WASHINGTON STATE UNIVERSITY

# Case Study on Nano-education Course Development: Sustainable Material Applications and Reuse in Treatment (SMART) of Water and Environment

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# Outline

- ❑ Background
- ❑ SMART Water and Environment
- ❑ Development of course on SMART
- ❑ Challenges
- ❑ Summary

# Background

- ❑ Challenges: climate change, population and industrial growth are posing threats to water and environment

- ❑ Sustainable and energy efficient water treatment, management, distribution, monitoring systems are needed
  - ❑ Emerging contaminants (drinking water, stormwater, wastewater)
  - ❑ Applications of advanced materials: challenges and opportunities
  - ❑ Sustainable usage of materials is one of the challenges
  - ❑ Developing a new course at Washington State University on sustainable material applications and reuse in treatment (SMART) of water and environment

# SMART Water and Environment Lab

- ***Sustainable Material Applications****:* Reduce the environmental footprint of material applications. relevance to water and environmental quality. (current research: graphene degradation)
- ***Sustainable Water Filtration****:* Develop materials for antifouling surfaces and membrane filtration for increasing flux, reducing energy and fouling. (current research: 2D nanomaterial based antifouling membrane; membrane collaboration with PNNL)
- ***Sustainable Material Reuse in Treatment****:* Reuse of materials in water treatment to reduce chemical and energy usage. (current research: regeneration of adsorbents for persistent pollutants; electrochemical regeneration of membrane surfaces)
- ***Renewable Materials in Treatment****:* Develop low cost filtration media using renewable materials. (current research: stormwater filtration via lignocellulosic materials).
- ***SMART Water and Environment***: Development and integration of sensors for monitoring of water and environmental systems (Current research: WSU smart city initiative)

# Sustainable Materials Management

- In 1900, 41% of the materials used in the U.S. were renewable (e.g., agricultural, fishery, and forestry products); by 1995, only 6% of materials consumed were renewable
- The majority of materials now consumed in the U.S. are nonrenewable, including metals, minerals, and fossil-fuel derived products
- Our reliance on minerals as fundamental ingredients in the manufactured products used in the U.S.—including cell phones, flat-screen monitors, paint, and toothpaste—requires the extraction of more than 25,000 pounds of new nonfuel minerals *per capita* each year
- This rapid rise in material use has led to serious environmental effects

