ENGINEERING SOLUTIONS FOR SUSTAINABILITY:
MATERIALS AND RESOURCES 3

Toward a Circular Economy

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Session #3: Educating the Future Engineer

Introducing the Circular Economy to Undergraduate Students

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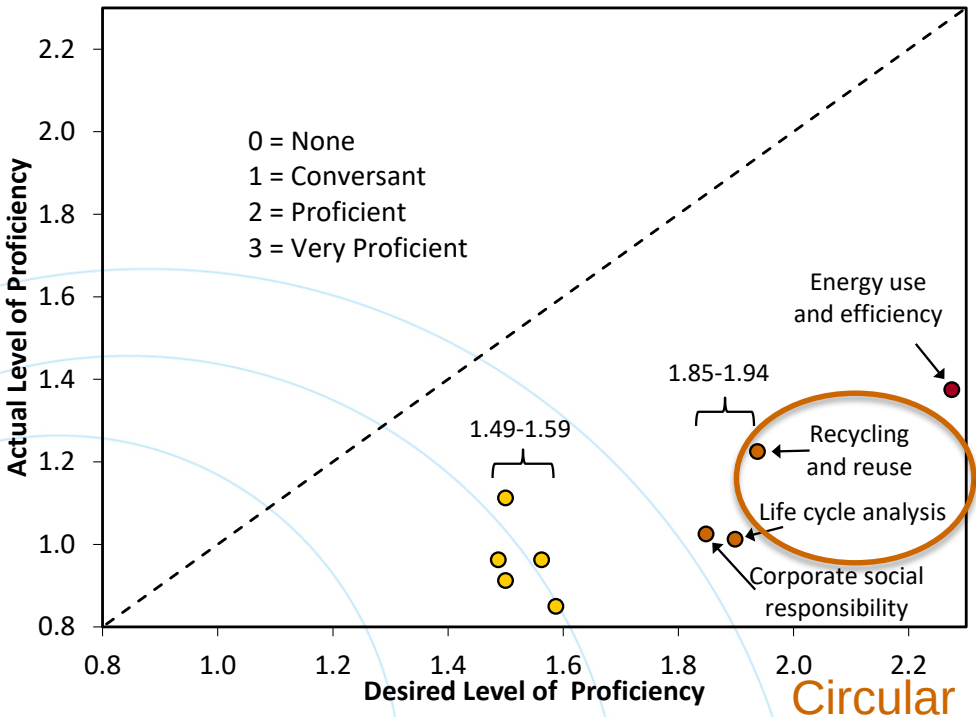
Contributors

- Jeffrey Fergus, Materials Engineering
  - 1-hour courses
- Nanette Chadwick, Academic Sustainability Programs
  - Sustainability Minor
- Brian Via and Soledad Peresin, School of Forestry & Wildlife Sciences
  - Sustainable Biomaterials and Packaging Major

Educational Needs – Industrial Survey



Circular Economy

Topic	Ave.
Energy use and efficiency	2.28
Recycling and reuse	1.94
Life cycle analysis	1.90
Corporate social responsibility	1.85
Environmental law and responsibility	1.59
Carbon management and climate change	1.56
Industrial ecology	1.50
Social and community issues	1.50
Water and land use and reclamation	1.49

Fergus, Twigge-Molecey, McGuffin-Cawley, *JOM* **65**[8] (2013) 935

Enhancing Education in Sustainability

- Integration into existing courses
  - Maintain curricular content
    - Pressure to increase content / decrease hours
  - If content is added – what is taken away?
    - Zero or negative sum game
- New courses
  - If required – what is replaced?
  - If elective – incentives for taking courses?
- New degree programs
  - Breadth *vs*. depth
  - Marketing of degree

Materials Engineering Sustainability Courses

- Objectives
  - Enhance understanding / appreciation of sustainability issues (preparation)
  - Illustrate importance of materials science and engineering (recruiting)
- Accessibility
  - Limited commitment
    - Courses do not count toward degree requirements
    - One credit hour (1 meeting per week)
  - Open to non-engineering majors

