CONCRETE SUSTAINABILITY

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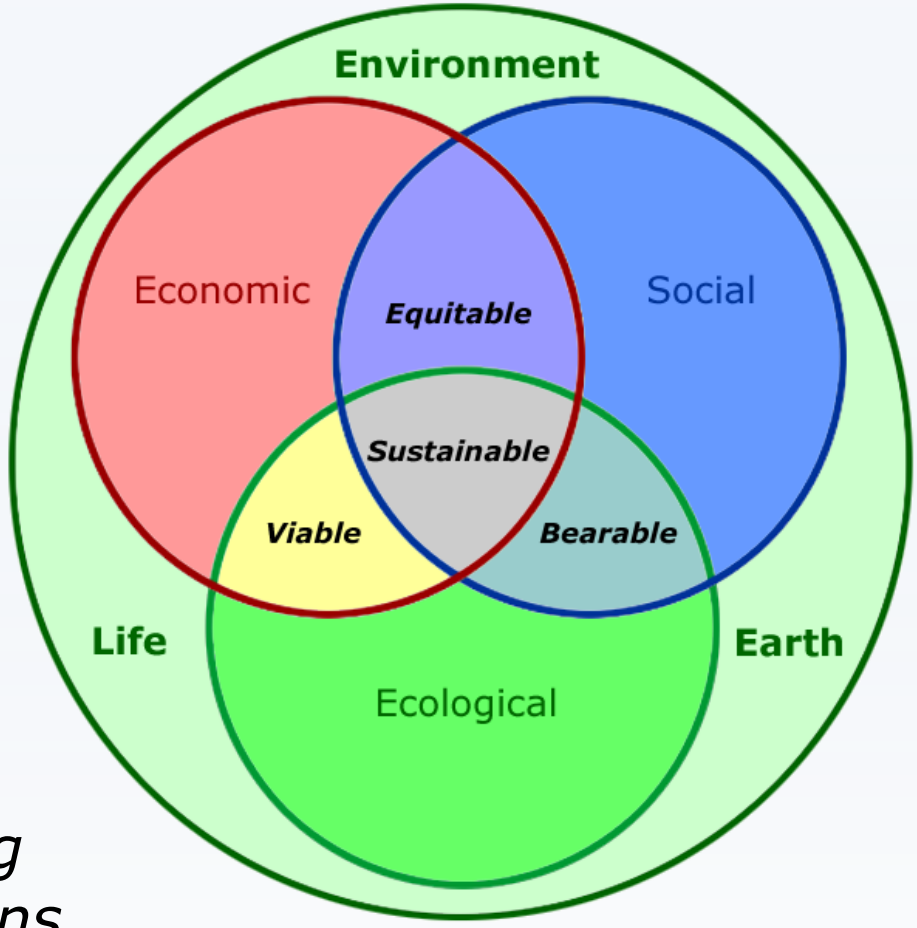
Overview and Objective

- Introduction to Sustainability
- Concrete Sustainability
- Pipeline for Concrete Sustainability
- Role of Cement on Sustainability
- Role of Supplementary Cementitious Materials (SCMs) and industrial byproducts on Concrete Sustainability
- Role of other Raw Materials

