

# Module 9 – Sustainable Business & Green Chemistry



Global Greenchem  
Innovation & Network Program



**Green Chemistry Toolkit**



Center for Green Chemistry &  
Green Engineering at Yale

# Module Goals



- Drive innovation and growth by align with corporate sustainability goals
- Understand how to integrate Green Chemistry into operations for economic and environmental benefits
- Reduce manufacturing costs and compliance risk



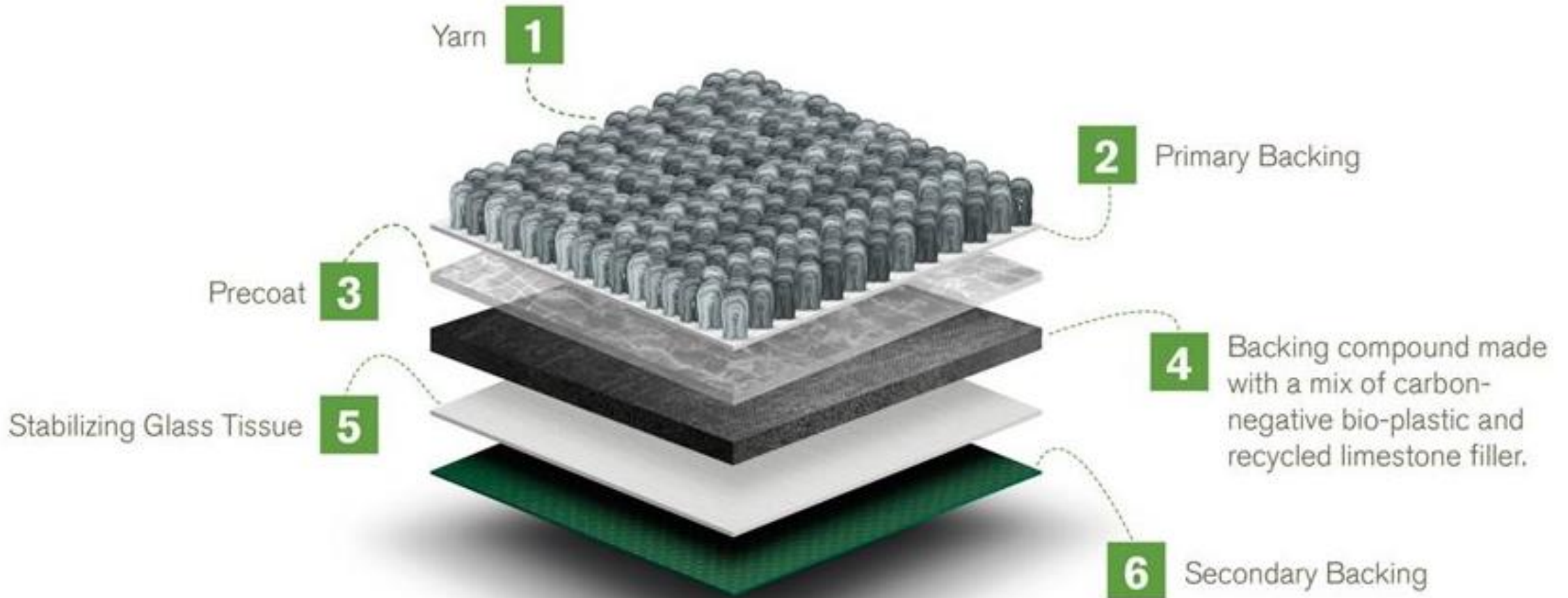


# Corporate Examples of Green Chemistry

- Dow Chemical's use of **atom economy to improve process efficiency** by using recycled carbon dioxide (CO<sub>2</sub>) in place of CFCs to create polystyrene
- Pfizer's adoption of green chemistry to **double yield, prevent pollution, and reduce energy/water use** in drug production of Zoloft and Viagra
- **Unilever's "Challenge" for Green Chemistry solutions**, carbon neutral cleaning products by 2030, and devoting \$12B to use renewable and recycled carbon



