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Engaging you to reimagine chemistry and engineering for a sustainable future.

We believe sustainable and green chemistry innovation holds the key to solving most environmental and human health issues facing our world today.

• Advancing Science
• Advocating for Education
• Accelerating Industry

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- Search Examples from Green or Sustainable Chemistry
- One hour webinar with experienced CAS experts including Q&A
- Pick from two options on Friday, September 10:

German Young Chemists' Network

JungChemikerForum (JCF) of the Gesellschaft Deutscher Chemiker (GDCh)

- Personal & Professional Development for Young Chemists
- Modern Impulses for the Future of Chemistry & Chemical Societies
- Chemistry Outreach & Cooperation for the Benefit of Society

JCF Sustainability Team
The European Young Chemists’ Network

- Diverse team representing 35,000+ early-career chemists from 28 countries
- Members of the national chemical societies are automatically members of EuChemS and the EYCN!
- Projects: Workshops, Webinars, Photography and Video Contests, Awards, Podcast, European Young Chemists Meeting, Interviews, Information on studying and working in Europe, Science Policy and much more ...

Webinars
Sustainability
Science Communication
Career Development
Grant Writing
and more

www.eycn.eu/youtube

The Green Evolution Webinar, 9th September 2021

www.eycn.eu/eycnvideo/chemistrytoword

The European Young Chemists’ Network

www.eycn.eu/podcast
www.eycn.eu/cr2021

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Welcome! Willkommen!

Webinar presented within the
ACS-GDCh co-operation agreement

September 9, 2021
The Green Evolution: Sustainable Chemistry in Global Scholarly Education

Presentation slides are available now! The edited recording will be made available as soon as possible.
www.acs.org/acswebinars

This ACS Webinar is co-produced with ACS on Campus, ACS Green Chemistry Institute, CAS, and German Chemical Society.
Sustainability and Green Chemistry

- Sustainable development is meeting the needs of the present without compromising the ability of future generations to meet their own needs.

  - United Nations in 2015 adopted 17 Sustainable Development Goals (SDGs), trying to end poverty, protect the planet, and promote peace and prosperity

- Green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.
Audience Survey Question
ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

In a global survey of 27,000 representatives from politics, business, science, and research in 2018-2019, what percentage of them is aware of the UN’s Sustainable Development Goals?

- Over three quarters (70%)
- About half (50%)
- About a quarter (25%)
- About a tenth (10%)
- About a twentieth (5%)


Economic Trends

- **Commoditization of chemical products**
  - Price pressure. Profit challenge.
  - New products needed to complement current products

- **Competitiveness of chemical products**
  - Product parity. Erosion of competitive advantages
  - Green technology may provide a new competitive edge

- **Feedstock supply**
  - Most current raw materials from petroleum sources. Supply/demand
  - Biobased materials represent sustainable and degradable alternatives

- **Corporate advantages**
  - Green chemistry can increase process efficiency, reduce waste, enhance safety, attract talent, and create new business opportunities
  - Green products may provide greater sales for some applications
Safety and Environmental Trends

• **Health and safety**
  – Negative publicity about chemicals and their effects on health and safety

• **Environmental stewardship**
  – Pollution of air and water

• **Improved analytical instrumentation**
  – Increased sensitivity of detection of lower levels of contaminants

• **Regulatory agencies in many countries and regions have tightened their regulations relating to chemicals**

• **Green chemistry can provide safer and more eco-friendly products and processes**
  – A good way to counter the negative image of “chemicals.”

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Socio-Political Trends

Increasing international acceptance of sustainability as a useful and needed development - UN Sustainable Development Goals

Chemistry’s Role in the SDGs

• Chemistry, with its broad reach into technology, the economy, human health, and security, has a part to play in all SDGs

• Seven SDGs are seen as being particularly strategic and relevant to the chemistry community

Support for Sustainable Green Chemistry

The sustainability/green chemistry concept is catching on:

– U.S. House of Representative (2019) and Senate (2020) passed a bill to direct the White House Office of Science and Technology Policy to support sustainable chemistry and develop road map
– Active R&D is on-going in academia, industry, and government labs
– P&G unveiled sustainability goals, making the packaging of its top 20 brands 100% recyclable or reusable (4/22/18)
– DuPont announced its 2030 Sustainability Goals, including 9 goals relating to innovation, operations, and inclusivity (10/30/2019)
– Unilever will source 100% of its cleaning and laundry product formulations with renewable or recycled carbon (2/9/2020)
– Several other companies have also announced their plans for sustainable products or processes
Scientific Trends

• **Some chemical fields are mature**
  – The knowledge of synthesis and analysis is generally known
    • Chemistry professionals and students can be trained to do them
  – Many segments of chemical industry are mature
    • Examples are commodity industrial chemicals, fertilizers, paints, textiles, etc.