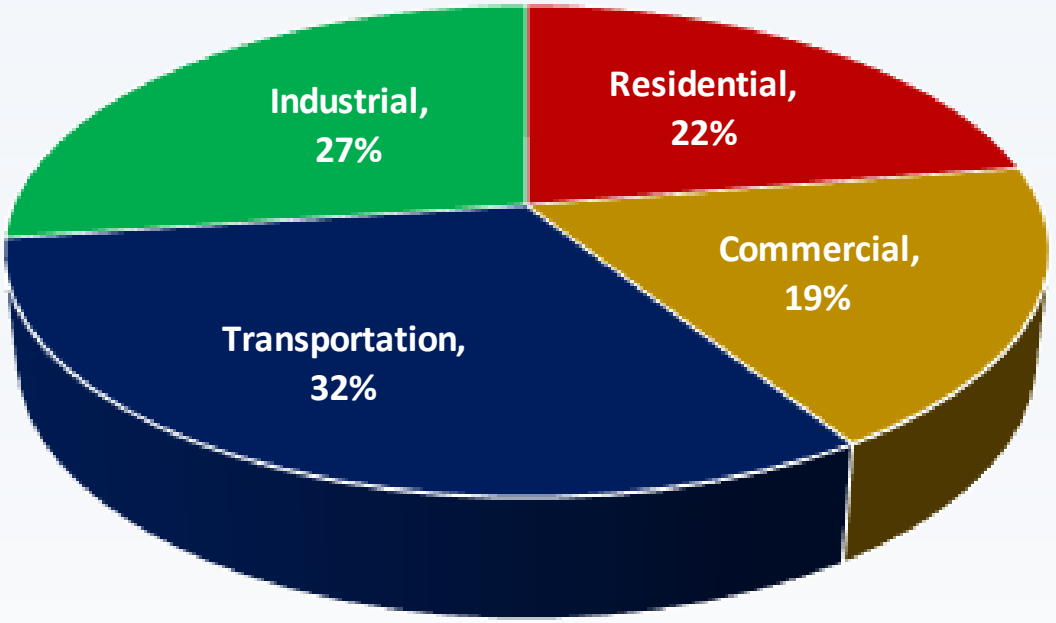
Introduction - Sustainability

- **What is Sustainability???**
- Balance of the Impact to **Triple Bottom Line**:
  - Environment (Ecology)
  - Society
  - Economy
- "*Meeting the needs of the present without compromising the ability of future generations to meet their needs.*"



Introduction - Sustainability

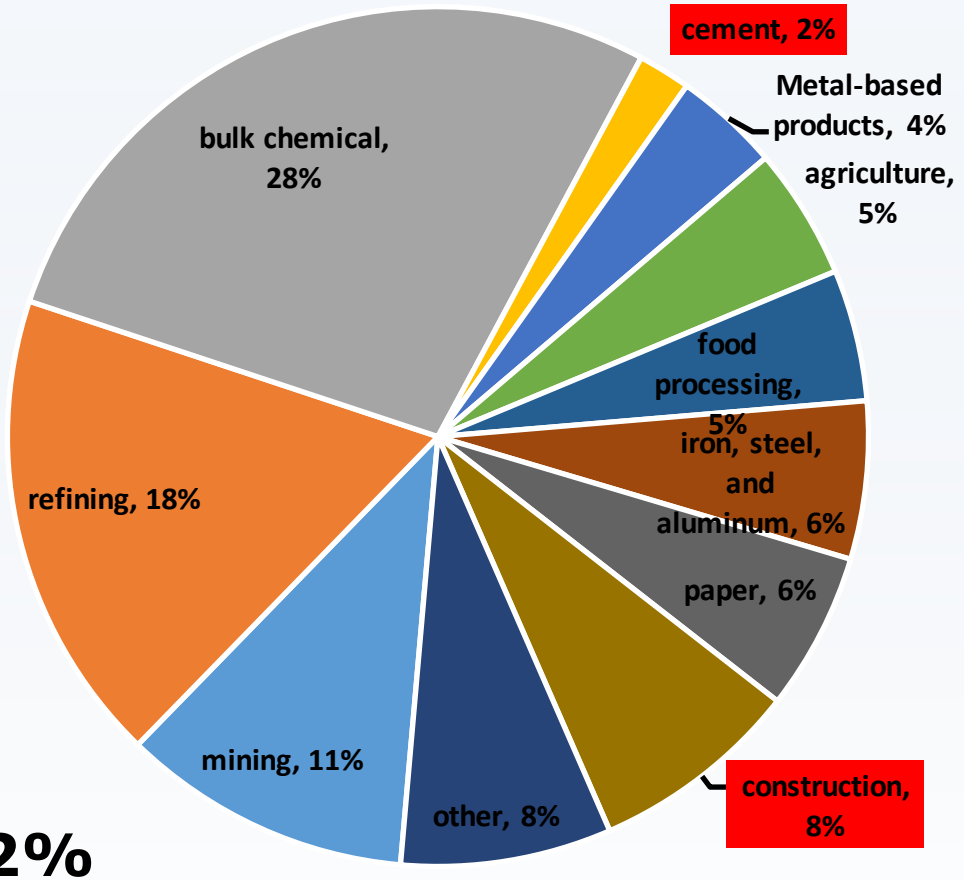
- **Energy Use according to U.S. Energy Information Administration (EIA)**
  - **Residential**
  - **Commercial**
  - **Transportation and Infrastructure**
  - **Industrial**