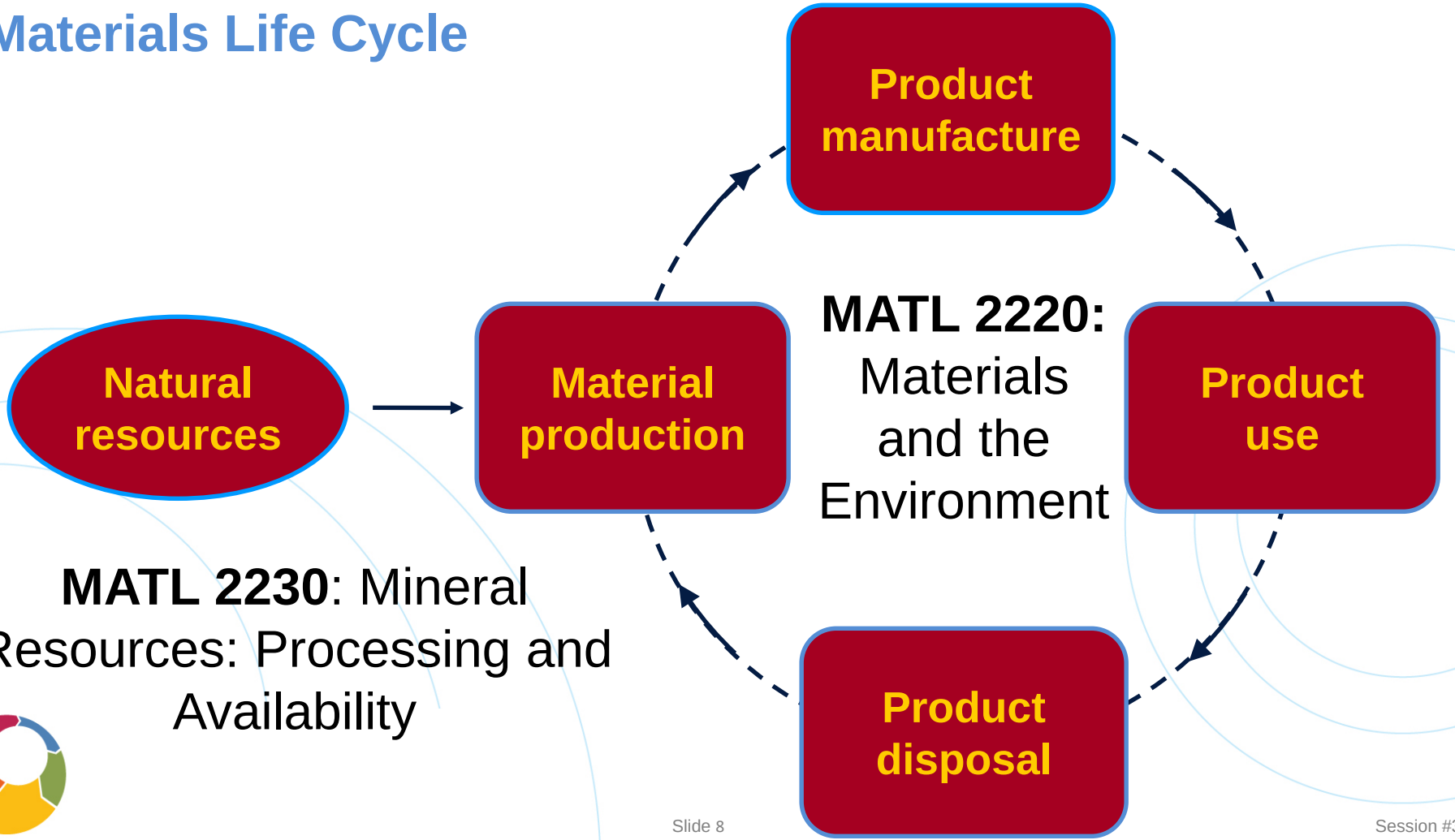
Materials Engineering Sustainability Courses