# Interface CircuitBac Green





# Green Chemistry in Product Development

- **BASF's Biodegradable films for crop and field management**
  - Ecovio M2351 polybutylene adipate terephthalate-poly(lactic acid) (PBAT-PLA)
- **Interface's 95% reduction in GHG over 20 years**
  - TacTiles: biobased adhesive, reduces VOCs, and enables end of life circularity
  - CircuitBac Green: bio-based materials with recycled limestone filler
    - 76% petroleum content, 87% less energy, 96% less CO<sub>2</sub>



# Developing Sustainable Business Models





**"Make something sustainable by starting with a renewable material, or a material that's been renewed, and keeping it in a form that it can be renewed at the end of the product's use"**

- Martin Wolf, Director of Sustainability and Authenticity, Seventh Generation





# Developing Business Models

- **Identify solutions to regulatory problems**
  - Bio-based materials to cut costs and reduce environmental impact by removing priority substances
  - Eg Dupont Thermax™ NH Series, rigid insulation foam without halogenated flame retardants
- **Supply Chain Management**
  - Intel's approach to managing supply chain risks through green chemistry ([Responsible Chemistry Guide, Chemical Restrictions](#))





# Aligning Green Chemistry with Corporate Strategy



- Virent's 100% plant-based bottle, from corn-derived plant-based paraxylene (bPX) and monoethylene glycol (bMEG)
- Limited run of about 900 prototype bottles
- Towards Net Zero 2050 and plastic reduction goals



<https://www.coca-cola.com/eu/en/media-center/bottle-prototype-made-from-plant-based-sources>





# Overcoming Barriers to Green Chemistry

- **REACH doesn't quite encourage green chemistry**
  - Early-stage innovation and research largely underfunded by private sector
- **Innovation programs like the *Global Greenchem Innovation and Network Programme* are “blended capital”**
  - Public money combined with in-kind support to attract private capital; this is a different strategy to foster innovation



# Case Study: Method Products - Market Success through Green Chemistry



- Method Products "GreensKeeping" process architecture:
  - What: ingredients, packaging, formulation, fragrance, color, preservatives
  - How: sourcing, manufacturing, distribution, incentivizing, measuring
  - Who: climate conscious, change, transparency, animals, healthy home, and community

method®



# Case Study: Method Products - Market Success through Green Chemistry



## GREENSKEEPING

### WHAT WE DO



### HOW WE DO IT



### WHO WE ARE



- The company uses Green Chemistry as a driver for innovation and marketing



# Case Study: Method Products - Market Success through Green Chemistry



# Green Chemistry for Climatech and the Circular Economy



- **Philips' circular lighting products:**

- A service involving a monthly fee, rather than having customers invest in lighting and maintenance (similar to chemical leasing)

*"Replacing property by use"*

- Leon Konings, Philips Lighting



# Green Chemistry for Climatech and the Circular Economy



# Identifying Strategic Partnerships



- **Partnerships with academic institutions for research and innovation**
  - Combine different disciplines (eg Business School, Chemistry PHD)
- **Leverage Innovation Programs (e.g. an Accelerator) to centralize resources of solutions, practitioners, and potential industries for pilots**
  - Convene a reception sharing the Accelerator, offering it as a location to help with their current challenges
- **Collaborative R&D projects to develop new green materials**



Image by [DIY Team](#) from [Pixabay](#)





# Identify Trends in Green Chemistry



- **Key trends influencing the future of green chemistry:**

- Enzyme-based catalysis for sustainable chemical processes
- Growing demand for bio-based chemicals and materials
- Benign solvents, enzymes nanoparticles as catalysts, value from waste, plastic innovation

- **Policy and Regulatory Landscape**

- EU's Green Deal and its implications for chemical manufacturing
- US Inflation Reduction Act