Energy Use by Industrial Sector (EIA 2018)

Introduction - Sustainability

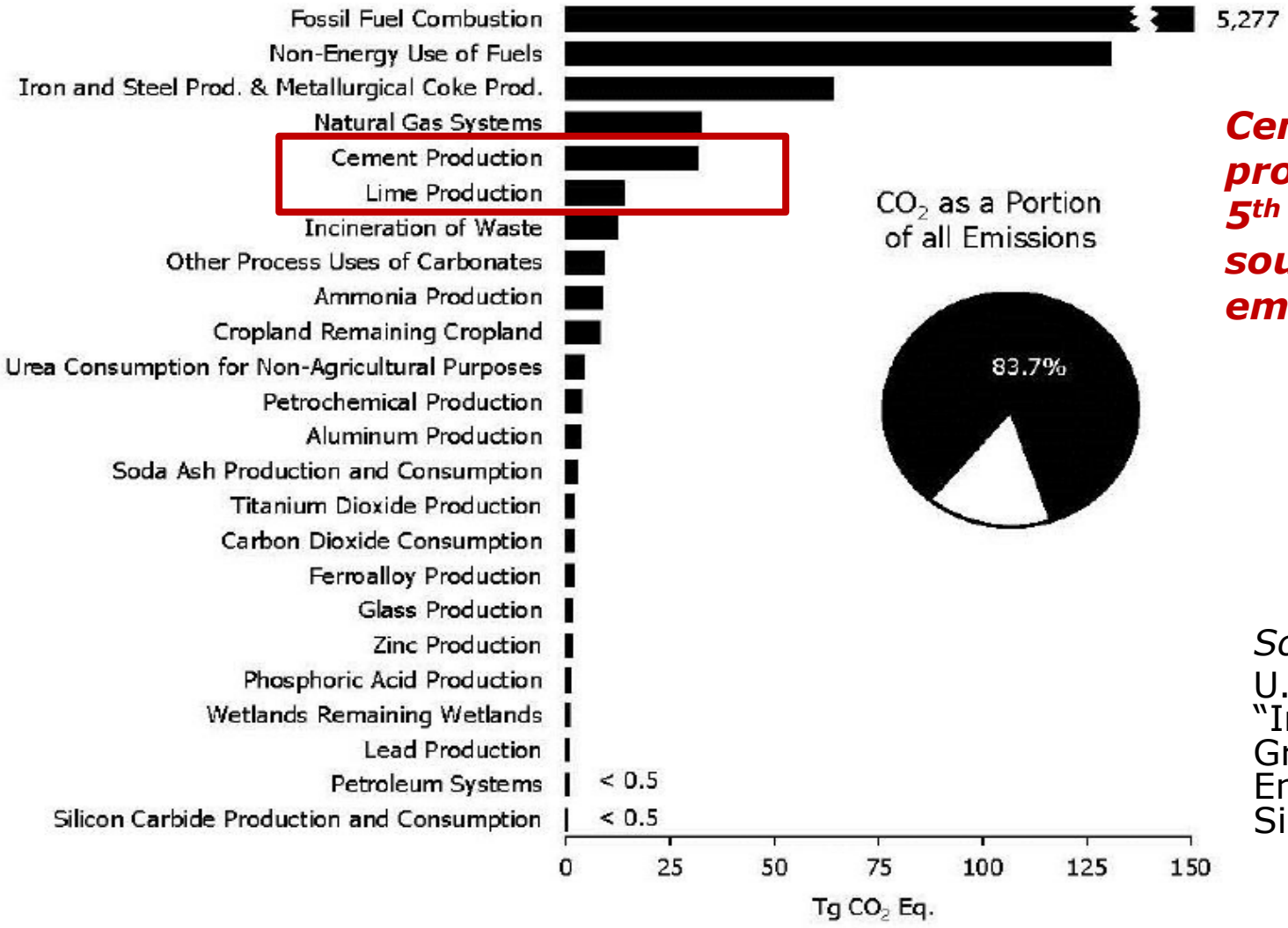
- **U.S. Energy Consumption by type of Industry**
  - **Construction 8%**
  - **Cement Production 2%**



U.S. Industrial Sector Energy Consumption by type of Industry, 2017

Concrete Sustainability

Figure ES-5: 2011 Sources of CO_2 Emissions



Cement production is the 5th largest source of CO_2 emissions in U.S.