- MATL 2210: Materials for Sustainable Energy Production and Storage
- MATL 2220: Materials and the Environment
- MATL 2230: Mineral Resources: Processing and Availability

Materials for Sustainable Energy Production and Storage

- Background
  - Energy use and production
  - Metrics for comparison of technologies
- Energy Conversion
  - Thermal
    - Combustion, Nuclear, Thermoelectric
  - Electrochemical
  - Solar
    - Heat, photovoltaic
  - Mechanical
- Energy Storage
  - Electrochemical, Mechanical, Chemical (Hydrogen)

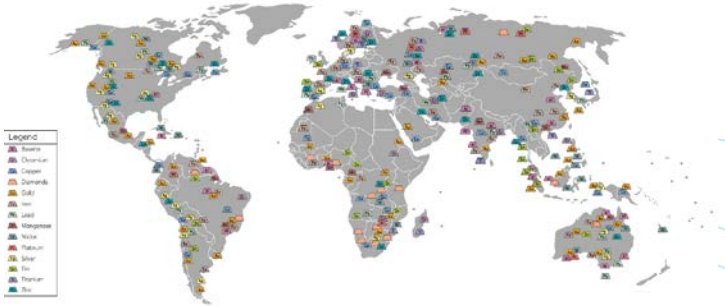
Materials Life Cycle



MATL 2230: Mineral Resources: Processing and Availability

Mineral Resources: Processing and Availability

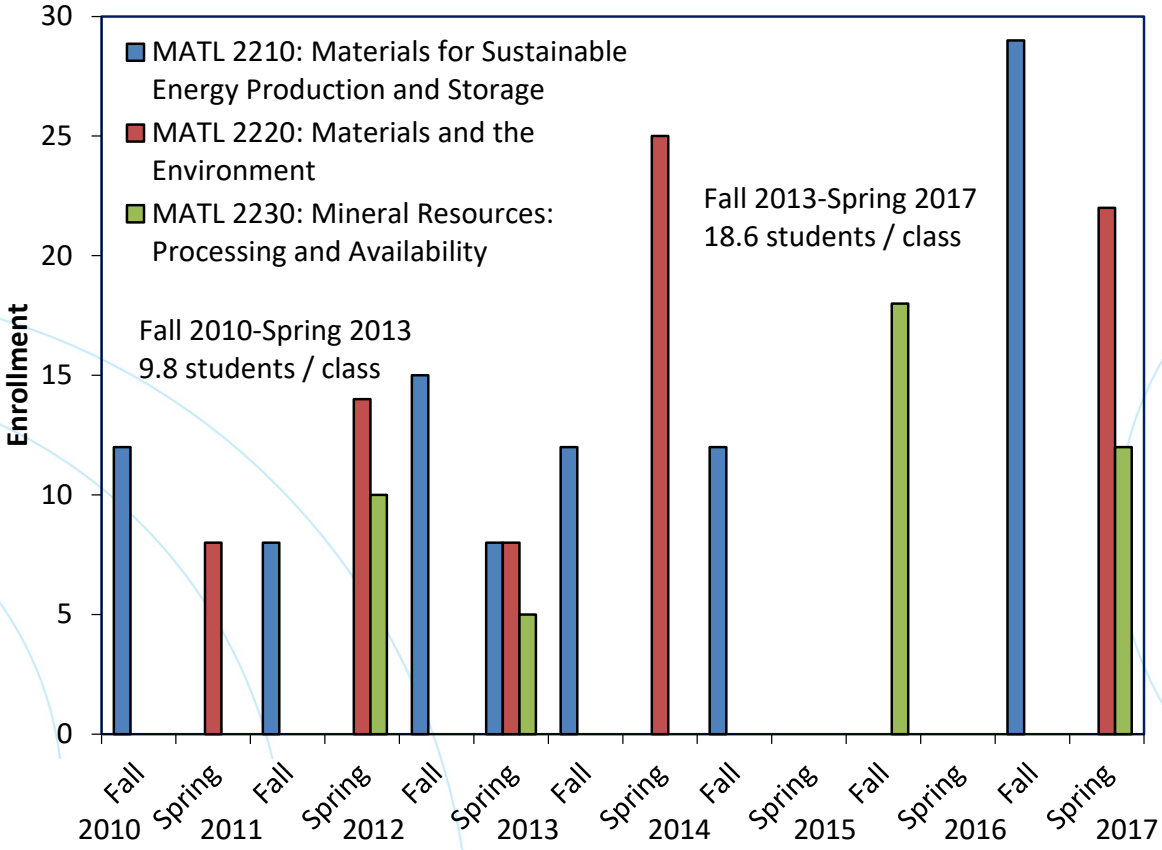
- Overview of materials science and engineering
- Where do the materials used to make products come from?
- How are they processed?
- Where are the resources located?
- Why are supplies of some materials limited?