# Policy Trends in Green Chemistry



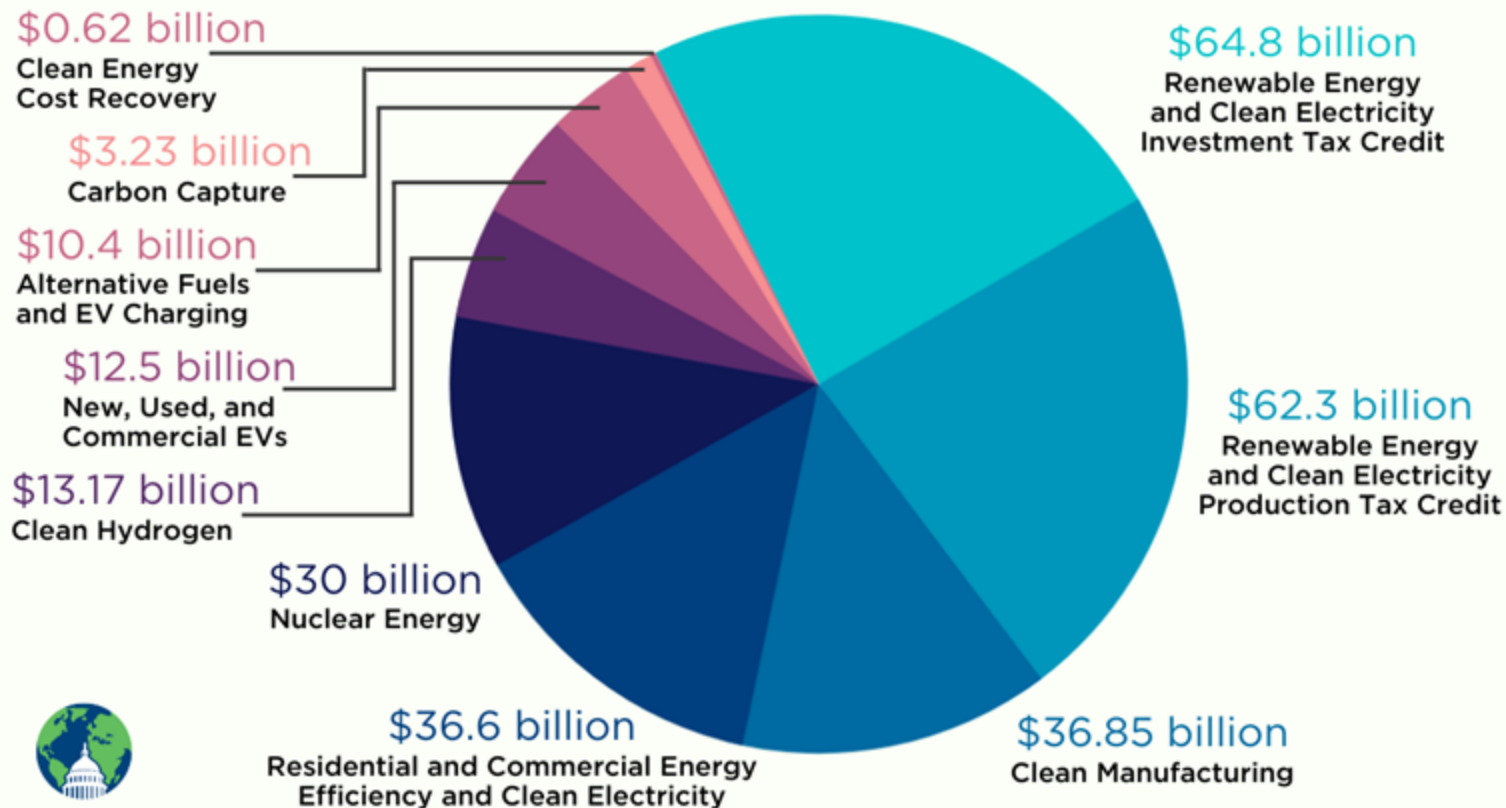
Green Deal policy framework around EU Sustainable Products Regulation (green) and the relationship to Ecodesign directive (blue): Nickel 2023



# Policy Trends in Green Chemistry



## Carrots Over Sticks: Green Tax Credits in the Inflation Reduction Act



**EESI**

Source: Congressional Budget Office

Graphic by: Alison Davis



# Case Study: Bayer Navigating Regulatory Compliance (2023)



- **Prevention, Atom Economy & Solvents and Auxiliaries:**
  - Reduce inputs in complex chemical production processes
  - Optimize use of solvents and auxiliaries; implement solvent recycling
  - Comprehensive waste management processes in place
- **Chemical Syntheses & Designing Chemicals:**
  - Stringent regulations guide approval and registration procedures
  - Potential environmental and human safety impacts assessed early in R&D
  - Discovery of new molecules aims to minimize environmental effects
  - Production processes and synthetic methods designed to reduce unintended chemicals and waste