• **Some chemical fields are promising or emerging** ("new frontiers")
  – Nanotechnology and biotechnology affords further opportunities for chemistry
  – Other areas include energy storage, catalysis, self-assembly, sensors, organic electronics, quantum computing, sustainability/green chemistry

• **Multidisciplinarity**
  – Many advances are being made at the interface between chemistry and other disciplines, such as biology, medicine, physics, nanotechnology, and computer technology.
  – **Sustainability** is a good example of the need for multidisciplinary approaches

• **New applications of chemical skills**
  – Examples include the grand challenges today (such as sustainability, energy, clean air and water, food, population, climate change, diseases)

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Sustainability Publications

Number of papers including "sustainable", "sustainability", or "Green Chemistry" in the title or abstract. Thanks to Matt McBride of CAS for supplying the data, 9/1/21.
Conclusions

• Sustainability/green chemistry represent the next evolution of chemistry research:
  – The economic, socio-political, and environmental trends all favor them
  – They are compatible with the current scientific trends
    • New Frontiers (promising and emerging)
    • Multidisciplinary R&D
    • New applications of chemistry skills

• They represent a great opportunity for the future
  – Re-shape chemistry’s image
  – Work in an up-and-coming and interesting scientific area
  – Apply our creativity and ability to open up new avenues
  – Contribute towards a better world tomorrow

Audience Survey Question
ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

How much average waste, per kg API, is co-generated during production of a commercial small molecule API, starting from commodity-type starting materials?

• 17 kg
• 99 kg
• 182 kg
• 1430 kg
Green Chemistry in Scholarly Education in Germany & Globally

Value Through Green Chemistry in the Pharmaceutical Industry

Frank Roschangar, PhD, MBA
ACS Webinar • September 9, 2021

About Sustainable Drug Development

We are committed to meet the needs of patients around the world while substantially reducing our environmental footprint!

Footprint of Pharmaceuticals *

182 kg of waste per kg API

* Based on iGAL aligned Gate-to-Gate assessment of 29 commercial small molecule APIs. ACS Sustainable Chem. Eng. 2021. ASAP. DOI: 10.1021/acssuschemeng.0c02940 (Open Access)
How can Green Chemistry tie into a Corporate Sustainability Strategy?

ECO-DESIGN + GREEN CHEMISTRY *
1. Prevent waste
2. Atom Economy
3. Less Hazardous Synthesis
4. Design Benign Chemicals
5. Benign Solvents & Auxiliaries
6. Design for Energy Efficiency
7. Use of renewable feedstocks
8. Reduce Derivatives
9. Catalysis (vs. Stoichiometric)
10. Design for Degradation
11. Real-Time Analysis for Pollution Prevention
12. Inherently Benign Chemistry for Accident Prevention

At BI, we intend to move towards a circular economy by incorporating the design principles of (1) Design for the Environment (Eco-design) and (2) Green Chemistry into the R&D of all pipeline medicines.


Understanding a Medicine’s Life Cycle

ACS Sustainable Chem. Eng. 2021, ASAP. DOI: 10.1021/acssuschemeng.sc109140 (Open Access)
How can Metrics Enable Green Chemistry?

Enable Eco-Design

- we can identify major contributors to the environmental footprint of a product
- we can compare alternatives (materials, unit operations and processes) to help make eco-friendly development decisions and identify opportunities to apply sustainable sciences, technologies and strategies

Case study of identifying environmental hot spots for two commercial APIs *

| Solvents / Recycling | Artificial Intelligence | Biocatalysis | Continuous Flow Chemistry |

Solenets contribute the most to the footprint → focus on solvent selection and on decreasing solvent use

* Cradle-to-Gate data obtained with PMI LCA Tool from the ACS GCI Pharmaceutical Roundtable

