as it stands applies to energy-related products. Option (2) therefore aims at expanding the scope to not energy-related products.[210] In fact, this

[202] Cf. Reihlen et al. 2013, 21 and Ardente and Mathieux 2012, 68.

[203] As awareness of REACH Art. 33 increases due to more focussed enforcement activities (https://echa.europa.eu/de/-/enforcement-project-to-check-compliance-with-the-obligations-of-substances-in-articles), implementation projects such as LIFE AskREACH (section 4.4.5) and, notably, the SVHC notification obligation introduced by the revised WFD (section 4.3.3).

[204] Cf. Annex I, Part 1, Section 1(3)(d) ED listing as an example substances "classified as hazardous". It needs to be assessed whether the ED mandates the regulation of substances fulfilling the criteria of REACH Art. 57, which are not reflected by CLP, i.e. e.g. PBT, vPvB and EDC.

[205] Art. 6(6) of EU Ecolabel Regulation introduces the same scope.

[206] Cf. Reihlen et al. 2013, 21 referring to additional groups of problematic substances deemed relevant.

[207] Cf. the thought starter set out in SWD(2018) 20 fin, 9.

[208] For a proactive approach see the substitution criteria defined by the European car industries together with chemical supplier BASF, cf. https://chemicalwatch.com/65734/basf-and-auto-industry-group-agree-substitution-criteria (9.9.2018).

[209] Poulsen et al. 2010, 78.

[210] As regards the legal framework conditions for such amendments, cf. the analysis by Schomerus and Spengler 2012, 8.

option is already anticipated by Recital 39 of the ED. An expansion could address (certain groups of) REACH articles, which, with a view to their chemical content, are not subject to specific sectoral legislation, such as textiles and furniture. In addition, setting ecodesign requirements for specifically regulated products, such as toys, should be possible to address regulatory gaps or to complement existing law with additional (e.g. information) obligations.[211]

5.1.3.2 Requirements for articles in REACH

A more specific definition of the registration requirements as to information on the use of a substance in an article would probably significantly enhance the exposure scenarios in the registration dossiers. Essential for this purpose is information regarding the concentration of the substances in the articles, data on migration and release rates (which often are material specific) as well as changes over time in this respect. Furthermore, the registered uses should not be too broad and unspecific. As a result, this would increase the informative value of exposure scenarios for the protection of consumers and the environment, but also for occupational safety in industrial and professional settings in which articles are used. More detailed specifications on substances in articles are also the best strategy to gain more knowledge about unintended releases.[212]

Mindful also of the Commission's mandate to, by 1 June 2019, assess whether or not to extend the scope of REACH Article 33 to cover other dangerous substances, taking into account the practical experience in implementing that Article (Art. 138(8)), the following additional options should be considered:

- Encourage proper EU-wide enforcement of Art. 33, e.g. by upscaling the FORUM pilot project in this respect[213]
- In order to overcome uncertainties related to the consumer "right to know", an answer to the consumer should be obligatory also in cases, where an article does not contain SVHC above 0.1% per weight
- In order to make the consumer "right to know" more practicable, overcome design flaws of Art. 33(2) by reducing the timeline for the reply to a more reasonable period, from 45 day to e.g. 3 days with the aim for an immediate electronic reply.
- Awareness raising campaigns on the consumers' right-to-know of SVHC in articles according to Article 33(2) could complement this approach.[214]

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[211] Cf. the interplay between RoHS and the ED in the status quo.

[212] Führ et al. 2015, 142 et seq.

[213] This reflects "Action 13: Enhance enforcement", COM(2018) 116 fin; cf. ECHA 2017, enforcement.

[214] Reihlen 2017, 16; the AskREACH project comprises a REACH Art. 33(2) consumer campaign launched in various member states simultaneously, cf. www.askreach.eu

5.1.3.3 Sectorial product legislation

In the context of the development of a "non-toxic environment" proposals with regard to procedural elements of product policy have been made: These include, i.a.,[215] "*the development of methods and guidance for an appropriate assessment of safety/risks from substances in articles. In addition, chemical safety of articles should include the management of environmental risks from toxic substances in articles.*" Thus sectoral product legislation should explicitly formulate IC&C requirements. Articles, as defined by REACH, often end up as "products" for professional or private users. In order to enable informed decision-making a centralised information collection and publication of information on substances in articles would reduce transaction costs on the part of the suppliers as well as for consumers.

5.1.3.4 Cross-sectorial product legislation

Looking at the EU product legislation at large a fairly fragmented patchwork of legal provisions is to be observed. By contrast the EU framework the legal provisions addressing the production process have reached a comprehensive level and are consolidated in the Industrial Emission Directive and its by-laws. With regard to emissions to water and air substantial progress has been reached in the last thirty years. The main area of improvement potential towards the GCP is to be identified in the product design and the related supply chain interaction triggering innovation processes towards GCP. Thus a comprehensive "Product Framework Package" merging the different pieces of legislation and filling the existing gaps (as proposed above) should be considered.

In this context not only requirements formulated in public law – as analyzed in this study – should be considered: In order to promote innovation processes also the legal context in pri-vate law, such as stepwise prolonged warranty for a product and its performance, should be taken into account.

5.1.4
A horizontal policy approach

A report for the European Commission in the context of the "Strategy for a non-toxic environment", discusses briefly the concept of a horizontal product policy, i.e.

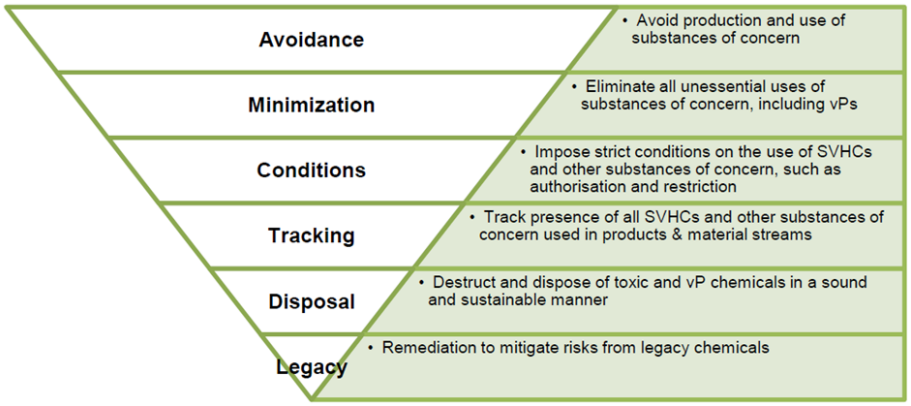
> "the need for an additional, overarching, horizontal policy process or platform with the overall objective of minimising human and environmental exposures to chemicals of concern and drawing on a range of different instruments and measures."[216]

[215] Reihlen 2017, 16.

