

# The disappointing performance of Green Chemistry & the possible success of Safe and Sustainable Chemistry

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*SERIES: Putting the EU Chemical Strategy for Sustainability (CSS) into action:  
Challenges and opportunities for Food Contact Materials (FCMs), March 18, 2021*

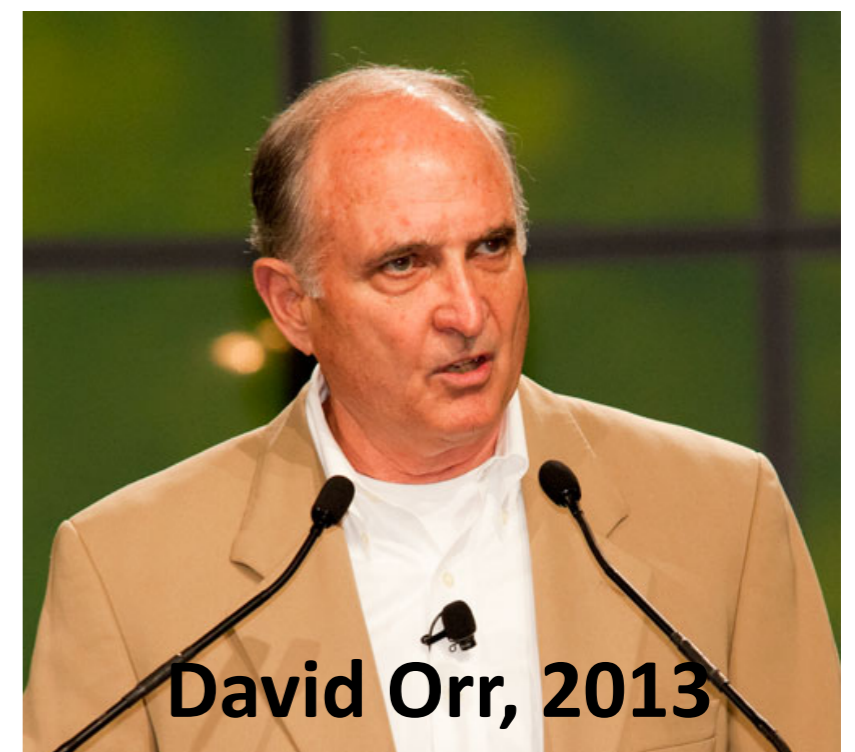
**The Problem of Education:** Education is not widely regarded as a problem, although the lack of it is.

The conventional wisdom holds that all education is good, and the more of that one has, the better.

The truth is that without significant precautions, education can equip people merely to be more effective vandals of the earth.

If one listens carefully, it may even be possible to hear the Creation groans every year in late May when another batch of smart, degree-holding, but ecologically illiterate, *Homo sapiens* who are eager to succeed are launched into the biosphere.

David Orr, *Earth in Mind*, 1994



"An essential book for this moment . . . I sincerely hope that everyone reads *Count Down*—the younger the better—so that they'll have the chance to preserve their fertility."  
—RUTHANN RUDOL, research director at the Silent Spring Institute

How Our Modern World Is

Threatening Sperm Counts,

Altering Male and Female

Reproductive Development,

and Imperiling the Future

of the Human Race

# COUNT DOWN

**Shanna H. Swan, PhD**

with Stacey Colino

Webinar on the  
importance of the  
content of  
**COUNT DOWN**

[https://www.youtube.com/  
watch?v=Ab4CMUs8o1I](https://www.youtube.com/watch?v=Ab4CMUs8o1I)

“Green Chemistry is the **design** of chemical products and processes that reduce or eliminate the use and generation of **hazardous** substances.”

# The Twelve Principles of Green Chemistry

## 1. Prevention

It is better to prevent waste than to treat or clean up waste after it has been created.

## 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 Chemical Syntheses**

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

## 4. **Designing Safer Chemicals**

Chemical products should be designed to affect their desired function while minimizing their toxicity.

## 5. **Safer Solvents and Auxiliaries**

The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

## 6. **Design for Energy Efficiency**

Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.

## 7. **Use of Renewable Feedstocks**

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

## 8. **Reduce Derivatives**

Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

## 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 break down into innocuous degradation products and do not persist in the environment.

## 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**

Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.



# Tough Questions

What is Chemistry's role in dealing with EDCs

## The First Principles of Green Chemistry:

- Green Chemistry aims to protect life,
- Green Chemistry needs to be interdisciplinary to be successful and,
- Because of the immense complexity, if funders want Green Chemistry to succeed, they will need to back a significant section of the field in the long- term.

# The Chemical Enterprise (CE) and Sustainability

Lodafs make today's CE categorically unsustainable.

Our handling of many lodafs today highlights our personal, institutional and civilizational inadequacies.