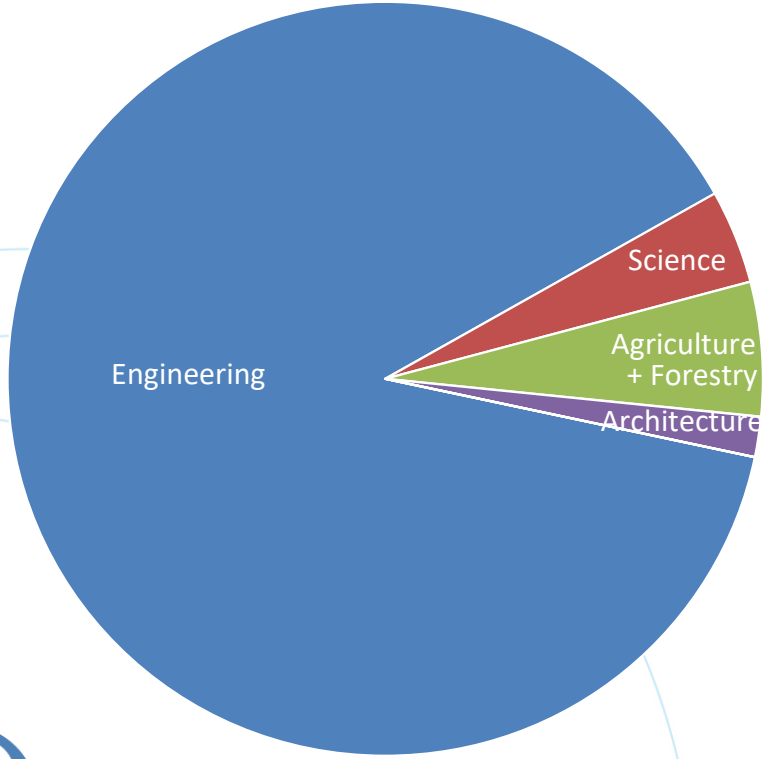
Materials and the Environment

- Overview of materials science and engineering
- The materials life cycle
  - Primary production, manufacturing, use, disposal
- Constraints
  - Economics, availability, legislation
- Materials selection
  - Materials properties, environmental impacts, recycling