[216] Milieu Ltd et al. 2017, 118.

Such an approach could facilitate the integration of chemical policies across the 5 stages, e.g. via horizontally applicable chemicals-related principles. At the same time, it would be a chance to foster Green Chemistry, perhaps facilitating adaptions of the different frameworks or even gaining synergies between different sectoral frameworks within the existing legislation. To this end, the report offers additional procedural options, including screening mechanisms for new chemicals and better information sharing, more training and capacity building.[217]

The report introduces some initial ideas on how to flesh out such an approach by means of the combination of several elements. In addition, the authors propose to establish a hierarchy in chemicals policy and management, similar to that which guides EU waste management policy (see Figure 3).



source: Milieu Ltd et al. 2017, 120

Figure 3: Hierarchy for chemicals policy in a horizontal approach

The objectives of this hierarchy also reflect the Green Chemistry approach. Defining "avoidance" as the default, in particular, is coherent to GC, which prefers hazard prevention over risk management. From a stricter GC perspective, though, "avoidance" should be defined along the lines "avoid production processes and use of substances, which are not consistent with GC".

Should the final "Strategy for a non-toxic environment" – or any of its successors – envisage such a horizontal approach, this would open up a window of opportunity to enhance it by further integrating the Green Chemistry Principles. One option might be reflecting on this hierarchy in performing the European Commission regulatory Impact Assessment as well as in the supporting staff working documents and the studies carried out in the preparation phase.

[217] Milieu Ltd et al. 2017, 118.

5.2
Institutional options on the meso-level

In addition to the regulatory options, the following sections further elaborate on two institutional options regarding meso-level support of substances in articles communications as well as an open stakeholder-driven platform "Product Design for Green Chemistry".

5.2.1
Full material declaration (FMD) on substances in articles

Regulatory requirements create the level playing field for innovation on a macro-level. However, in most cases they are not sufficient to initiate innovation processes towards the GCP (or, likewise, oriented towards the UN-SDG´s). On the other hand actors in companies or other organisations on their own do not have the capacity to innovate entire supply chain systems. Thus the micro-level needs support from institutional arrangements on the meso-level, such as sectoral or cross-sectoral coordination. Meso-level support can i.a. improve efficiency of supply chain management activities of the single actors.

About 90 % of the environmental impact on air, land, water, biodiversity of a typical consumer article manufacturing company occur in its supply chain.[218] Supply chain management is thus pivotal for the minimised use of harmful substances. Legislators are increasingly addressing this issue; e.g. REACH Art. 33 requires suppliers to communicate downstream information on SVHC in articles. Companies need thus to establish transparency in their chains, which reaches beyond their tier 1 supplier (e.g. the importer). Enforcement of restricted substance lists (RSL) is indispensable (which substances must not be included in articles – "negative reporting"). In addition, the automotive sector as well as some companies from other sectors (mostly electronics) combine negative reporting with positive reporting, aimed at full material declaration (FMD). FMD means declaration of supplied (part) products down to basic substance level, i.e. all substances used and not only the regulated ones. With this degree of traceability, companies can actively manage and control the substances used for the making of their articles. [219] This is an obvious advantage in view of dynamic regulatory substances lists such as the "candidate list", which is updated twice a year, since a company aware of all chemicals in its products can ensure to be compliant today and tomorrow concerning future requirements. Moreover, transparency and traceability of substances in articles is a pre-condition not only for compliance but also for substitution.[220] Supplemental information such as test reports, emissions of greenhouse gases

[218] McKinsey 2016.

[219] Schenten et al. 2018.

[220] Cf. "Action 5: Promote substitution of SVHCs", COM(2018) 116 fin.

(product carbon footprint, PCF), material sources and human rights monitoring data can be easily linked to FMD datasets.

Against this background, a study on behalf of the commission concludes that "[t]he use of complex IT solutions should generally be promoted, at least in complex supply chains, as the benefits of using them appear to generally outweigh the costs, also for small companies. The benefits would increase with the number of tool users and the extent of supply chain coverage".[221] From a meso-perspective, EU policies should support (inter-)sector solutions which support proactive companies heading for FMD and at the same time support companies with limited capabilities in this respect, for which achieving communicating compliance declarations (e.g. article x does not include SVHC above 0.1%) would be the first milestone on the way to FMD. In addition, proliferation of sector requirements could be reduced, and suppliers' willingness to cooperate in turn increased, if sector approaches were interoperable and data easily interchangeable. In this respect, understanding the capabilities and limitations of communication standards applied by different sectors, and thus also by tools providing IT solutions for such sectors, is pivotal. A "Proactive Alliance" of different industry representatives initiated in 2018[222] therefore aims to formulate policy recommendations on standard design.

5.2.2
Platform: Product design for Green Chemistry

Commitments to Green Chemistry implies the need to adapt product and production design accordingly. To this end, this study argues that Green Chemistry needs to be considered already in product (and production) design, as e.g. use of problematic substances in a product can be avoidable depending on its design. In this respect, a major challenge for actors can be finding appropriate (non-) chemical substitutes, which contribute to GC while avoiding regrettable substitution and at the same time not compromising a product's or processes' purpose as well as economic viability. Besides, the dynamic nature of GC adds significantly to complexity.

One option to tackle this challenge is establishing a learning process specifically aimed at product design for Green Chemistry, which stimulates the interaction and creativity of all actors[223] along the product life-cycles, while also integrating additional stakeholders e.g. from science bringing in contrast information. This broad design perspective could also help to solve trade-offs among the GCP, and potentially also between Green Chemistry and other environmental aspects. A platform could structure this process, which should be

[221] Reihlen and Halliday 2017, 68.

[222] Note **Fehler! Textmarke nicht definiert.**.

[223] See also Tickner and Jacobs 2016, 27.

voluntary and driven by private actors[224] while normative goals can provide guidance. State actors should create incentives to motivate actor participation by providing funding and by supporting the organisation and administration of the complex networks.

Measured by these aims, existing networks for product design are a good basis but incomplete in scope as they address mostly the resource efficiency perspective, but do, at least not specifically, address the role of problematic substances (Annex III). The latter aspect is at the centre of various specific platforms focussing chemicals in the context of sustainable development (see Annex II). In addition, the "cradle to cradle" approach can provide guidance for design for circularity.[225] A platform aimed to facilitate product design for Green Chemistry needs to integrate all mentioned perspectives.

One module of the platform should support alternatives assessment and chemical substitution. Also in this respect, many toolboxes and databases exist, which provide guidance on the substitution process as well as case study reports documenting success stories with respect to specific substitution challenges.[226] However, these approaches are rather reactive and their practical effects therefore are presumably limited.