Source: U.S.EPA (2012) "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012"

Concrete Sustainability

Improving sustainability of cement & concrete production can have a significant impact on improving sustainability of civil infrastructure for future generations

http://www.nrmca.org/greenconcrete/

- Every year, more than **4 billion tons of cement** for concrete are produced worldwide
- As of 2017, about **9 billion cubic meters** of concrete are made every year
- Average of **0.92 tons of CO_2** emitted per **ton of cement** produced

Concrete Sustainability

- Concrete Sustainability
  - Service Life
  - Durability
  - Functionality
  - Serviceability
  - Aesthetics

Pipeline for Concrete Sustainability

Short-term Life Cycle

Concrete Production

Stage I: Raw Materials Extraction and Acquisition

Cement | Cementitious Materials | Aggregate | Water | Admixtures

Stage II: Transport of Raw materials to Production Facility

Local Availability | Amount & distance to be transported | Fuel

Stage III: Concrete Production

Energy Requirements | Resource & Water Use

Stage IV: Construction

Transport | Fuel | Machinery/Labor | Cast-in-Place/Precast

Long-term Life Cycle

Stage V: Maintenance

After XX years in service | Structure Repair (% of materials to be replaced)

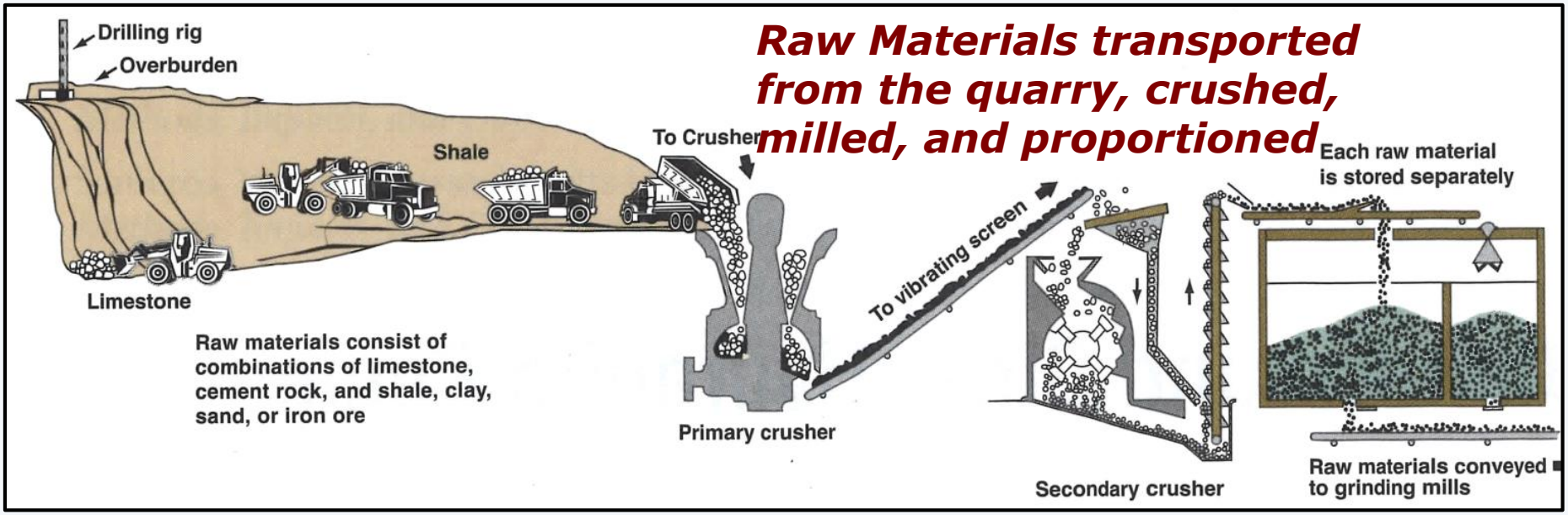
Stage VI: Demolition and Disposal/Recycling