US EPA, 2009,Sustainable Material Management

# Material Consumption in US

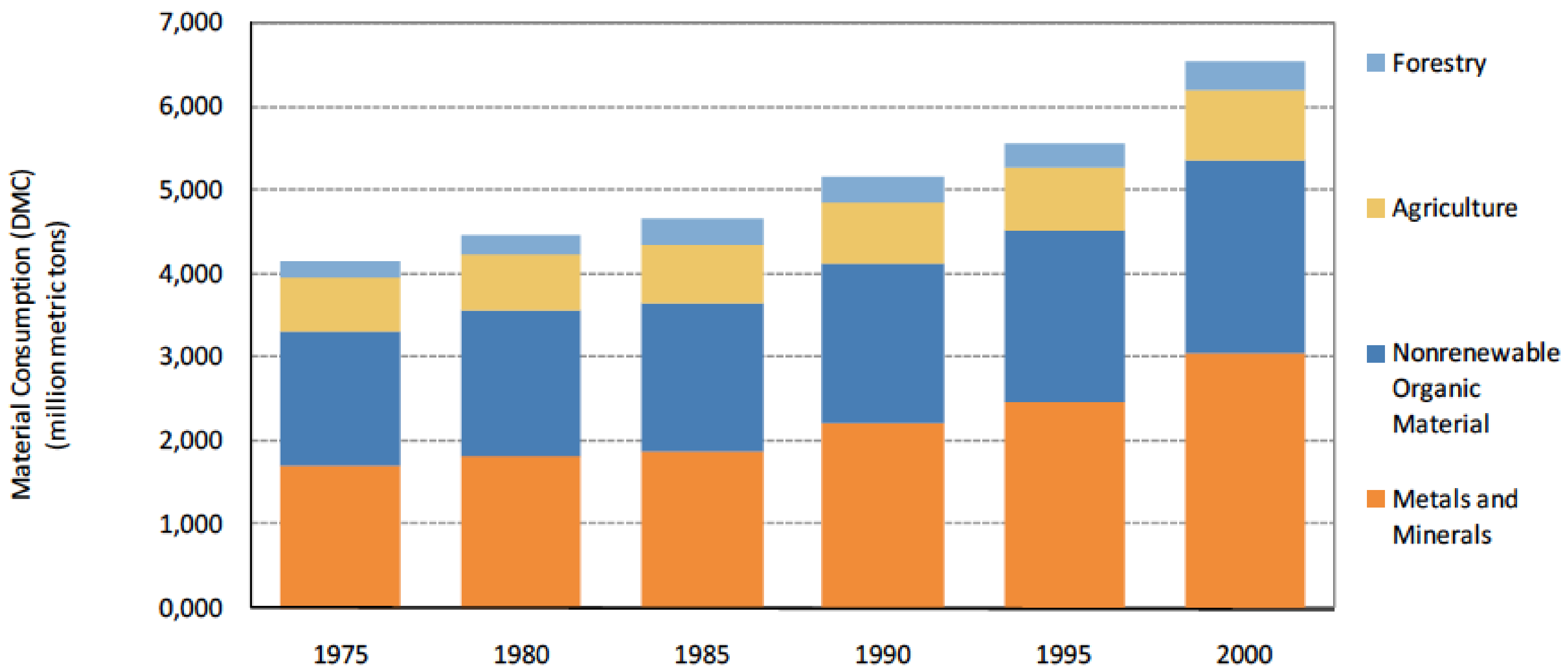



*Figure 1: Materials Consumption in the United States by Sector of Origin, 1975–2000*
*Source: WRI Material Flows Database 2005*

# Flow of Materials

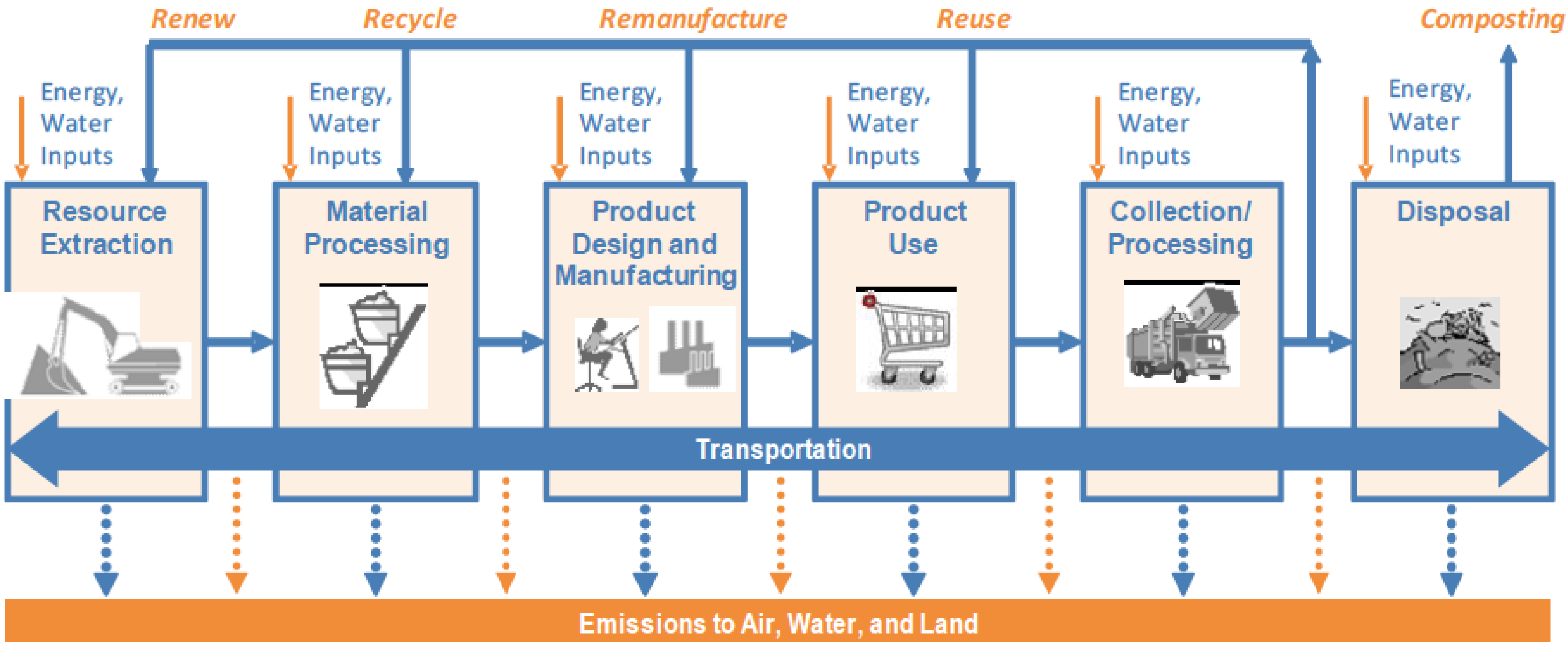
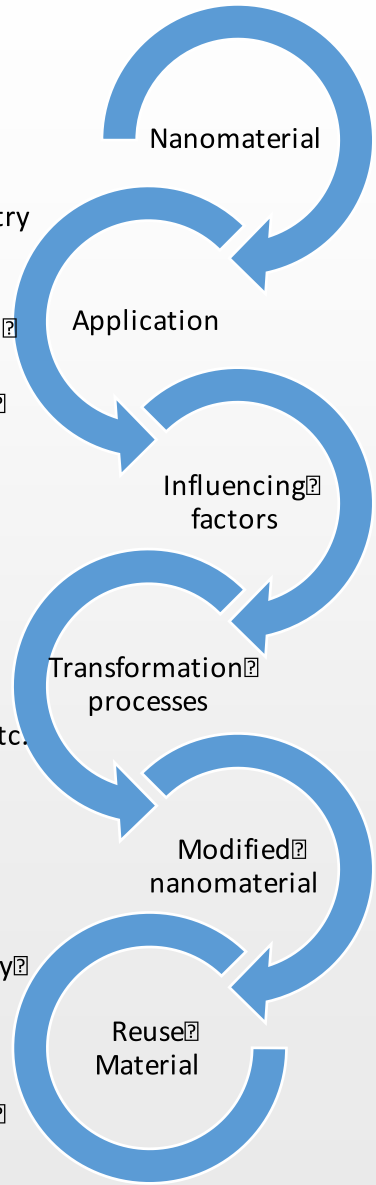