# Identify funding for Green Chemistry: Capital Stack



	GRANTS	CATALYTIC CAPITAL	VENTURE CAPITAL	VENTURE DEBT	COMMERCIAL DEBT	PROJECT FINANCE
EXPECTED RETURN RANGE / IRR	0%	0-10%	30%+	5-25%	5-15%	3-15%
DILUTION / OWNERSHIP	N	Y	Y	N	N	N
COMPLEXITY	HIGH	LOW	MED	MED	HIGH	HIGH
STAGE	ALL	EARLY	EARLY, GROWTH	EARLY	GROWTH	GROWTH



# Identify funding for Green Chemistry: Green Bonds



# Funding and Investment Examples: Commercial Debt



- **Air Liquide (2024):** €500m for eprojects relating mainly to low-carbon hydrogen, carbon capture and low-carbon air gases (10 year, 3466%)
- **BASF (2020):** €1B to reduce carbon emissions and enhance sustainable chemical production with Green Finance Framework (7 year, 0.25%)
- **Evonik Industries (2021):** €500M for biodegradable chemicals, energy efficiency, and hazardous substance reduction (2215%, 60 year buyback)



# Funding and Investment Examples: Commercial Debt



- **DSM (2019):** €1B loan from 15 banks with interest rate tied to targets, including reducing CO<sub>2</sub>, energy efficiency, and renewable energy
- **Borealis (2021):** €250M loan for increasing circular feedstocks from EIB
- **Umicore (2022):** €500M loan from 13 banks to refinance debt for CO<sub>2</sub> reductions and increasing sustainable product solutions





# Funding and Investment Examples: Venture Capital



- **Solugen's US\$30M Series B** (2019): A specialty chemicals producer of bio-based peroxide solutions with participation from Y Combinator
- **Air Company US\$30M Series A** (2022): Producer of Ethanol from waste CO2
- **Chemify US\$43M Series A** (2023): Software to discover complex molecules on demand using digital blueprints faster, more efficiently, and safely



# Examples Green Chemistry Ecosystems



- **"Green Chemistry Campus in the Netherlands"**
  - Focus on pyrolysis and bio-aromatics
  - Offers labs, offices, meeting rooms, technological and business expertise for a community of entrepreneurs inspiring and helping each other
  
- **"Action Agenda and the Platform Green Chemistry New Economy"**
  - Focus on replacing plastics, building materials, textiles and coatings with plant-based alternatives, recycled feedstocks, and captured CO<sub>2</sub>
  - €338M from Dutch Government with private co-investment of €550M





# Workshop:

## Identifying Green Chemistry Potential

- **Objective:** Work in groups to identify industries and companies, the products they produce, and assess viability for green chemistry strategies.
- **Output:** Brainstorm 2-3 products, companies, or sectors where green chemistry principles could help identify improvements.
- **Presentation and Feedback:** Teams present their list of potential targets to the group with any reflections on what would be most well-received or relevant.



# Practical Tips



**If you want to work on Green Chemistry in a corporate setting, these tips might be useful:**

- Green Chemistry strengthens competitiveness by reducing impact and driving innovation in a globalized market
- Assess annual reports, transition plans, and corporate social responsibility policies as a source for inspiration and opportunity
- Develop a compliance matrix for local and international regulations to navigate regional regulatory differences in target sectors
- Incorporate cross-functional R&D teams with green chemistry principles



# Discussion Questions



To finalize this session, these discussion questions are useful to reflect on the concepts you have learned.

- How can businesses use green chemistry to drive innovation in product development?
- How can green chemistry reduce manufacturing costs and improve compliance?
- What metrics effectively measuring economic impact of green chemistry initiatives?
- How can companies overcome market adoption barriers for green chemistry products?
- What role do global regulations play in shaping green chemistry strategies?





Yale School of  
the Environment



Center for Green Chemistry &  
Green Engineering at Yale

Advance Science

Catalyze  
Implementation

Prepare the next  
generation

Raise Awareness

# Thank You!

For questions, please reach out:

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<https://www.globalgreenchem.com>

📱 <https://www.chemistryforsustainability.org>

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