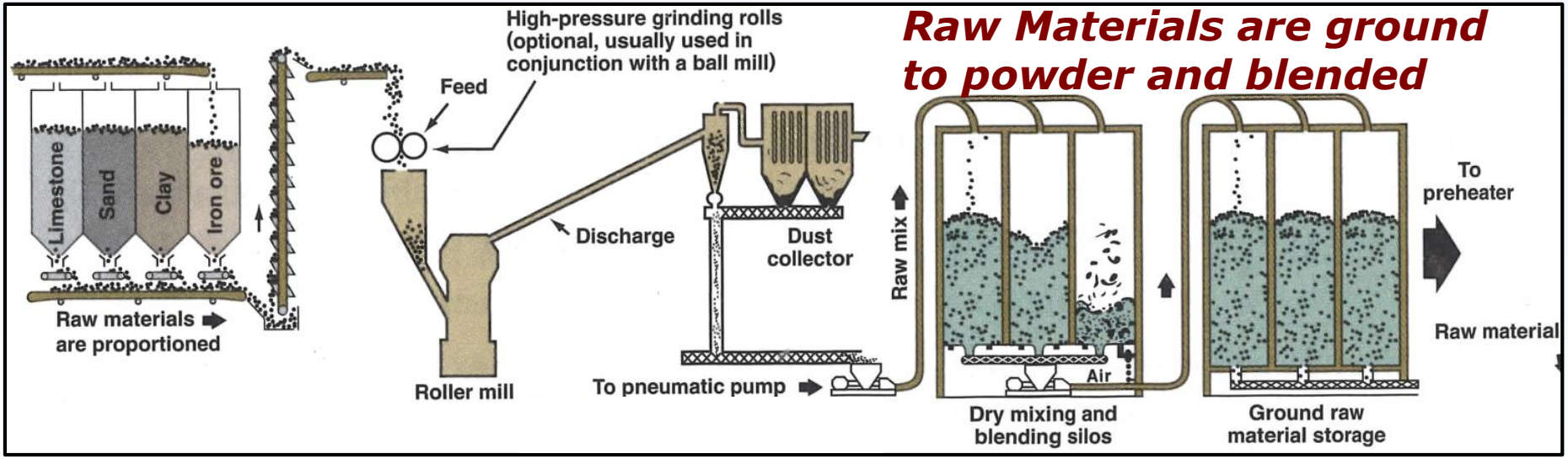
Service Life | Recycling | Demolition & Disposal