The scientific basis and facts of lodaf threats are undeniable.

Some lodaf threats are fast-acting.

Academic, industrial and regulatory chemistry all need reality checks and much change to deal properly with lodafs.



## The importance of sustainability ethics, toxicity and ecotoxicity in chemical education and research

**Terry Collins,† Associate Editor for the Americas of *Green Chemistry*, strongly emphasises the important role of green chemistry in ensuring our sustainable future**

Our modern high-technology civilization is not sustainable. This statement, since the publication of the Brundtland Report, has come to encompass two ideas presented here from the negative perspective. Firstly, many essential activities that, individually and collectively, are carried out each day to make our civilization work cannot be carried on into the indefinite future in anything approximating their current form. Secondly, we are operating our civilization in such a way that significant substance underpins the judgment that the welfare of future generations will not be comparably advantageous to our own. These ideas, now broadly accepted in a growing consensus, imply that someone is responsible for fixing things. If unsustainable technologies are part of the problem, the technical leadership has clear responsibility, and chemists are important members of that technical leadership. We must first ask, for each chemical problem identified, whether solutions are conceivable. If the answer is yes, our responsibility translates into a duty to engage fervently in finding solutions. If the answer is no, our responsibility translates into a duty to alert civilization to move away from the dependence that is undermining it.

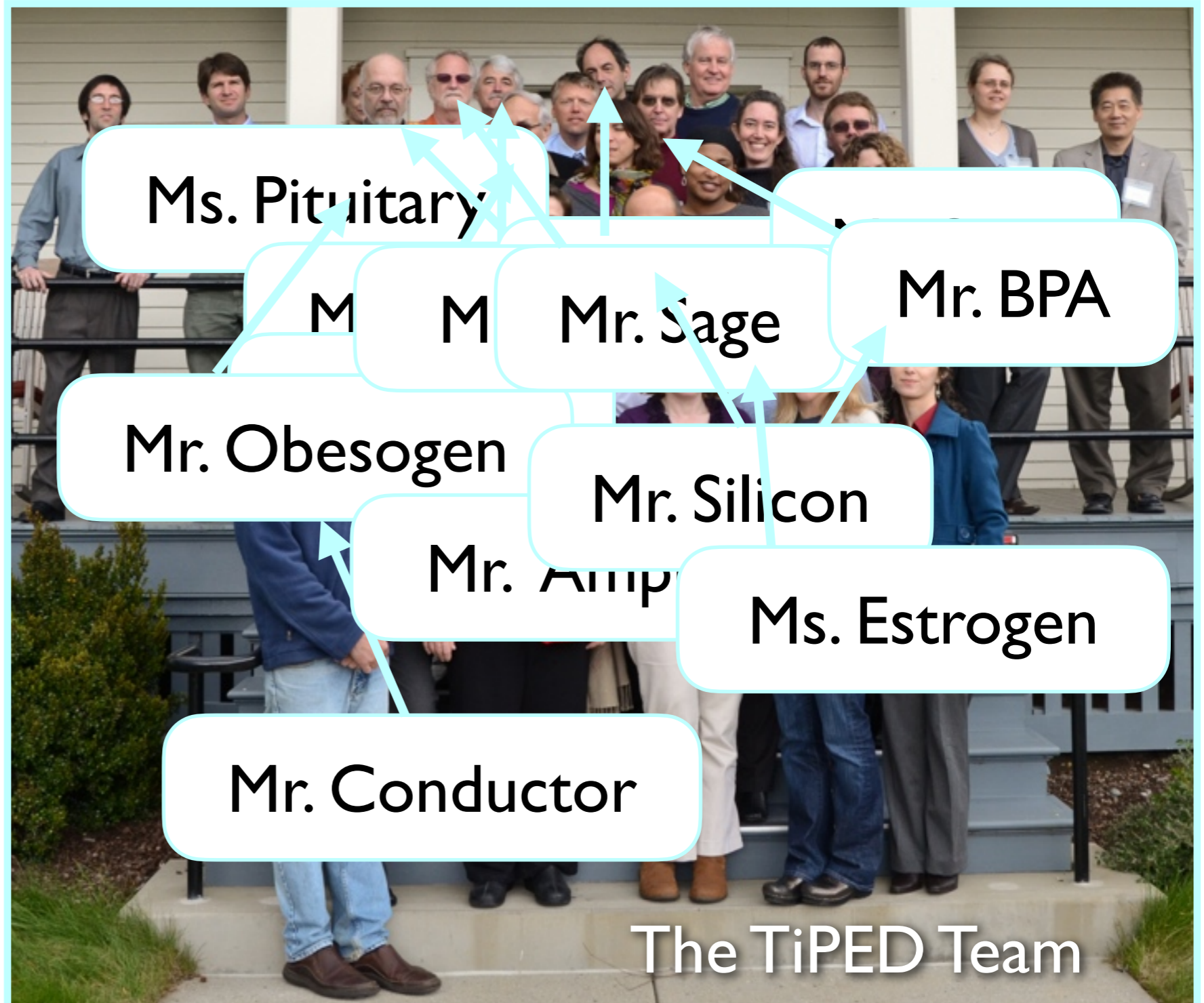
Many technologies are part of our sustainability dilemma because their operation is incompatible with the long-term wellbeing of living things. Most of the known offenders are fundamentally chemical in nature and have developed since the First World War. We have been experiencing their benefits and discovering their damage for only a brief moment in human history and so it is not surprising that their novel sustainability challenges are difficult for us to deal with. The twentieth century growth in new technologies brought a dramatic increase in the quantity and complexity of the matter that flows daily from the ecosphere into the economy as its nourishment and, after the economic value has been extracted, back to the ecosphere from the economy as its waste. Some of the waste is toxic or ecotoxic, a portion of this exceptionally so, almost invariably in ways that were not perceived when the source technologies were developed. And undoubtedly, we will find other grim downsides of anthropogenic environmental pollutants to add to endocrine disruption, cancer causation, and stratospheric ozone depletion. Chemists are the master manipulators of matter and therefore, in principle, have the ability to design against toxicity and ecotoxicity.