*Figure 2: The Flow of Materials*
*Source: State/EPA 2020 Vision Workgroup*

# SMART for Nanomaterials




**Nanomaterial**
- 0D (quantum dots)
- 1D (nanotubes, nanorods)
- 2D (Graphene)
- 3D (bulk material, nano composite) etc.

**Application**
- Elctronic industry
- Biomedical industry
- Pharmaceutical industry
- Environmental application etc.

**Influencing factors**
- Sunlight
- Temperature
- Oxidant
- pH etc.

**Transformation processes**
- Degradation
- Dissolution
- Oxidation
- Aggregation etc.

**Modified nanomaterial**
- Altering functional groups
- Tuning properties etc.

**Reuse Material**
- Environmentally friendly
- Sustainable
- Less environmental risk

# Objectives of the course

- Overall objective of this course was to train students on sustainable material applications
- The course was particularly focused on water and environment
- The course covered topics related to
  - Advanced Materials Background
  - Nanomaterial Fabrication
  - Environmental Transformations of Nano-enabled products
  - Environmental Applications of Nanomaterials
  - Environmental Implications

# Project

- This course was heavily focused on  individual projects
- Each student will choose his/her research materials or technology (any existing or emerging materials or technology)
- Each student will develop SMART strategies for their selected materials throughout the course
- The students will put together a summary paper
- The students will give a presentation on the subject
- This was designed to help students develop their technical communication skills that engineers need to be successful in their careers

# Teaching Materials

- Book: Environmental Nanotechnology: Applications and Impacts of Nanomaterials, Second Edition by Mark Wiesner, Jean-Yves Bottero
- Journal articles
- Reports from EPA, etc.
- Handouts

# Course Outline

| Subject/Topic |
| --- |
| Overview of advanced materials<br>Overview of SMART<br>Nanotechnology as a test case for SMART<br>Nanomaterial fabrication<br>Characterization of nanomaterials |
| Environmental applications of nanomaterials<br>Membrane processes<br>Nanomaterial enabled sensors<br>Nanomaterial for groundwater remediation<br>Reactive oxygen species generation on naomaterial |
| Environmental transformation of nanomaterials and nano-enabled products |
| Physical chemical properties: Transport, aggregation, Deposition |
| |
| Environmental Implications<br>Ecotoxicology principles for manufactured nanomaterials |
| Toxicology impacts of nanomaterials |
| Nanomaterial in ecosystems |
| Risk forecasting and life-cycle considerations |
| Nanotechnology governance for sustainable science and policy |
| Emerging Topics |
| |
| Student Project Presentations |

# Course Approach

- Integration of critical thinking
- Development of critical thinking is one of the main goals
- Project based learning
- Problem based learning
- Homework is also individualistic for developing critical thinking
- Exams are also individualistic