How Green is your Green Chemistry? iGAL 2.0 *


13 pharmaceutical companies from 2 industry consortia

2 universities

Prof. Sheldon

* ACS Sustainable Chem. Eng. 2021, ASAP. DOI: 10.1021/acssuschemeng.1c03140 (Open Access)
An Industrial Application of Green Chemistry in Pharma

Industrial example of a biocatalytic cascade:

The pharma industry depends on motivated and creative green chemists to make a difference and bring innovative, effective, safe and sustainable medicines to patients


Green Chemistry and Sustainable Chemistry In Scholarly Education in Germany & Globally

Prof. Dr. Klaus Kümmerer
Institute of Sustainable Chemistry

LEUPHANA UNIVERSITY OF LÜNEBURG
- A UNIVERSITY FOR FREEDOM AND RESPONSIBILITY
- A HUMANIST UNIVERSITY
- A SUSTAINABLE UNIVERSITY
- AN ENTREPRENEURIAL UNIVERSITY
http://www.leuphana.de/en/institutes/isec.html

Research & Education International Sustainable Chemistry Collaborative Center
www.isc3.org
The Back Side of “Success” Story of Chemical Industries

- **350,000 chemicals/mixtures globally marketed** (Wang et al., Environ. Sci. Technol. 2020, 54, 2575–2584)
- **Thereof approx. > 30,000 environmentally relevant, products of incomplete degradation not included** (German EPA, 2010)
- **Hazardous to health 62 % of chemicals volume used in Europe 2016** (Source: European Environmental Agency)
- **Ca. 1.6 mill. deaths in 2016 attributable to chemicals, many more affected** (Source: World Health Organization)
- **Neurological behavioural disorders caused by chemicals: Costs >170 Bill. US $ per year in EU** (Source: UNEP Environment 2019)
- **Several hundred synthetic chemicals present in humans** (Source: UNEP Environment 2019)
Trend
Use of Resources Will Double Until 2060

Use of Resources Will Double Until 2060

[Graph showing trends of usage of resources from 2017 to 2060, with categories for Brazil, Russia, India, Indonesia, China, South Africa (mostly non-renewable) and Rest of the World (mostly renewable and non-renewable)]

Non renewable

Mostly non renewable

Mostly renewable

Sustainable Chemistry &
Resources
K. Kümmerer
Research &
Education


Sustainability
(Most profound human value Proposition)

Chemistry for Green Synthesis, Processing and Chemicals

Chemistry for Sustainability

Normative Framework

Broader Normative Framework

Human Value Proposition:
Greener is better

Human Value Proposition:
Circular is better

Human Value Proposition:
More Sustainable is better

Systems Thinking
Non Chemical Design
Alternative Business Model
Chemical Services
Ethics
Social Aspects

Without chemicals

With less chemicals

Non Chemical Design

Alternative Business Model

Ethics

Social Aspects

Stakeholders
Future Thinking: Chemistry, Sustainability, and the Role of Chemists


Source: EU Parliament, modified

Audience Survey Question
ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

How satisfied are you with green chemistry/sustainable chemistry in your country of residence?

• Very Satisfied
• Satisfied
• Neither Satisfied or Dissatisfied
• Dissatisfied
• Very Dissatisfied
2021 Survey GDCh Jungchemiker (Young Chemists) on Sustainable Chemistry in Education*
(https://jcf.io/teams/nachhaltigkeit)

- 503 participants, all continents (2/3 Europe), 46 countries, average age around ≈ 25
- Adequacy of SC in teaching: better in „developing“ countries, worse in „developed“
- > 90% of students ask for more
- > 80 expect that sustainability is more relevant for future professional life

* no differentiation between Green Chemistry (GC) and Sustainable Chemistry (SC)

Green Chemistry Education (GCE) and Sustainable Chemistry Education (SCE):
Undergraduate & Graduate Level (including Education of Teachers)*

- Increasing number of programs for GC in higher education, e.g. Sichuan University (China), U York, U Amsterdam, U Nottingham, but still on low level, …
- GCE often included in already existing context/modules, e.g. organic synthesis
- SCE rarely, if at all in teachers education
- Modules most often not mandatory
- External sources (e.g. ACS Green Chemistry Institute UNEP, UNIDO, U Sao Carlos (BR))
- A few Summer Schools (e.g. IUPAC, ACS Green Chemistry Institute, Leuphana U Lüneburg)
- Rarely extra occupational programs (U York, U Leuphana)