Actual market impulses can provide additional stimuli to the "Product Design for Green Chemistry" Platform. The "Market Place" developed by the Swedish NGO ChemSec might stand as a role model as it seeks to bring together supply and demand in the context of chemical substitution[227] and stands for a more proactive approach to substitution. On the one hand, providers of such solutions can create entries for their products in a searchable database. On the other hand, potential customers can place a call for specific substitution needs at the ChemSec tool.

5.3
Other institutional options

Additional institutional options aim at capacity building and stimulating market impulses as well as learning processes for Green Chemistry. Research initiatives, both on EU and on company level, could address specific problems in the context of the GCP.[228]

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[224] See e.g. the US based Green Chemistry & Commerce Council (GC3), https://www.greenchemistryandcommerce.org/ (11.9.2018).

[225] Cf. https://www.epea.com/cradle-to-cradle/ (12.10.2018).

[226] Cf. the overview at Camboni 2017, 23.

[227] See https://marketplace.chemsec.org/ (11.9.2018).

[228] See, e.g., the dutch initiative for a "Safe Chemicals Innovation Agenda -Towards a Research Agenda for Safe Chemicals, Materials and Products" and the outcome of the related workshop held in Amsterdam on March 28, 2018.

Chemistry related university and professional training programmes should put more emphasize on Green Chemistry "design thinking" approaches based on problem-based learning and multidisciplinary contributions to tackle the challenge.[229] Further options include scaling up research and Green Chemistry entrepreneurship and start-ups[230] as well as a more nuanced Green Public Procurement. The related Communication by the European Commission was published in October; it aims to "encouraging the use of innovative, green and social criteria" to make the most out of public procurement.[231]

[229] Milieu Ltd et al. 2017, 50, 88; cf. note 48 supra.

[230] UNEP 2017.

[231] COM(2017) 572 fin, SWD(2018) 16 fin, 91.

6
Conclusions

Assessing the current situation and showing options to further integrate the "Green Chemistry Principles" (GCPs) into the regulatory framework of European chemicals policy is the objective of this study. Green Chemistry (GC) is the utilisation of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products. Besides, reaction efficiency, including energy efficiency, and the use of renewable resources are other motives of Green Chemistry. Putting the GC concept in a broader market context, however, it can only prevail if in the perception of the relevant actors it is linked to tangible business cases. Therefore, the study analyses the product context in which chemistry is to be applied, as well as the substance's entire life-cycle – in other words, the six stages in product innovation processes (cf. section 2.2):

1. Substance design,
2. Production process,
3. Interaction in the supply chain,
4. Product design,
5. Use phase and
6. After use phase of the product (towards a "circular economy").

Green Chemistry aims at continuous improvement processes integrated in the (re-) design of chemical substances, of processes and products. Hence, the different actors of the supply chain have to interact in a way that prepares the ground for GC innovation. Against this background, the assessment criteria for the regulatory framework (cf. section 3.4) have to reflect the principles of Green Chemistry (GCP), but also the capability of the regulatory framework to foster learning processes by providing transparency and inclusive governance elements (Learning Process Principles – LPP) (both captured in Table 14).

The report presents an overview to what extent the existing framework, i.e. legislation and the wider institutional context along the six stages, is setting incentives for actors to adequately address problematic substances and their potential impacts, including the learning processes intended to invoke creativity of various actors to solve challenges posed by these substances (cf. chapter 4). In this respect, measured against the GC and Learning Process assessment criteria, the study identified shortcomings ("delta") at each stage of product innovation (cf. section 4.6).

Some criteria are covered by the regulatory framework and to a relevant extent implemented by the actors. With respect to those criteria, there is thus no

priority need for further action. Other criteria are only to a certain degree covered by the regulatory framework, due to various and often interlinked reasons. For those criteria, entry points for options to strengthen or further nuance coverage of the respective principle already exist.

A. Green Chemistry Principles		B. Learning Processes Principles	
1	prevent waste	1	provide transparency on the chemical, its properties and use as well as the (possible) impacts on human health and environment
2	maximize atom economy	2	provide incentives to communicate information referred to in 1 to relevant supply chain partners and other stakeholders
3	design less hazardous chemical synthesis	3	provide incentives to include GCP in research strategies and activities
4	design safer chemicals	4	offer formalized participation possibilities (in administrative procedures)
5	use safer solvents/conditions	5	provide elements of continuous inclusive governance formats
6	increase energy efficiency	(6)	(include GCP in the curricula of university and other professional training programs)
7	use renewable feedstocks		
8	avoid chemical derivatives		
9	use catalysts		
10	design for degradation		
11	analyze in real-time to prevent pollution		
12	minimize the potential for accidents		

Table 15: Overview assessment criteria

Most relevant are the deltas with regard to those instruments that influence the design phase; both for the chemical substance as such and for the end-product containing the substance. Due to the multi-tier supply chains, provisions fostering information, communication and cooperation (IC&C) of the various actors are crucial to underpin the learning processes towards the GCP.

The policy options introduced in chapter 5 aim to tackle these shortcomings in the context of the respective stage in order to support those actors who are willing to change their attitude and their business decisions towards GC. The findings are in general coherence with the strategies identified by the Green Chemistry & Commerce Council to foster GC.[232] The following policy options comprise of EU regulatory options (macro level) as well as institutional options on the meso-level:

[232] *Inter alia* smart legal requirements, enhancement of market dynamics; facilitation of actor collaboration and flow of information about green chemistry solutions among suppliers and product makers, cf. GC3 2015, 16.

- **Stage 1 substance design**: Policy instrument: REACH Regulation

  Addressing delta: "safer design" (GCP 4), "design for degradation" (GCP 10) and "inclusive governance" (LLP 5)

  - Adaptation of REACH by introducing new Articles 14 (6a) and 37 (5a) to implement the basic obligation of "safer design" (GCP 4) and "design for degradation" (GCP 10) (find more details in section 5.1.1.1)
  - Improvement of the procedure to handle applications for authorisations (AfA) (Art. 64 REACH) by supporting third parties in AfA to provide relevant information on alternatives (section 5.1.1.2)
  - Creation of a mechanism in the AfA procedure to take into account PPORD substances in AfA alternatives assessment (Art. 64 REACH) (section 5.1.1.3)
  - Consider of a new chapter in REACH Title II implementing the REACH principle of substance responsibility in the PPORD context (section 5.1.1.3)
  - Establish a digital dashboard to address the science-policy-gap ("WikiREACH") in order to foster data quality (section 5.1.1.1)

- **Stage 2 production process:** Industrial Emission Directive (IED)
  Addressing delta: "prevent waste" GCP 1, "resources efficiency" (GCP 2), "safer chemical synthesis" (GCP 3) and "increase energy efficiency" (GCP 6)

  - Explore the possibilities to enhance of the scope and accuracy of the BREF/BAT documents in the context of the JRC Sevilla process under the IED, regarding the above named GCPs (section 5.1.2); in particular with respect to the use of less hazardous substances, resource efficiency and waste prevention.