# Sample Homework

1. Select one nanomaterial from your project. Develop a flow chart for your selected nanomaterial using EPA handout for sustainable materials management. Describe in details and be specific.
2. During the industrial production of your selected nanomaterial, large spill of waste materials took place nearby soil environment.
    a. What type of pollutants will you expect in the spill? Consider the synthesis process of the selected nanomaterial. Describe in details and be specific.
    b. How likely will the waste materials reach to groundwater? What are the parameters of waste materials and soil that will govern their transport? Consider both organic and inorganic pollutants. Describe in details and be specific.
    c. How will you be able to confirm whether pollutants from your waste materials have reached to groundwater? Consider the characterization techniques discussed in this course. Describe in details and be specific for each pollutant.
    d. After the tests, you found that all the pollutants from the waste materials reached to groundwater. What will be your strategy for groundwater remediation of the contaminated site? Describe in details and be specific.

# Sample Exam Problem

**Problem 1.**

Stormwater pollution is a huge concern in Washington state. You have been tasked to develop an innovative pavement which can treat stormwater using sunlight. You have decided to use photocatalytic treatment based on nanotechnology. Stormwater contains polycyclic aromatic hydrocarbons, pesticides, and heavy metals. You found that you will need both oxidants and reductants for this photocatalytic process. What will be your strategy to develop this innovative nanotechnology-based pavement? Which nanomaterials will you choose? Justify scientifically with equations and schematic if necessary.

# Challenges

- Lack of textbooks
- Lack of example problems for problem-based learning
- Diversity in academic background of students makes difficult
- Nanotechnology course requires lot of background knowledge (thermodynamics, chemistry, etc)
- Difficult for the new students

# Summary and Future Directions

- As the materials are at the forefont of technological revolution,  training students on sustainable material applications will be good for their career
- Project- and problem-based learning is helpful for teaching this type of course
- Individualistic homework and exams can improve critical thinking ability of the students
- Future modifications of the course will be done based on the student outcomes and comments
- Any suggestions?

