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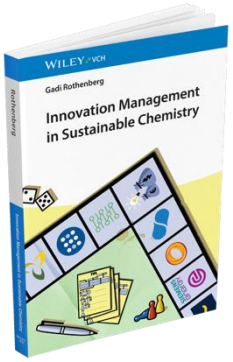
Innovation Management in Sustainable Chemistry, First Edition. Gadi Rothenberg.

These files accompany my textbook ***Innovation Management in Sustainable Chemistry*** *(Wiley-VCH, 2026, 352 pp. ISBN 9783527354511). They are intended to help teachers using this textbook in their courses. The material is divided in four parts:*



1. *Course description and suggested lecture structures.*
2. *Example and background material for an in-class group exercise.*
3. *All the key chemical structures in the original Chemdraw format.*
4. *Detailed solution manuals for selected exercises.*

The material is provided open access and free of charge. You may adapt and re-use it in whichever way you like. Everything is provided 'as is'. Should you find mistakes or have any comments, please send me an e-mail.

Teaching is something very personal. This course and textbook reflect my own teaching philosophy. I use a combination of lectures, in-class group exercises and homework assignments. Students are encouraged to think for themselves, analyse information from multiple sources and form pragmatic, well-founded opinions. The discussion of real-life case studies emphasises critical thinking and analysis. Students learn how to focus their assessments on the key aspects of each proposition.

When it comes to teaching, I am a big fan of Carl Sagan and Richard Feynman. I believe that storytelling is a powerful way of teaching science because it helps connect facts and concepts to experiences. When the student follows a story, they see how ideas fit together and why they matter. Similarly, when they discuss the chain of events that led to people's inventions or the founding of a start-up, it creates an emotional anchor. This makes it easier for them to remember what they've learned, since the mind naturally recalls information tied to emotion and personal meaning. Through stories, science becomes less about memorizing facts and more about understanding them.

All feedback is welcome.

Gadi Rothenberg
Amsterdam, October 2025.

General description. *Innovation Management in Sustainable Chemistry* is a textbook accompanying an interdisciplinary course aimed at science and engineering students interested in start-ups and entrepreneurship. The course bridges science and business. Students attend lectures, discuss real-life case studies, participate in group exercises, and complete homework assignments. They gain tools for project and process evaluation alongside a solid foundation in sustainable chemistry.

Course Objective. Understand the basic concepts of sustainable chemistry and sustainable development and apply these to evaluate business cases and develop new ventures. Explore business models, intellectual property strategies, and other practical tools for valorising sustainable technologies.

Course Content. The course has three parts. First, we cover the principles and drivers of sustainable chemistry and explain how these relate to sustainable development. Students learn and practice metrics such as the E-factor and Atom Economy. They examine different industrial sectors, identifying opportunities for new businesses based on sustainable principles. Recycling, re-use, and renewable resources are discussed from a realistic perspective. The principles are illustrated using two industrial examples: the synthesis of ibuprofen and the synthesis of ethyl acetate.

The second part of the course focuses on transforming sustainable science into sustainable business. Students are introduced to project and venture evaluation using SWOT analysis, PEST analysis, and Life-cycle assessment (LCA). They learn about business archetypes, narratives, and business models. They participate in group exercises on value creation and value capture. The

course emphasizes practical aspects of setting up start-ups, including intellectual property strategies, team selection, and raising capital – from FFF money to venture capital.

With these principles in hand, we examine seven real-life case studies where innovations in sustainable chemistry led to the creation of new businesses. These include clean synthesis and green energy via heterogeneous catalysis, electrochemical and microbial conversion of CO_2 to chemicals, production of first-generation biodiesel, application of environmental monitoring methods, and converting biomass derivatives into thermoplastic and thermoset polymers. Analysing how these ventures succeeded (or failed!) helps students grasp the realities of building a sustainable start-up.

Using the course textbook. Chapters 1 and 2 provide the background on sustainable chemistry and creating a sustainable business. Depending on the students' background, you may need more/less emphasis on the chemistry principles. If the students can easily solve the exercises at the end of these two chapters, they probably have a good understanding of the material. You can then move to the case studies (chapters 3–9) and recap/emphasise technical areas based on the 'tech boxes' which are highlighted in grey. The case studies are stand-alone. You can teach them in any order and/or pick those subjects that are most suited to your course needs.

Suggested lecture structure. The lectures follow the book chapters and are divided into eight subjects. The following lecture structure can be adapted to both 16h (eight sessions of 2×45 min) or 32h modules. The industrial case studies (lectures 3–8) are stand-alone and can be covered in any order. Note that chapters 8 and 9 are combined in one lecture because they are both about making polymers from biomass, but you can split them in two lectures or choose just the thermoplastic or thermoset materials.

1. **Introduction to Sustainable Chemistry** (Chapter 1)
    a. Principles and drivers of sustainable chemistry.
    b. Material cycles and global sustainable development.
    c. Sustainable chemistry metrics and evaluation.
    d. Industrial example: Ethyl acetate manufacturing.
    e. Industrial example: Ibuprofen manufacturing.
2. **From Sustainable Science to Sustainable Business** (Chapter 2)
    a. Introduction to project and product evaluation.
    b. Business archetypes, narratives, and business models.
    c. Understanding value creation and value capture.
    d. Intellectual property: Patents and trade secrets.
    e. Fundraising: From FFF money to venture capital.
3. Case study: **Environmental Sampling and Water Monitoring** (Chapter 3)
    a. Introduction to water quality monitoring.
    b. Principles of passive sampling.
    c. Understanding intellectual property in device and process context.
    d. Dealing with market barriers and growth challenges.
    e. Supplier and distributor models.
4. Case study: **Do-it-Yourself Chemical Company** (Chapter 4)

   a. The power of organic growth.
   b. Hydrogen: Energy carrier or media hype?
   c. Principles of catalysis at surfaces.
   d. Building a company from the ground up.
   e. Challenges in biomass conversion.

5. Case study: **CO_2-to-chemicals using Microbes and Electricity** (Chapter 5)
   a. Opportunities and challenges in CO_2 conversion.
   b. Rheticus – an example of large industry collaboration.
   c. Understanding the operations of business units.
   d. Understanding TRLs and risk assessments
   e. CO_2 electrolysers.
6. Case study: **Biodiesel using Heterogeneous Catalysis** (Chapter 6)
   a. Introduction to biofuels and biodiesel manufacturing.
   b. Two companies: Solarix and Yellow Diesel – business models.
   c. Principles of heterogeneous catalysis and reactive distillation.
   d. Scaling up from lab to industry.
   e. Market barriers and opportunities.
7. Case study: **Hydrogen Generation and Storage** (Chapter 7)
   a. The phoenix company concept.
   b. The business case for hydrogen as an energy carrier.
   c. Catalytic hydrogen release.
   d. 3D printing as a catalyst synthesis tool.
   e. From crazy ideas to industrial demonstrations.
8. Case study: **Making Polymers from Biomass** (Chapters 8 and 9)
   a. Introduction to thermoplastic and thermoset polymers.
   b. Once-in-a-lifetime chemical discoveries.
   c. The challenges of changing industrial paradigms.
   d. Successful raising of capital to $500 million.
   e. The importance of partnership and trust.