# publications on GCE and SCE (1998–January 2021, based on Clarivate Analytics 202153); topics: green chemistry education or sustainable chemistry education; *no differentiation between Green Chemistry (GC) and Sustainable Chemistry (SC)
Sustainable Transformation to Sustainability
- Sustainability as a cross-cutting topic

- **Interdisciplinarity – Transdisciplinarity**

- **Social basis of society**
  (learning // management // governance)

- **Physical basis of society**
  (biotic // abiotic) -> Chemistry

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Methods and technologies to integrate the material, ecological, economical and social needs of a society, for sustainable development

- Inter- and Trans disciplinary Approach

- **A major in Sustainable Chemistry**
  - The realm of Sustainable Chemistry
  - Green Chemistry
  - Environmental chemistry
  - Computational chemistry
  - Analytical Chemistry
  - Benign by Design
  - (Eco)Toxicology
  - Resources
  - ...

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Professional Master Sustainable Chemistry (MSc)
2 - Year Curriculum (90 ECTS)
German and European Accreditation; prerequisite: BSc or MSC in Chemistry

- Benign by Design
- Sustainable Chemistry and Regulatory Affairs

Small Format Certificates (20 ECTS)
- Benign by Design
- Sustainable Chemistry and Regulatory Affairs

www.leuphana.de/sustainable-chemistry
www.leuphana.de/en/professional-school/masters-studies/sustainable-chemistry-management.html

- Unique extra occupational expert inter and trans disciplinary training
- Real world oriented content
- International teaching staff (academia, industry, administration)
- Blended learning, most online

- 25 November 2021: On-Line Information Day
- 10 December 2020: Application deadline
- March 2022: start next cohort
Take Home Message

1. GC and SC are on the rise, including education
2. Much more is needed
3. Enables a more sustainable contribution of chemistry to a more sustainable world
4. Sustainable Chemistry is the awarding inter- and trans disciplinary approach and systems thinking instead punctual solutions
Join a CAS SciFinder® Training on Sustainability
Learn How SciFinder® Can Support You To Make Science Sustainable

- Search Examples from Green or Sustainable Chemistry
- One hour webinar with experienced CAS experts including Q&A
- Pick from two options on Friday, September 10:

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(Zoom link will be posted in chat)
The Green Evolution: Sustainable Chemistry in Global Scholarly Education

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Advancing Polymer Science with Organic Catalysts

Date: Wednesday, September 15, 2021 @ 2:30pm ET
Speakers: Andreea Dave, University of Birmingham, UK and Robert Waymouth, Stanford University
Moderator: Rachel Letteri, University of Virginia

What You Will Learn:
- Application of organic catalysts for stereocontrolled step growth polymerization
- Development of high-temperature organic catalysts for polymerization and depolymerization
- Using organic catalysts to selectively depolymerize plastic mixtures
- New designs for ultrastable organocatalytic polymerization reactions
- Synergies between continuous flow chemistry and rapid organocatalytic polymerization reactions
- New catalysts enabling the design of emerging functional materials for gene delivery

Co-produced with: ACS Division of Polymer Chemistry

Designing Around Structural Alerts in Drug Discovery

Date: Friday, September 17, 2021 @ 2:30pm ET
Speaker: Nick Williams, Bristol Myers Squibb
Moderator: Deepali Doshi, GSK Pharmaceuticals

What You Will Learn:
- The identity of structural alerts that have been associated with problems in drug discovery and development
- The fundamental mechanistic organic chemistry underlying structural alerts that are subject to bioactivation
- Strategies and tactics to design around structural alerts

Co-produced with: ACS Division of Medicinal Chemistry, American Association of Pharmaceutical Scientists, and ACS Publications

Service Dogs in Your Chemistry Lab

Date: Wednesday, September 22, 2021 @ 2:30pm ET
Speakers: Patricia Redden, Saint Peter’s University (Sandy Rapa), Empower Agility Consulting, LLC / Ashley Meyer, Independence Science
Moderator: Prathna Bass, Indiana University - Purdue University Indianapolis

What You Will Learn:
- What does the Americans with Disabilities Act cover regarding access rights for service dogs
- How is a service dog selected for certain jobs or disabilities, and what type of training is required
- What types of service dogs exist and what is the process to obtain one

Co-produced with: Chemists with Disabilities (CWD) Committee, ACS Department of Diversity Programs, and ACS Diversity, Inclusion & Respect Advisory Board

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