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# Material Management

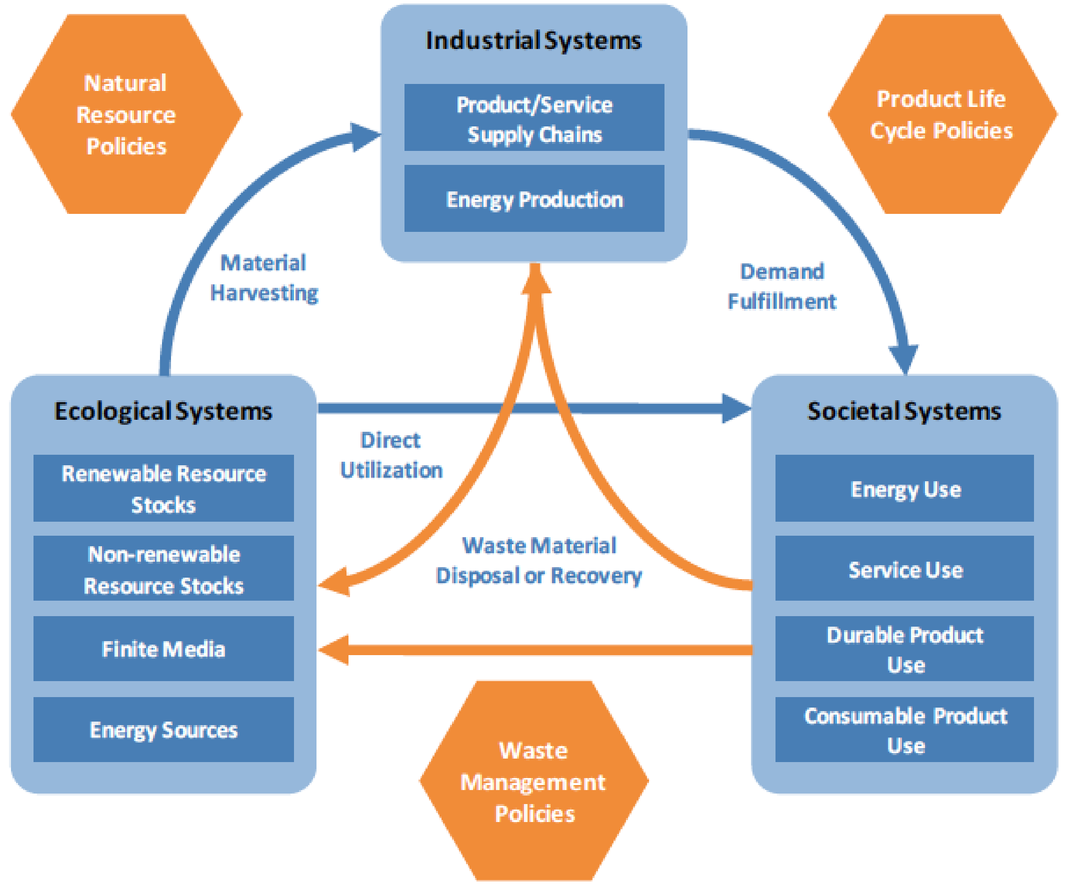
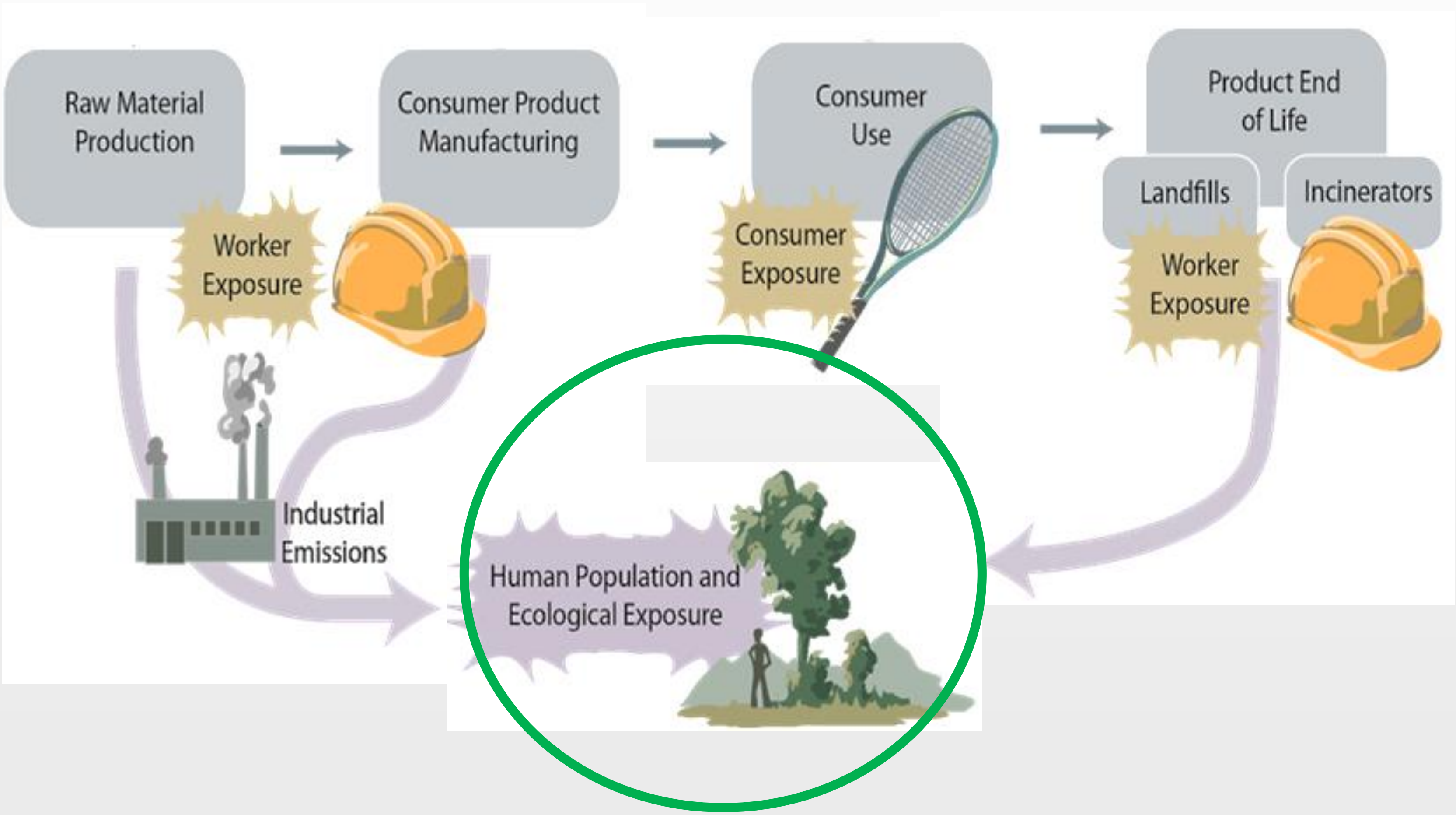



*Figure 3: Framework for Examining Materials Management*

*Source: Fiksel, Joseph. "A Framework for Sustainable Materials Management," Journal of Materials, August 2006*

# Life Cycle Stages




Adapted from the National Nanotechnology Initiative