Cement Production

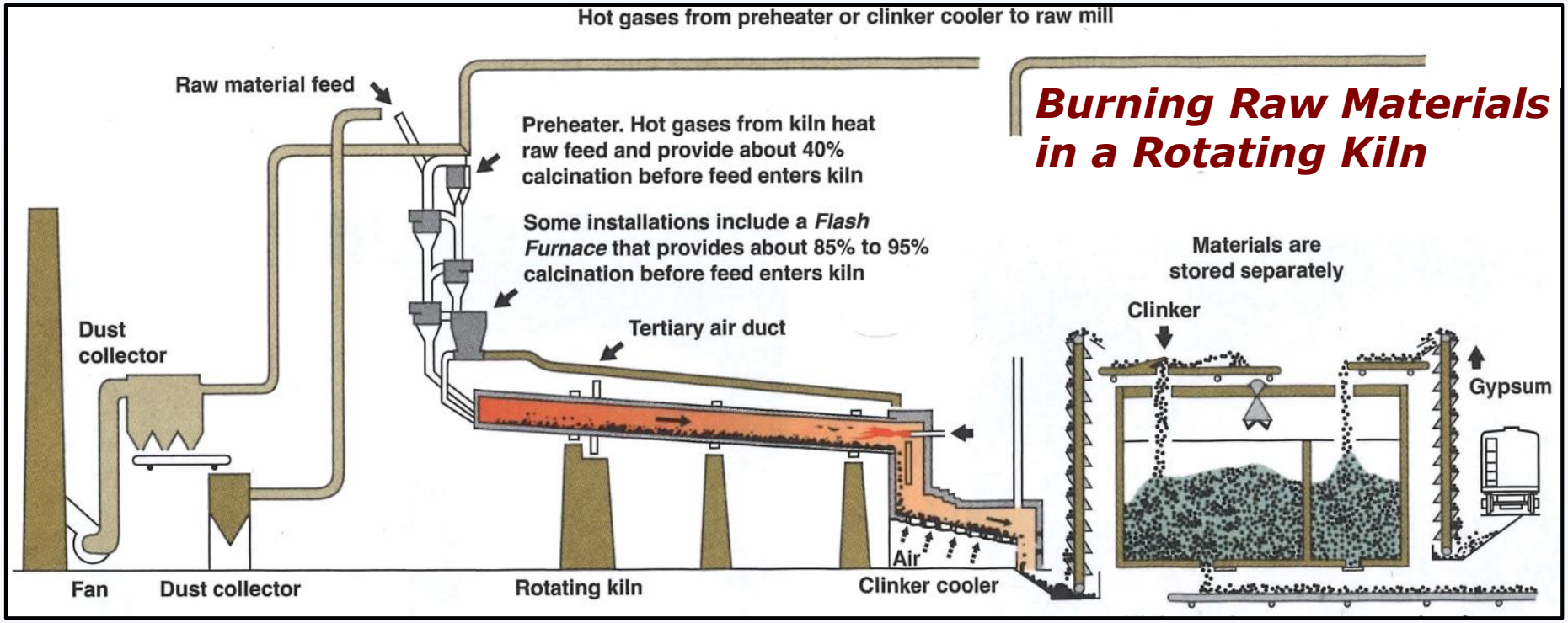
- **Cement Materials**
  - **Calcium oxide, CaO:** from limestone, chalk, shells, shale or calcareous rock
  - **Silica, SiO2**: from sand, or old glass bottles
  - **Alumina, Al_2O_3**: from bauxite, recycled aluminum, clay
  - **Iron, Fe_2O_3:** from clay, iron ore, scrap iron and fly ash
  - **Gypsum, $CaSO_4$:** found together with limestone

Cement Production





Cement Production



- Raw Materials are burned at **1450 °C (2700 °F)**
- Calcination Process:
  - **$CaCO_3 \rightarrow CaO + CO_2$**
  - Accounts for **more than 55% of CO_2 emission**

Cement Sustainability – SCMs & Byproducts

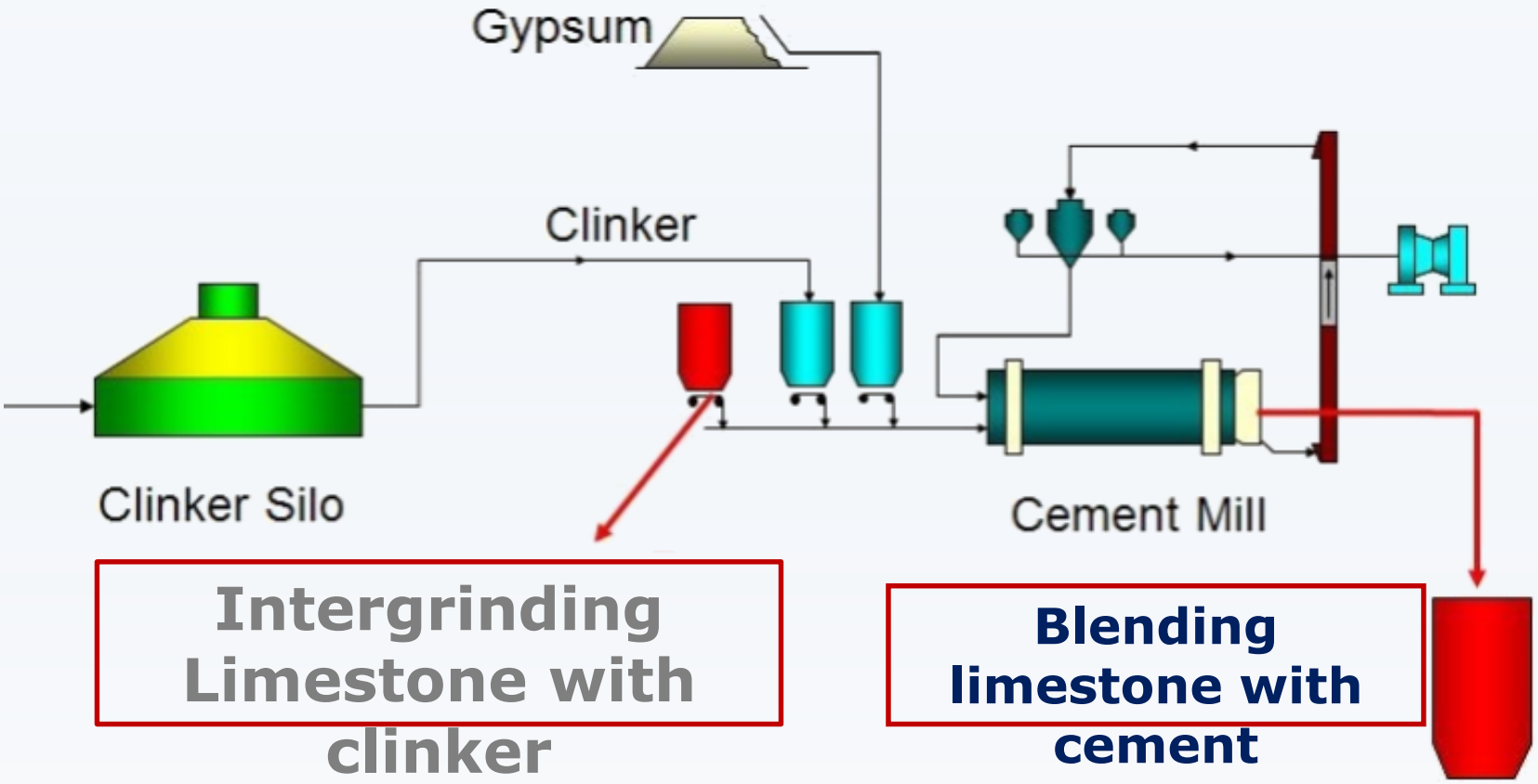
Limestone: A by-product created by the crushing of rocks to produce crushed a