- **Stage 2 production process:** Industrial Emission Directive (IED)
  Addressing delta: "inclusion of GCP in research strategies and activities" LPP 3

  - Utilisation of the information exchange platform for the enhancement of BAT under the IED (operated by the European IPPC Bureau, JRC Sevilla) to provide specific "incentives for the inclusion of GCP in research strategies and activities" (LPP 3) (section 5.1.2)

- **Stage 2 production process:** Industrial Emission Directive (IED)
  Addressing delta with regard to the input streams: "prevent waste" (GCP 1) and indirectly "maximize atom economy" (GCP 2) and "use renewable feedstocks" (GCP 7)

- Enhance the scope of the basic obligations in terms of use of renewable feedstock as well as the explicit obligation of the applicant to demonstrate that the "use of less hazardous substances" has been considered with the view of eliminating substances of concern in order to "rectify at source" the related emissions, both from the plant itself but also in later stages of the life cycle of the products that leave the plant.
- Introduction of taxes on raw materials on the IED governed input streams based on Council Consensus or national legislation (section 5.1.2)

• Stage 3 Interaction in the supply chain: REACH Regulation context. Addressing delta: "communicate on substances along the supply chain" (LPP 2)
  - Implementation of a full material disclosure reporting in article supply chains as a meso-level approach based on a stakeholder driven process and public support to improve the communication of information (section 5.2.1)

• Stage 3 Interaction in the supply chain: Sectoral product legislation. Addressing delta: "communicate on substances along the supply chain" (LPP 2)
  - Formulation of explicit Information, Communication & Cooperation (IC&C) requirements in sectoral product legislation to enable informed decision-making, centralized information collection and publication of information on substances in articles (alternatively implemented via "Horizontal policy approach on substances in articles"; see below) (section 5.1.3.3)

• Stage 4 Product design: Ecodesign Directive (ED).
  Addressing delta: "provide transparency on the chemical, its properties and use as well as the (possible) impacts on human health and environment" (LPP 1)
  - Modification of informal procedures and expert groups to better integrate problematic substances into ED implementation (section 5.1.3.1)
  - Adaption of ED to expand the directive's scope to not energy-related products (section 5.1.3.1)

• Stage 4 Product design: REACH Regulation.
  Addressing delta: "provide transparency on the chemical etc." (LPP 1) and "communicate on substances along the supply chain" (LPP 2)
  - Specification of the information requirement on the use of substances in articles in REACH Annex VI Section 3 and Annex I Sections (e.g.

0.7, 0.8 and 5) to increase the informative value of the exposure scenarios in the registration dossiers (section 5.1.3.2)

- Expansion of the consumer "right to know" regarding SVHC by adapting the REACH Art. 33(2) to make answers to the consumer in any case obligatory and reduce the time frame to respond (section 5.1.3.2)

- Cross-cutting issues
  - Horizontal policy approach on substances in articles addressing all actors along the product life-cycle; integrated, e.g., in the COM impact assessment in order to increase coherence (section 5.1.4)
  - Establishing a comprehensive Platform: Product design for Green Chemistry as all-embracing knowledge hub connecting all actors along the product life-cycle (section 5.2.2)
  - Additional institutional options (meso-level and beyond)

Looking at the status quo of the EU framework the legal provisions addressing the production process have reached a comprehensive level and are consolidated in the Industrial Emission Directive and its by-laws. With regard to emissions to water and air substantial progress has been reached in the last thirty years. The main area of improvement potential towards the GCP is to be identified in the product design and the related supply chain interaction triggering innovation processes towards GCP. Here a fairly fragmented patchwork of legal provisions is to be observed. A comprehensive "Product Framework Package" merging the different pieces of legislation and filling the existing gaps (as proposed above) should be considered.

In this context not only requirements formulated in public law – as analyzed in this study – should be considered: In order to promote innovation processes also the legal context in private law, such as stepwise prolonged warranty for a product and its performance, should be taken into account.

Table 15 summarizes all discussed policy options. It indicates which policy level should take the initiative to amend the institutional framework, and also highlights which are the core actors to be involved in the implementation. Additionally a brief characterisation of the main impact induced by the policy action is given.

In the course of the study some GC principles were identified, which appear to be to a large extent out of scope of the assessed frameworks. While this has not been further elaborated in this study, it has to be analysed by which means the actors' decisions might be influenced and which role the European legislative framework might play in this respect. Based on this analysis it has to be considered and further discussed how new European instruments could be the established.

Table 16: Recommended policy options

Delta characterization (summary)	Policy option (study section)	Policy level (legal context)	Core actor group addressed	Impact characterization	Remarks / Time perspective
	Substance related legislation				
Stage 1: REACH: GCP 4 and 10 (table 3)	basic obligation "safer design" (5.1.1.1)	EU legislation (new Art. 14(6a) /35(5a) REACH)	R&D in chemical companies	Additional documentation requirement, dossier update	REACH Review 2019
Stage 1: REACH GCP 4 and 10 (table 3)	Support third parties in AfA to provide elaborated information on greener alternatives (5.1.1.2)	ECHA policy in the application for authorisation (AfA) procedure (Art. 64 REACH)	Innovative companies and other third parties (e.g. research organisations)	Enhance innovation process by strengthening the authorisation regime	Immediate enhancement possible
Stage 1: REACH GCP 4 and 10 (table 3);	Link PPORD and AfA alternatives assessment (5.1.1.3)	EU legislation (Art. 9 REACH); ECHA policy in the AfA procedure (Art. 64 REACH)	R&D in chemical companies, Applicants for authorisation	Incentives for safer PPORD substances; less authorisations of SVHC	REACH Review 2019
Stage 1: REACH GCP 4 and 10 (table 3);	PPORD: Duty to apply for exemption (5.1.1.3)	EU legislation (probably new chapter in REACH Title II)	R&D in chemical companies, ECHA	Incentives for safer PPORD substances; initiating learning processes for GC	REACH Review 2019
Stage 1: REACH LLP 5 (table 5)	Digital dashboard to address the science-policy-gap ("WikiREACH") in order to foster data quality (5.1.1.1)	Implementation of existing provisions (Art. 22(1), (2) and (3), 14(7), and 41, 20(6) and 77(2)(e)) facilitated by IT tool	Registrants, authors of peer review studies, ECHA	Incentives for Registrants to update dossiers based on available data	Immediate enhancement possible depending on technical feasibility