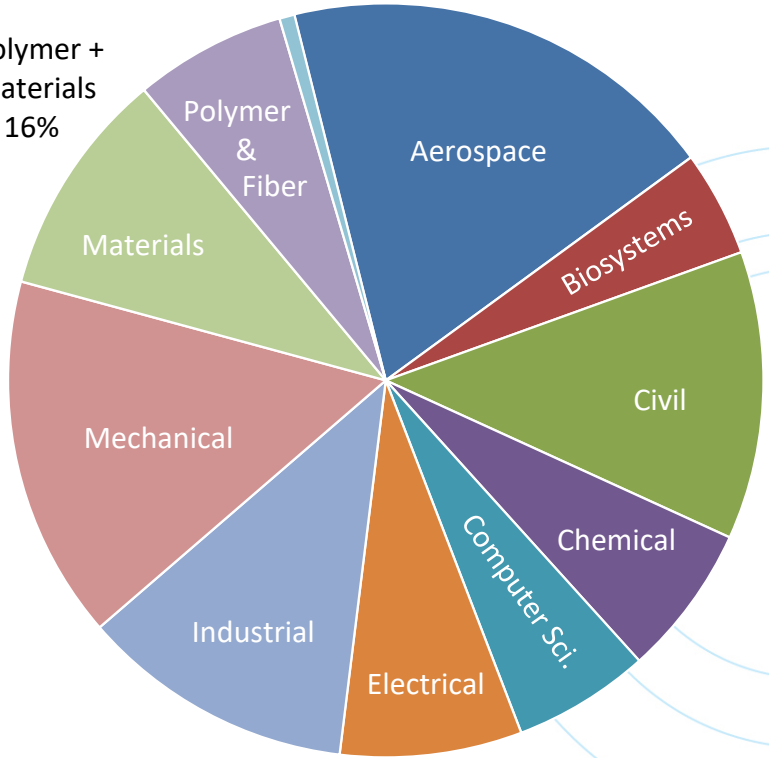
Course Enrollment



Course Enrollment



Polymer +
Materials
= 16%



Course Format

- One class per week
- Course requirements
  - Short (1-2 slide) presentations
    - One every 2-3 classes
    - Examples:
      - Source of particular element
      - Energy use of selected product
      - Example of potential energy harvesting opportunity
      - Environmental impact of materials used in selected product
  - Final presentation
  - Test