During the twentieth century, chemists essentially mastered synthetic chemistry. Of course, there is much more to learn but our synthetic organic colleagues can now make virtually any organic chemical found in nature. This is a dazzling historical accomplishment for human beings from a starting point in a little over a century ago. But also during the twentieth century and on rare occasions much earlier, we realised that certain chemicals exhibit potent toxicity and ecotoxicity. How is it that we chemists have become incredibly powerful at making molecules and materials while hardly informing our students of anything in the subject areas of toxicity and ecotoxicity? Is this not a major breakdown in common sense? Does this not leave our students incompetent to practice chemistry while simultaneously ensuring that known harmful consequences are avoided for themselves, other people and the environment? These errors of the twentieth century, still rampant in the United States but being set right in a growing number of universities elsewhere, cannot be allowed to persist into the twenty-first century. The case for action is strengthened as the sustainability dilemma dawns on us all, bringing into focus the until-now obscure subject of sustainability ethics, which must be taught as an integral component of chemical education. The most important book in the field was written by Hans Jonas—'The Imperative of Responsibility: Finding an Ethics for the Technological Age'.

How should education change to better promote a sustainable future? In most universities the requirements of understanding for new chemists in the fundamentals of sustainability ethics, toxicity and ecotoxicity asymptotically approach zero. When, where, and how will this knowledge that is pivotal for producing chemists who can competently advance towards a sustainable future through their work be introduced into the curriculum? Those portions of endocrine disruption, cancer causation and ozone depletion that result from human activity arise because of the chemical properties of the economy–ecosphere matter flows. Toxicity and ecotoxicity arise because certain chemicals, having functional groups or regions that are, for example, electrophilic, nucleophilic or lipophilic, interact through these philicities with biochemicals or environmental chemicals to produce reactions that negatively impact the natural order. The philicities are unifying concepts of chemical reactivity. It would not be a huge departure from the current mechanistically oriented pedagogical approach to integrate reactions that have toxic and ecotoxic consequences as illustrations of the reactivity concepts. Bernd Jastorff, Reinhold Störmann and Uwe Wölcke from the University of Bremen do precisely this in their highly creative German textbook entitled, 'Struktur-Wirkungs-Denken in der

†Lord Professor of Chemistry and Director of the Institute for Green Oxidation Chemistry, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA.

**Test adequately  
all commercial  
chemicals for  
iodafs, especially  
for chemicals  
intended to  
become  
everyday-  
everywhere  
products**



***Designing endocrine disruption out of the next generation of chemicals***

Schug T., Abagyan R., Blumberg B., Collins T., Crew, D., DeFur P., Dickerson S., Edwards T., Gore] A., Guillette L., Hayes T., Heindel J., Moores A., Patisaul H. Tal, T., Thayer K., Vandenberg L., Warner J., Watson C., vom Saal F., Zoeller T., O'Brien K., Myers JP., *Green Chem.*, **2013**,15, 181-198

**Beta-tested TAML Activators in the resulting TiPED**



# Can Chemistry Become Sustainable?

**Perhaps!** Five performances are of equal importance to the value proposition of a sustainable chemical technology: focusing just on two has led us to innumerable unsustainable technologies.