	IE- and Seveso Directive				
Stage 2: IED GCP 1 and 6 (table 6)	Scope and accuracy BAT documents (5.1.2)	JRC Sevilla process under the IED	Operators of industrial installations/authorities	Enhance GCP considerations in licensing procedures	Enhance Com. decision C(2012) 613 + mandate to JRC
Stage 2: IED LPP 3 (table 7)	Information exchange platforms (5.1.2)	Supported by JRC Sevilla	R&D on production processes	Enhance distribution of BAT	
Stage 2: IED governed input streams GCP 1 and 7 (table 6)	Taxes on raw materials (5.1.2)	Council Consensus or national legislation	R&D on production processes	Additional incentives on resource efficiency	Political process needed

	Product related legislation				
Stage 4: ED LPP 1 (table 10)	Better integrating problematic substances into ED implementation (5.1.3.1)	Modify informal implementation procedures and expert groups	Expert groups in ED preparatory studies, products designers and manufacturers	Increased awareness for problematic substances in ecodesign	Enhance guidance on ED implementation
Stage 4: ED LPP 1 (table 10)	Expand ED scope to not energy-related products (5.1.3.1)	EU legislation (ED)	products designers and manufacturers	Increased awareness for problematic substances in ecodesign	ED Revision
Stage 4: REACH LPP 1 (table 10)	Information requirement on the use of substances in articles	EU legislation (REACH Annex VI Section 3 and Annex I Section 0)	Article producers and importers	More certainty on exposure conditions enhances risk management	REACH Review 2019
Stage 4: REACH LPP 1 and 2 (table 10)	Consumer "right to know": Obligatory answer + reduced time (5.1.3.2)	EU legislation on SVHC (Art. 33(2) REACH)	Article suppliers	Enhanced transparency regarding SVHC in articles, substitution impulses	REACH Review 2019
Stage 3: Product law LPP 2 (table 9)	Formulate explicit IC&C requirements in sectoral product legislation	Other EU legislation (also via "Horizontal policies"; see next line)	All actors in article supply chains	Supports compliance with substance law in sectoral product legislation	Political process needed

	Horizontal policy approach				
Cross-cutting	Horizontal policy approach on substances in articles (5.1.4)	To be defined; not only public law requirements but also civil law (e.g. a stepwise prolonged warranty) should be considered	All actors along the product life-cycle	Comprehensive approach to control risk from substances in articles	Political process needed
	Institutional options (meso-level and beyond)				
Stage 3: REACH LPP 2 (table 9)	Full material disclosure in article supply chains (5.2.1)	Stakeholder driven process, public support	All actors in article supply chains	Enables actors to actively control and manage substances used in articles	Supports Art. 9(1) Waste FD database
Cross-cutting	Platform: Product design for GC (5.2.2)	Stakeholder driven process, public support	All actors along the product life-cycle	All-embracing knowledge hub: product design for GC	
LPP 6 deficit along all stages	Green Chemistry "design thinking" approaches (5.3)	National educational, university and professional training programmes	Students and professionals	Enhance the competences to think in alternative solutions based on a broader system perspective	MSCA may initiate a debate on national level supported by ECHA
Cross-cutting	GC entrepreneurship and start-ups (5.3)	National and regional innovation programmes	Public and private funding organisations	Induce innovation by supporting independent actors	
Cross-cutting	Green public procurement (5.3)	Public bodies on all policy levels	Purchasing units of public bodies	Support demand pull towards GCP-products	Integrate GCP in procurement guidance

Green Chemistry Principles to a large extent out of scope of the regulatory framework of European chemicals policy	
No 2	maximize atom economy
No 7	use renewable feedstocks
No 8	avoid chemical derivatives
No 9	use catalysts

Table 17: Green Chemistry Principles to a large extent out of scope of the framework

This report presents options how to further align EU policies relevant for the manufacturing and use of chemical substances with the concept of "Green Chemistry" and thus to contribute to the United Nations Sustainable Development Goals, in particular SDG 12/12.4.

Green Chemistry is focussing on environmental impacts linked to the production of chemicals. In essence, Green Chemistry stands for a "benign by design" approach, aiming at hazard reduction and sustainable resource use in the chemical synthesis. Since chemicals are produced for specific needs and intended functions the incentives towards a "Greener Chemistry" are to a large extent provided by the design of the end-product and the culture of co-operation in the respective supply chain. This "bigger picture" offers a variety of options to enhance the innovation process towards the Green Chemistry Principles. In the context of the "Non-toxic Environment"-Strategy and the efforts towards a "Circular Economy" the actors on EU Level are invited to consider the proposals developed in this study to enhance the institutional framework.

Looking at the status quo of the EU framework the legal provisions addressing the production process have reached a comprehensive level and are consolidated in the Industrial Emission Directive and its by-laws. With regard to emissions to water and air substantial progress has been reached in the last thirty years. The main area of improvement potential towards the GCP is to be identified in the product design and the related supply chain interaction triggering innovation processes towards GCP. Here a fairly fragmented patchwork of legal provisions is to be observed. A comprehensive "Product Framework Package" merging the different pieces of legislation and filling the existing gaps (as proposed above) should be considered.

7
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8
Annexes

8.1
Annex I: 12 Principles of Green Chemistry

1. POLLUTION PREVENTION

It is better to prevent waste than to treat and clean up waste after it is formed.

2. ATOM ECONOMY

Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. LESS HAZARDOUS SYNTHESIS

Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. DESIGN SAFER CHEMICALS

Chemical products should be designed to preserve efficacy of the function while reducing toxicity

5. SAFER SOLVENTS AND AUXILIARIES

The use of auxiliary substances (solvents, separations agents, etc.) should be made unnecessary whenever possible and, when used, innocuous.

6. DESIGN FOR ENERGY EFFICIENCY

Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted to ambient temperature and pressure.

7. USE OF RENEWABLE FEEDSTOCKS

A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.

8. REDUCE DERIVATIVES

Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.

9. CATALYSIS

Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. DESIGN FOR DEGRADATION

Chemical products should be designed so that at the end of their function they do not persist in the environment and instead breakdown into innocuous degradation products.

11. REAL-TIME ANALYSIS FOR POLLUTION PREVENTION

Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.

12. INHERENTLY SAFER CHEMISTRY FOR ACCIDENT PREVENTION

Substance and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.[233]

[233] GC3 2015, 22, based on Anastas and Warner 1998, 30.

8.2 Annex II: Selected platforms and networks relevant for Green Chemistry

Name	Organisation(s)	Target actors	Region	Operation
Green Chemistry & Commerce Council (GC3)	Lowell Center for Sustainable Production at the University of Massachusetts, Lowell.	Companies and other organizations working collaboratively to accelerate green chemistry across sectors and supply chains	USA	- Vision: Green chemistry, green engineering and design for the environment are standard practice throughout the economy, contributing to innovation, improved public health and protection of the environment. - Strategic approach: Develop and promote tools, policies and business practices to drive green chemistry throughout supply chains, Foster collaboration among businesses, government, non-governmental organizations, and academic researchers, Identify and leverage enablers of green chemistry adoption
OECD – Sustainable Chemistry Platform	OECD/ OECD's EHS Division in the Environment Directorate	Government, academia, industry and NGOs; international	Global	This site was set up to facilitate information exchange, review of new developments and further elaboration of incentives for Sustainable Chemistry and to facilitate networking of stakeholders. This platform intends to identify specific areas and projects of Sustainable Chemistry that would benefit from international co-operation (e.g. chemical leasing and sustainable products from nanotechnology).