Silica Fume: Byproduct of silicon alloy production

Fly Ash: Product of coal combustion at power plants

Slag: Byproduct of metal ore smelting & processing

Cement Sustainability



Limestone can be added either by intergrinding with the clinker or homogeneously blending it with cement

Cement Sustainability – SCMs & Byproducts

- **Role of Limestone By products in Sustainability**
  - Reduce the amount of limestone required for the calcination process
- **Role of Supplementary Cementitious Materials in Sustainability**
  - Reduce the need for virgin materials
  - Decrease the amount of cement (embodied energy emission) required for a concrete mixture
  - Puts to use materials otherwise destined for landfill

Raw Materials Sustainability

- **Aggregates**
  - Sand, Gravel, or Crushed Stone
  - Constitutes 60 to 75% of concrete by volume
- **Role of Aggregates in Sustainability**
  - Reserve natural resources
  - Reduce the amount of landfill waste material
- **Sustainable Aggregates include:**
  - Recycled hardened concrete
  - Industrial by products such as blast furnace slag aggregate
  - By product of crushing of coarse aggregates. Usually blended with fine aggregate (sand)

Raw Materials Sustainability

Recycled Concrete:
Crushed concrete from demolished sites

Blast Furnace Slag Aggregate:
Byproduct of metal ore smelting & processing

Raw Materials Sustainability

- **Water**
  - Account to ~4 to 7% of the concrete mixture
  - Process water has High PH (> 8.5) which could be harmful to the survival of aquatic organism if discharged into the ground
    - Can be reused in concrete mixing, or
    - Can be treated by injecting CO_2 to lower the PH levels.
- **Cement Kiln Dust**
  - Cannot be recycled
  - Used for Soil solidification / Stabilization
- **Concrete Carbonates (CO_2 Sink)**
- **Use of Tire Derived Fuel**

2018 National AAAEA Conference

Thank you!

Questions?

Introduction - Sustainability

- **Best Practices for Sustainable Design**
  - **Energy efficiency and conservation**
  - **Manage Water Resources**
  - **Waste reduction and Recycling**
  - **Renewable energy and Low Carbon Fuels**
  - **Open space and offsetting carbon emissions**
  - **Efficient transportation**
  - **Green Buildings**
  - **Community and individual action**

Environmental Sustainability

LIFE CYCLE ASSESSMENT

Economic Sustainability

LIFE CYCLE COST ASSESSMENT