**because a chemical technology performs well,**

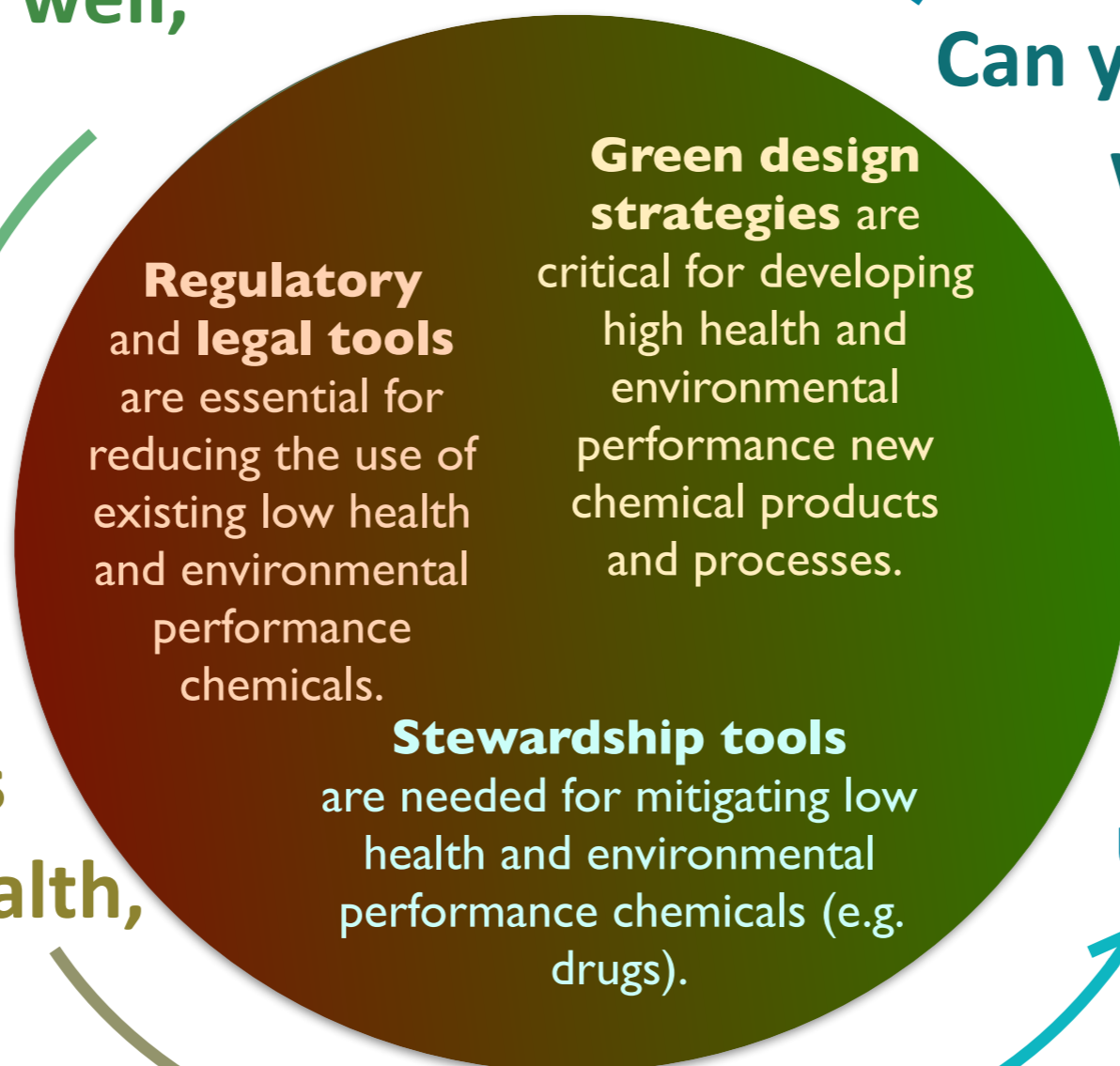
while knowing to the highest standards of contemporary science that,

**no adverse effects impact human health,**

**environmental welfare,**

**Can you generate wealth,**

**while the technology is universally fair?**



**or**



# Tough Questions

## Will the EU CSS follow through in dealing with EDCs

1. Will the EU have a LARGE budget for studying marketplace chemicals for lodafs/locafs?
2. What will the EU do when it knows a **valuable** commercial chemical is eliciting lodafs/locafs?
3. How will the EU treat an academic who claims that a chemical should be removed from commerce because it elicits lodafs/locafs—a hero(ine)?, ignored?, defunded?
4. Is the EU better than being part of our failing civilization that cannot even protect its the reproductive capacities of its people because we have all become so seduced by chemical products and processes including this that elicit lodafs/locafs?

Moving forward into the future, the EU's ability to formulate correct answers to these questions will determine, just for starters, the reproductive vitality of EU youth.