European Technology Platform for sustainable chemistry (SusChem)	SusChem was founded by six European bodies which represented the main stakeholders from academia and industry in the sector: - Cefic (European Chemical Industry Council) - DECHEMA (German Society for Chemical Engineering and Biotechnology) - EuropaBio (European Association for Bioindustries) - GDCh (German Chemical Society) - ESAB (European Federation of Biotechnology Section of Applied Biocatalysis - RSC (Royal Society of Chemistry, UK) The European Commission has provided financial and consultative support.	Industry, academia, governmental policy groups and the wider society / Europe	Europe	
Chemie³	- German Chemical Industry Association (VCI) - Mining, Chemical and Energy Industrial Union (IG BCE) - German Federation of Chemical Employers' Associations (BAVC)	Chemical industry in Germany / Europe	Germany/Europe	mission: To foster sustainability in the chemical industry by promoting sustainable business practices throughout the chemical industry (12 Guidelines on sustainable chemitry formulated by the partners of the initiative: see https://www.chemiehoch3.de/de/home/die-initiative/leitlinien.html?guideline=2&cHash=1b6b810cb7d7e2b767259fcdac85ee44)

ISC3 – International Sustainable Chemistry Collaborative Centre and network	- GIZ On behalf of: - German Federal Ministry for the Environment - German Federal Environment Agency Partner: - UNEP - UNIDO - ECEH	- industry and politics as well as the civil society and research - network: Researchers and experts from enterprises, universities and research institutions, the chemical industry and from civil society	Global	- Features about: "benign by design" - mission: The key principals of ISC3 to achieve transformation: Collaboration, Innovation and Education. Believe that important transformation drivers are new business models that are based on sound ecological, social and economical principals. - establishing of hubs on a global and regional level - managing a knowledge platform and a network of experts -ISCnet – International Sustainable Chemistry Network: to contribute to a sound management of chemicals and waste and to stimulate and disseminate new innovations in sustainable chemistry that satisfy all aspects of sustainability and contribute to the implementation of the UN Sustainable Development Goals - good practice examples from the industry

8.3 Annex III: Selected platforms and networks for product design taking into account sustainable resource use

Name	Organisation(s)	Target actors	Region	Operation	Coverage of problematic chemicals use
The round table, Eco Design of plastic packaging	Founded by: IK Industrial Association for Plastic Packaging e.V. Moderation: Office team ewen Initiative of experts from companies along the entire value chain of plastic packaging as well as scientific and consumer protection organisations	Actors in the value chain, above all: - Top management in the packaging, food, consumer goods and retail industries - Product managers, marketing managers and other decision-makers in the idea-finding phase - Developers and designers of packaging - Marketing and specialist consulting agencies	Germany, Europe	The aim of the Round Table is to promote the eco-design of plastic packaging, primarily by developing a guide and recommendations with the following key elements: - Website - Compactly formulated "core" guidelines for decision-makers - Toolbox with internal and external links to practical orientation aids such as checklists, tools for recyclable design, knowledge databases and examples of best practice	/
European Network of Ecodesign Centres (ENEC)	- Effizienz-Agentur NRW – North Rhine-Westphalia (founded by the Ministry for the Environment in North Rhine-Westphalia) - OVAM – Flanders, Belgium (Public Waste Agency of Flanders) - EA – Switzerland (eco-innovation and expertise center) - Pôle Eco-conception – Rhône-Alpes, France (association of industries) - Ihobe – Basque (Agency of the Basque Government) - Ecodesign Centre (EDC) – Wales (UK based knowledge-intensive organization supported by the Welsh Government)	regional, national and global policy-makers including the European Commission and United Nations	Global	- offering guidance on ecodesign, from 'policy to practice' - mission: openly exchange knowledge, experience and best practice on all aspects of ecodesign to ensure more companies to apply ecodesign - focus: stimulating demand for ecodesign, enabling ecodesign and its application - use the network as a platform to share knowledge, experience and best practice (e.g. policies, instruments, tools, services, case studies etc.) on all aspects of ecodesign, from regional policy development and delivery through to implementation in industry and education	/

Ecodesign Circle	Interreg Baltic Sea Region European Regional Development Fund Partners: - Swedish Industrial Design Foundation - Design Forum Finland - Estonian Design Center - Gdynia Design Center, Poland - International Design Center - German Environment Agency, Umweltbundesamt	Design center and their clients, enterprise manager, designer, lecturer, engineers, public sector organizations, SMEs	Baltic Sea Region	Project Aim: - To enhance the capability of SMEs to make use of ecodesign - to increase the capacity of designers in the environmental dimension of design - to improve the Baltic Sea Region-wide cooperation between design centres, promoting ecodesign "Made in the Baltic Sea Region" - to facilitate the development of new products and create jobs for tomorrow's markets - support and facilitate cooperation among design centres to help their clients drive forwards the circular economy - show positive cases from the Baltic Sea Region and demonstrate the market potential of ecodesign - bridge the gap between environmental science, design thinking and business reality - learn as professional designers, engineers or lecturers how to eco-design circular systems - a way for enterprises and public sector organisations to evaluate design sustainability and integrate into the circular economy - support enterprises and designers in developing new ecodesign products / services for changed consumer needs	/
Design-Thinkers Academy Network	DesignThinkers Academy	All interested actors ("Creative thinker and doer")	Global	- open platform to facilitate and inspire a rich conversation between creative thinkers and doers - aim: to develop a learning community to have a positive impact on people's lives, careers and the everchanging world (Most topics about design thinking, but some posts about sustainable design)	/
This is design thinking	Created from: Hasso Plattner Design Thinking Research Program Support: Jan Schmiedgen and Karen von Schmieden	Scientists and practitioners	Global	Blog everyone can contribute to: - best practice and failure stories to learn from - collect and contrast positions regarding design thinking - contribution by writing articles	/
Projekt eco-efficiency	Chamber of Commerce and Industry of Zaragoza, Spanien	SMEs, chambers of commerce and industry, insti-	Europe	- Platform for the exchange of experience and knowledge, Access to the project results of the eco-efficiency project and promotion of the implementation	/

network	San Valero Foundation, Spanien IFOR-NET, Spanien Ecoversum, Deutschland Dimitroff Unternehmensberatung, Österreich Kolping Bildungswerk, Deutschland Agroinštitút Nitra, štátny podnik, Slovakia EU-Förderprogramm bis 2011 Leonardo da Vinci – Multilaterale Projekte, Innovationstransfer Netzwerk über das Projekt hinaus	tutions		of eco-efficiency measures in SMEs - The ECO-EFFICIENCY project: Transfer of innovation to qualify employees in SMEs and to combat climate change - objective is to implement good practices and the best available techniques for economic optimization derived from the environmental improvements in SMEs.	
European Cooperation in Science and Technology (COST)	- intergovernmental framework consisting in 36 Member States and a Cooperating State	- researchers, engineers and scholars	Europe, Global	- closing the gap between science, policy makers and society throughout Europe and beyond - Build capacity by connecting high-quality scientific communities in Europe and worldwide - Provide networking opportunities for Early Stage Researchers (ESR) - Increase research impact on policy makers, regulatory bodies and national decision makers as well as on the private sector. - there are networks regarding eco-efficiency and eco-design	/