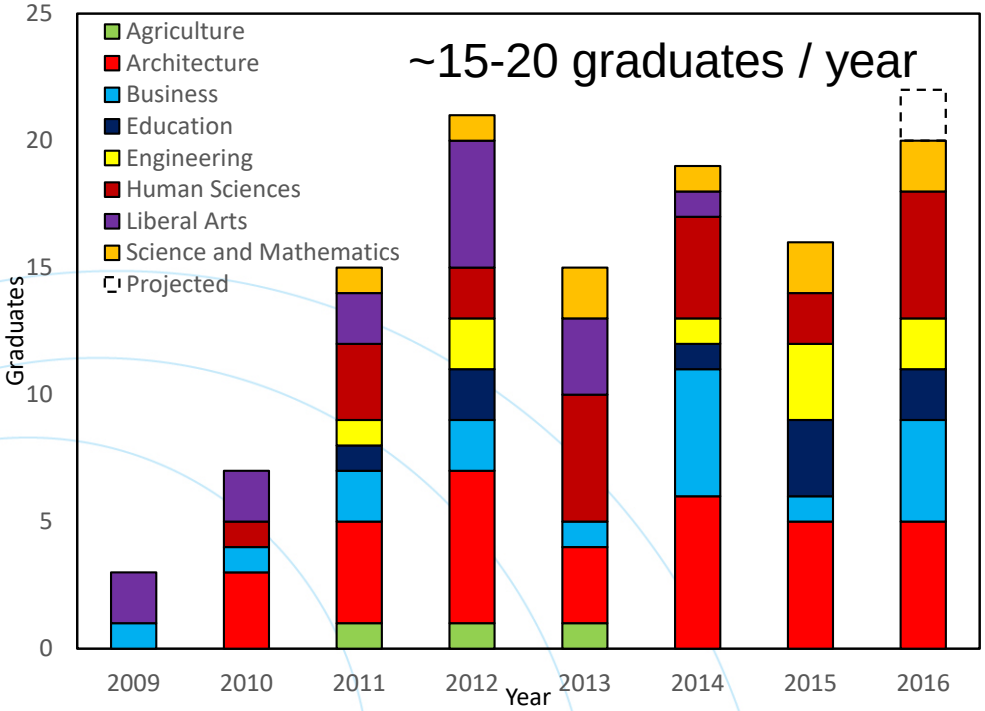
Diverse Student Background

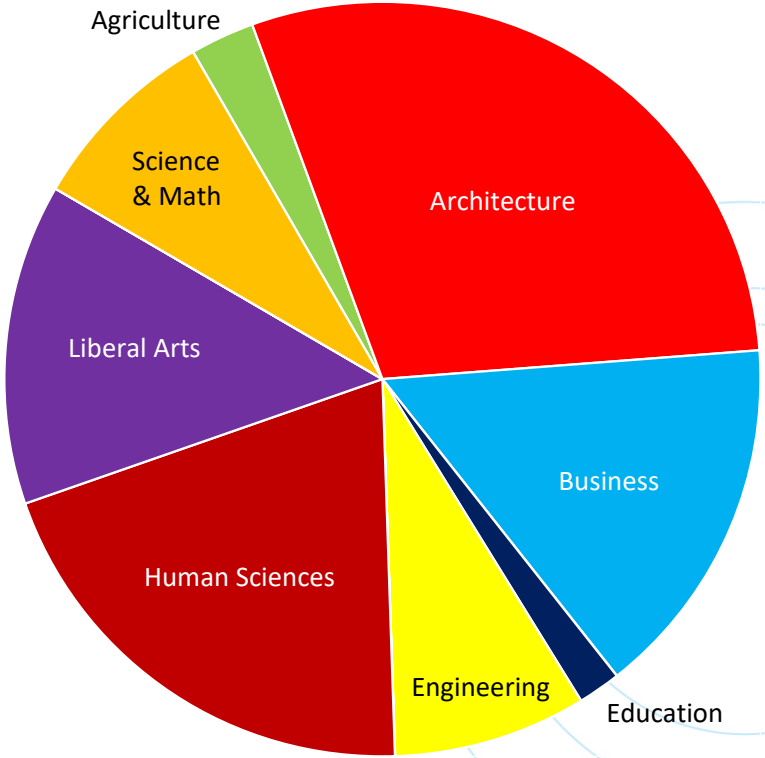
- Differing technical backgrounds of students
  - Topics presented at basic level
- Students use examples / apply knowledge from major discipline
  - Electrical engineering for power conversion
  - Civil engineering on water treatment
- Examples from personal experience / interests
  - Musical instruments, sports, hunting

Minor in Sustainability Studies

- Required courses (6 credit hours)
  - Introduction to Sustainability (~90 students / semester)
    - Systems Thinking; Consumption & Waste
  - Senior Capstone in Sustainability
- Elective courses (9 credit hours)
  - Society and Markets, Environment, Social Justice
  - Popular electives
    - Global Consumer Culture
    - Ecotourism
    - Bioenergy and the Environment
    - Physical Geography
    - Landscape and Culture
    - Religion and the Environment
    - Environmental History
    - Environmental Ethics

