CAPE GREEN ENGINEERING WEBINAR
UNIT 2: APPLICATION OF GREEN ENGINEERING PRINCIPLES

Sustainable Utilization of Materials & Energy

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SUSTAINABLE UTILIZATION OF MATERIALS & ENERGY

• The Fundamentals
• Overview: Materials
• Overview: Energy
• Responsible Use of Materials & Energy: The Circular Economy
• Industrial Ecology: Principles & Practices
• Live Interactions
THE FUNDAMENTALS

• Atoms, Molecules & Compounds

ATOMS

MOLECULES

COMPOUNDS
THE FUNDAMENTALS

• Principles of Bonding

THE CHEMICAL BOND

THE PHYSICAL BOND
• Chemical Reactions

Example: COMBUSTION

\[
\text{CH}_4 (g) + 2\text{O}_2 (g) \rightarrow \text{CO}_2 (g) + 2\text{H}_2\text{O} (g) + \text{heat}
\]
THE FUNDAMENTALS

• HOW FAR, HOW FAST?
  THERMODYNAMICS

KINETICS
The Thermodynamic Laws

1st Law
Energy is conserved, its form can be converted

2nd Law
Energies can flow, equilibrate

3rd Law
“Driving force” for equilibration uniquely defined

0th Law
Thermal equilibrium is transitive
MATERIALS

• Types of Materials
  ORGANIC
  INORGANIC
MATERIALS

• Some Organic Materials
  Biopolymers
  Synthetic polymers
MATERIALS

• Some Inorganic Materials
  Metallic compounds
  Composite compounds
  Ceramic compounds
MATERIALS

• Nano-materials
Energy

Kinetic Energy
- energy of movement
- energy of objects in motion
- energy of particles moving through a wire
- energy causing push or pull

Potential Energy
- stored energy
- energy is stored to be used later

Thermal Energy
- energy of moving particles (heat)

Mechanical Energy

Chemical Energy
- energy stored in food, fuel

Sound Energy
- form of energy we can hear

Elastic Energy
- energy stored in objects that are stretched

Light Energy
- form of energy our eyes can detect

Nuclear Energy
- energy stored in the centre of particles

Gravitational Energy
- energy stored in an object when it is above the earth's surface

We experience energy in different ways...
• How is energy typically, produced, delivered & used?
Various paths of energy from source to service lines indicate possible energy pathways.
RESPONSIBLE USE OF MATERIALS & ENERGY

- The Circular Economy
• **Energy Balance:** Identify all energy inputs including energy to operate equipment and energy content of raw material. What fraction of the input energy is “recovered” in process outputs?

• **Material Balances:** Account for the fate of all the raw material inputs - such as air, water, etc. - in the process. What portion of the materials entering the process is contained at the exit stage?

• **Technical Feasibility Essentials:** Identify the thermodynamic and kinetic performance limits of the process and the degree to which the available technology hardware provides safe and reliable operation.
  - Scale at which performance has been suitably proven
  - Technology readiness levels
  - Supporting Infrastructure
  - Project Location
  - Timescale

• **Environmental Considerations:** Identify the current and future effect of the process on the local land, water and air resources and the economic cost of environmental protection, as well as the potential cost of clean-up and restoration, where necessary.
  - Local Pollutants
  - GHG Balance
Avoiding Unnecessary Energy Use
Re-organise systems so that energy use can be reduced to the minimum, for example by designing buildings to be warmed by the sun, using natural light and ventilation, or enabling people to get access to the amenities they want with fewer and shorter car journeys.

Use Energy more Efficiently
Finding ways of getting more benefit per unit of energy, for example by using higher efficiency appliances, generating heat and power together or insulating buildings better to retain heat.

Use Renewable Energy
Switch to less damaging low-carbon energy sources, especially renewables, for example solar and wind power, energy crops or hydro.
INDUSTRIAL ECOLOGY

• A Case Example
Impact of demand response on a daily load curve
World Energy Outlook 2017

Without demand side response

With demand side response

Variable renewables
Dispatchable renewables
Oil & gas
Coal
Nuclear

Total demand
Curtailed renewables
Shifted demand

100
200
300
400
500
600

0h 8h 16h 24h

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INDUSTRIAL ECOLOGY

Significant attention paid to resource efficiency, with focus on local resource use

- RECYCLED & REUSED CONTENT
- NATURAL & RENEWABLE MATERIAL & ENERGY
- RESOURCE-EFFICIENT PROCESS
- LOCAL CONTENT
The Future We Want
“For the things we have to learn before we can do them, we learn by doing them.”

-Aristotle

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