European Technology Platform for Advanced Engineering Materials and Technologies (EuMat)	Funded by the EU	- Industry (large, medium and small, embracing the whole production and supply chain, including component, equipment and sub-system suppliers, service providers and user industries; those involved in technology transfer; also, industry associations) - Public authorities (regulators and policy makers, funding agencies; in the particular notified and licensing bodies) - Scientific and Technical Community (apart for education and research also those involved in innovation and interested in the issue of European Innovation Area); - Associations and Consortia from other EU projects - Financial community and Civil society	Europe	The main goal of EuMaT is to contribute to the best relation and dialogue between industry, R&D actors and institutions aiming at improving the coordination and synergies at national and European level in the field of Materials R&D. The primary objective of EuMaT is to produce the Strategic Research Agenda which, with appropriate involvement of industry and other main stakeholders will provide basis for identification of needs and establishing priorities in the area of advanced materials and technologies. In addition, EuMaT promotes - interdisciplinary education and training, and technology transfer and innovation - societal considerations in the R&D (e.g. potential impacts on public health, safety, environmental risks) - cooperation and initiatives at international level	/
Manufuture	- EU	- researcher, other technology platforms, SMEs and other independent enterprises	Europe	One objective is Eco-efficient products and manufacturing Perspectives - To create the Manufuture knowledge community - increasing the engagement of industrial stakeholders - To share the strategy for building a Sustainable Manufacturing in Europe, focusing on the financing of strategic manufacturing R&D activities - To strengthen cooperation with other ETPs - To implement the strategy for international networking and cooperation	/

8.4 Annex IV: Selected platforms and networks for safer and more efficient production processes

Name	Organisation(s)	Target actors	Region	Operation	Coverage of problematic chemicals use
Cleaner Production Germany	- publisher: German Environment Agency	- scientists, engineers, consultants, local government decision makers and other representatives of public authorities - interested staff members in companies, environmental agencies and NGOs - everyone with questions about environmental technology	Germany, Global	- more than 3,000 publications on research findings and best practice examples on the topic "Environmental technologies – Made in Germany" - topics: clean air technology, climate protection, clean up technology, clean energy, energy and material efficiency, sustainable mobility, waste management and recycling, water management - gives access to technology providers and contacts, and presents selected contents in high-quality films and 3D animations - provides information on various support schemes and contains details of technology providers and contact persons	- sub-topic of waste management and recycling: hazardous waste treatment
Effizienzfabrik	German Engineering Federation Federal Ministry of Education and Research	- industrial engineering experts	Germany	- communicates the latest results of exciting research projects - offers the perfect platform for exchanging ideas and knowledge in the area of resource efficiency and electric mobility	/
EREK Network - European Resource Efficiency Knowledge Centre Network	European Commission implemented by organisations including Technopolis Group, VDI Zentrum Ressourceneffizienz, WRAP, Motiva, Enviros, WAAT and Arctik	- European companies, especially SMEs - national, regional and local organisations across Europe that work with SMEs	Europe	- helps the companies and organisations save energy, material and water costs - provides tools, information and business opportunities that show new and better ways to be resource efficient and benefit from circular economy business models which turn waste into an asset - provides access to international knowledge, technical expertise, latest information on Resource Efficiency, good-practice examples of European businesses and a selection of best available technologies on an online platform and at life events in various European regions - makes multimedia and virtual training opportunities to learn from Resource Efficiency experts available - organizes specialist events and activities on Resource Efficiency trends and developments, and updates on professional events within the European Resource Efficiency community	- conferences (such as International Conference on Industrial and Hazardous Waste Management) and best practice examples (World's first scaled-up water-free and chemical-free dyeing solution) are part of the network

European Resource Efficiency Platform	European Commission	- European Commission - Members States - private actors	Europe	This platform wants to provide high-level guidance to a more resource-efficient economy	/
Green Factory Bavaria	University Erlangen-Nürnberg and other academic organisations, Bavarian Ministery of Economic Affairs, Energy and Tecnology	- Bavarian companies	Bavaria (South Germany)	- network to improve the usage of energy resources in Bavarian factories - the goal is to develop a platform to transfer know-how from applied research to industry and exchange of experience among companies - Universities and companies work together to develop technical solutions and methodical procedures for reducing resource consumption and present their findings in the Green Factories - Companies are supported by individual consulting services, Internet-based checklists and benchmarking analyses help to determine the need for action	/
KET4CleanProduction	- funded by the EU - executive organisations: 20 partners from 18 European countries for example Technical Research Centre of Finland VTT Ltd., Joanneum Research Forschungsgesellschaft mbH, Fraunhofer IPA, INL - International Iberian Nanotechnology Laboratory, Slovak Business Agency, Steinbeis 2i GmbH, Vaeksthus Copenhagen	- SMEs	Europe	- aim: create a self-sustainable ecosystem gathering technology infrastructure, SME users and suppliers of innovative advanced manufacturing technologies - connects SMEs and KETs Technology Centres across Europe - helps SMEs to solve their clean production challenges and - as a result - to stay sustainable, innovative and competitive - encourages the use of advanced manufacturing technologies and related key enabling technologies (KETs) - upgrades the production processes towards a more energy- and material- efficient state - creates an open innovation ecosystem with a one-stop access platform for cross-border innovation services for manufacturing SMEs through a network of superior" KETs Technology Centres" (KET TCs) and Enterprise Europe Network (EEN) partners - facilitates SMEs connectivity to KET TCs through joint project proposals for micro grants	/
Network Ressourceneffizienz	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety financed by National Climate Initiative	- politicians - companies - associations - chambers - trade unions - the sciences	Germany	- bundles interdisciplinary and practice-oriented know-how and experience on resource-conserving production, products and management and serves the mutual information and networking of different actors - Networking, information and exchange of experience on promising approaches to the efficient use of resources take place via:	/