Minor in Sustainability Studies

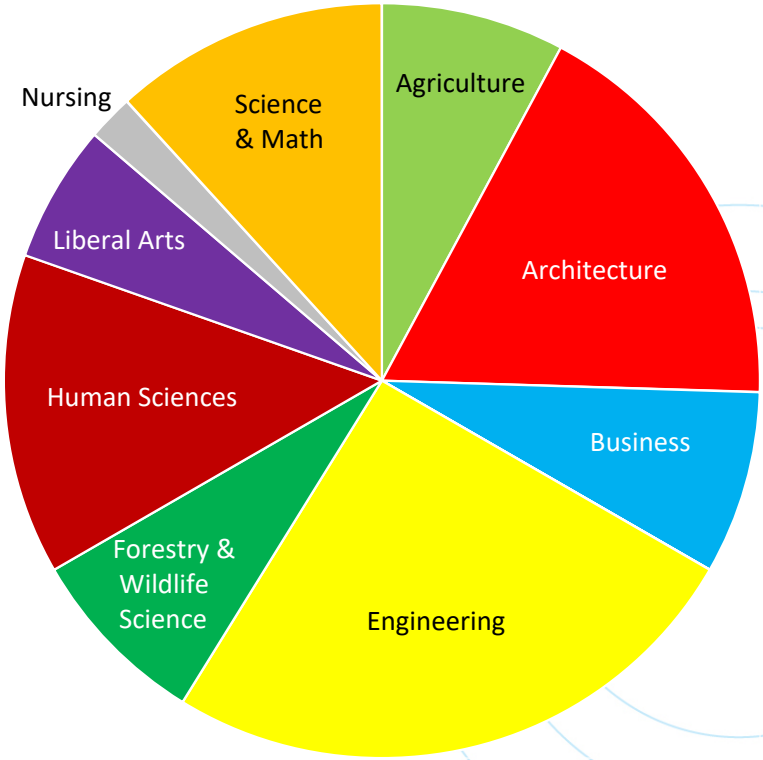




109 graduates since 2009

Minor in Sustainability Studies – Engineering

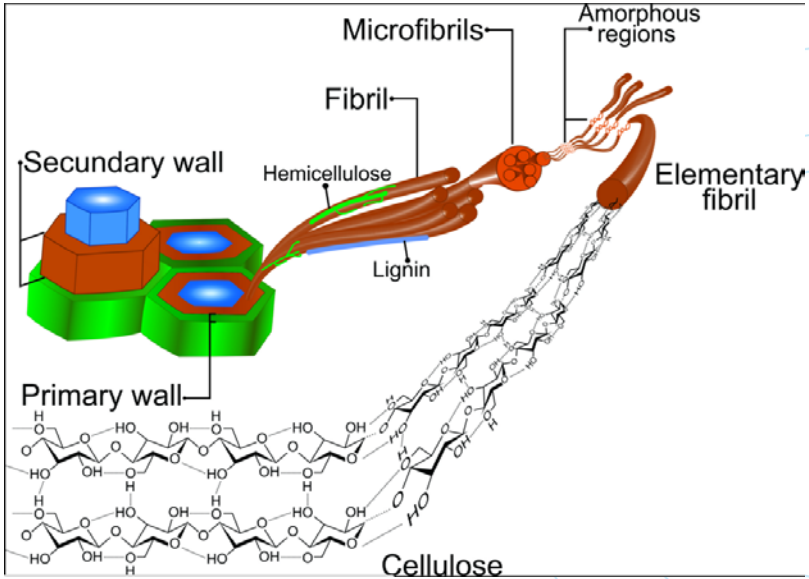
- Engineering Electives
  - Biosystems Engineering
    - Natural Resource Conservation Engineering
  - Mechanical Engineering
    - Renewable Energy Resources and Applications
  - Materials Engineering
    - Materials for Sustainable Energy Production and Storage
    - Materials and the Environment
    - Mineral Resources: Processing and Availability



Fall 2016 Enrollment: 51 Total
37% STEM (17% of graduates)

Sustainable Biomaterials & Packaging Major

- Focus on products and packaging from bio-mass sources
- Technical issues
  - Resources: Agriculture, forestry
  - Products: Materials properties, design
- Non-Technical issues
  - Economics
  - Logistics
  - Marketing



Sustainable Biomaterials & Packaging Major

Biomass & Logistics

- **Planting (Seedling)**
- **Feedstock Quality**
- **Harvesting**, *Transportation*
- *Supply Chain Management*
- *Distribution & Logistics*

Processes & Products

- **Traditional Forest Products**
- **Forestry Materials Packaging**
- **CLT, Wood Composites**
- **BioBased Polymers for Packaging**
- **Bioenergy**
- **Pulp & Paper for Packaging**
- *QC Control & Testing*

Sustainability & Business

- *Marketing & Business*
- *Life Cycle Analysis*
- *Eco-Design*
- **Economics**
- **Product Development**
- *Recycling*

Biopackaging & Materials

Other Disciplines

Sustainable Biomaterials & Packaging Major

- Forestry & Wildlife Science
  - 14 new course (38 hours)
  - Forestry

- Architecture
  - Industrial / Environmental Design
- Agriculture
  - Crop, Soil & Environmental Science
- Business
  - Marketing, Supply Chain Management
- Engineering
  - Biosystems / Industrial / Materials Engineering

Conclusions

- Full integration of circular economy concepts ideal but challenging
- Individual courses
  - Use for graduation requirements
  - Appropriate breadth vs. depth
- Interdisciplinary minor
  - Coordination / focus of courses
  - Accessibility of multiple majors
- New curricula
  - Market to students and employers