		- federal and state institutions		Regular network conferences targeted information and assistance for small and medium-sized enterprises Announcement of best practice activities Expert events on selected topics (e.g. NeRess on site) Information campaigns to raise public awareness (e.g. brochure "Competitive Advantage Resource Efficiency") the central Internet platform (www.neress.de) - promotes a more efficient use of resources for products and services in production, trade and consumption - develops proposals for the design of framework conditions that provide incentives and remove barriers	
RECPnet - The Global Network for Resource Efficient and Cleaner Production	- Swiss Confederation - UNEP - UNIDO - 70 providers of RECEP services on a global level	- members - enterprises - organizations	Global	- goal: to contribute to the effective and efficient development, application, adaptation, scaling up and mainstreaming of RECP concepts, methods, policies, practices and technologies in developing and transition economies - provides specialized, quality-assured, technical and advisory services and by facilitating and synergizing its members' capacities - aims to facilitate North-South, South-South and South-North-South collaboration, including the transfer of RECP-relevant knowledge, experiences and technologies. - the strategy consists of: Capturing and promoting best practices RECP information and knowledge, improving the knowledge and skills bases of Members, advocating the relevance, needs and benefits of RECP for enterprises and other organizations	- topics such as chemical leasing, innovative approaches to the sound management of chemicals and chemical waste, responsible production - safe management of chemicals and chemicals, hazardous waste and emissions (in the manual of SMEs) are a subject of discussion

8.5 Annex V: Comparison of GC with relevant international standards (ISO 14040/ISO Guide 64)

12 Principals	ISO 14040	ISO Guide 64
1. Prevention	- **Chapter 5.2.3, p. 25:** Consideration of "disposal of waste and products generated in the process; recovery of used products (including re-use, recycling and energy recovery)" when setting the system boundaries.	- **Chapter 3.2.3.2, p. 5**: "Consideration of the following options for avoiding environmental impacts: internal/external reuse or recycling, recovery or treatment" **- Chapter 3.3.1.2, p. 7**: Be aware of product design approaches during standard development such as "reuse, recycling and recovery of materials" - **Table 3 „Acquisition", p. 16**: "Recommendations for provision in standards – Using materials which can be easily recovered or recycled; - Using recycled or reused materials; - Checking the merits of a reusable version of the product; - Reusing components in or from other products" - **Table 6 „Normal use", p. 18**: "Recommendations for provisions in standards - Minimizing the amount of waste generated by the product during use"
2. Atom economy		
3. Less hazardous chemical syntheses	- **A1, p. 35**: Areas of application Life cycle assessment: "Environmental Impact Assessment - EIA"	- **Chapter 3.2.3.2, p. 5:** "For example, hazardous, toxic or otherwise harmful substances and materials prescribed in product standards should be substituted by other less harmful substances and materials, whenever possible and feasible." - **Chapter 3.2.4.2., p. 6:** "The identification of harmful effects to the environment in product manufacturing, use and disposal should be followed by initiatives to prevent incidents and accidents and to minimize consequences for the environment, including human health." - **Table 3 "Acquisition", p. 16:** " Recommendations for provision in standards - Restricting the use of hazardous substances to the unavoidable functional need, with special regard to toxic and very toxic, as well as carcinogenic, mutagenic and reprotoxic substances." - **Table 9 "End-of-Life", p. 21:** " Recommendations for provision in standards - Avoiding, as far as not functionally indispensable, the use of persistent hazardous substances "

4. Designing safer chemicals	- **Chapter 4.2.3, p. 16**: "Direct Application: Product development and improvement" - **A1, p. 35**: Scope of the Life Cycle Assessment "Integration of environmental aspects into product design and development (environmentally sound product development) (ISO/TR 14062)"	- **Chapter 3.2.3.2, p. 5:** " It also includes the promotion of the hierarchical approach to the prevention of pollution, which means giving preference to preventing pollution at its source, arriving at a waste and emission-free production by source reduction or elimination (including environmentally sound design and development, [...])" - **Chapter 3.3.1.1, p. 7:** "Standards writers should as much as possible take into account environmental aspects of product design, as product design is the strongest tool for avoiding potential environmental impacts at all stages of the product life-cycle." - **Table 3 " Acquisition", p. 16:** "Recommendations for provision in standards - Prescribing performance criteria, which includes environmental performance, rather than materials or substances to be used ".
5. Safer solvents and auxiliaries		- **Table 4 "Manufacturing", p. 17:** "Recommendations for provision in standards - Specifying ancillary materials which allow minimum pollution in the production stage " - **Table 8 "Use of additional products", p. 20:** " Recommendations for provision in standards - Enclosing instructions to use a minimum of additional products ".
6. Design for energy efficiency	- **Chapter 5.2.3, p. 25:** Consideration of "production and use of fuels, electricity and heat" when setting system boundaries	- **Chapter 3.2.2.2, p. 5:** " There are also several considerations associated with energy. Among these are the conversion efficiency of a selected source and the efficient use of energy." - **Table 3 "Acquisition", p. 16:** " Recommendations for provision in standards - Minimizing the use of energy and the emission of greenhouse gases during raw material acquisition " - **Table 4 "Manufacturing", p. 17:** "Recommendations for provision in standards - Minimizing the use of energy and the subsequent emission of greenhouse gases during production"
7. Use of renewable feedstocks		- **Chapter 3.2.2.2, p. 5:** " When environmentally beneficial, preferences should be given by the standards writer to renewable resources, as well as for the different options for end-of-life treatment." - **Table 3 "Acquisition", p. 16:** " Recommendations for provision in standards - Using renewable resources and minimizing the use of nonrenewable raw materials "

8. Reduce derivatives		- Chapter 3.2.5.2, p. 6: " Instead of asking what level of harm is acceptable, a precautionary approach asks the following questions: Is this product or this activity even necessary?" - Table 9 "End-of-life", p. 21: " Recommendations for provision in standards - Avoiding inseparable composite materials - Minimizing the number of different materials used "
9. Catalysis		- Chapter 3.2.4.2, p. 6: Consideration of prevention and minimization of environmental risks includes, for example, " the reduction or avoidance of the use of hazardous substances, either as a component in the product or as a facilitator or catalyst in its production "
10. Design for degradation		- Table 8 "Use of additional products", p. 20: " Recommendations for provision in standards - Making the additional products reusable or recyclable, refillable and biodegradable "
11. Real-time analysis for Pollution prevention		
12. Accident prevention		- Chapter 3.2.4.1, p. 6: Inclusion of " the consequences and the likelihood of incidents and accidents " - Chapter 3.2.4.2., p. 6: " The identification of harmful effects to the environment in product manufacturing, use and disposal should be followed by initiatives to prevent incidents and accidents and to minimize consequences for the environment, including human health. [...] This includes, for example, the reduction of risks to human health related to non-occupational incidents and accidents "