A Multi-Layered View of Chemical & Biochemical Engineering

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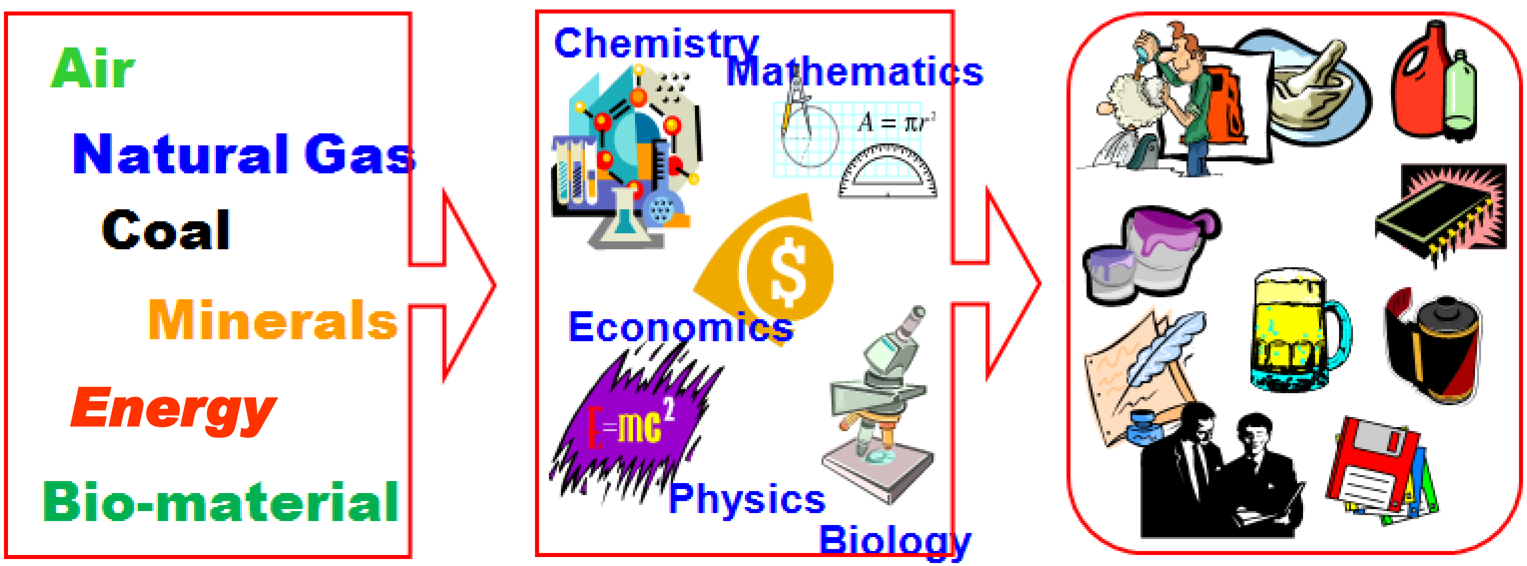
What is chemical engineering?

As we know it

Chemical engineering is the application of science, mathematics and economics to the process of converting raw materials or chemicals into more sustainable forms. The term economics is important here. It largely involves the design and maintenance of chemical processes for large-scale manufacture.



DTU

What we know chemical engineers do?

Highlights

- **Works with unit operations for purposes of chemical synthesis and/or separation (chemical reaction, mass-, heat- and momentum- transfer operations)**
- **Apply physical laws of conservation of mass, energy and momentum**
- **Apply principles of thermodynamics, reaction kinetics and transport phenomena**
- **Solve problems – design & operate processes**
- **More than just process engineering – applies chemical knowledge to create better materials and products that are useful to the modern society**

DTU

The key chemical products

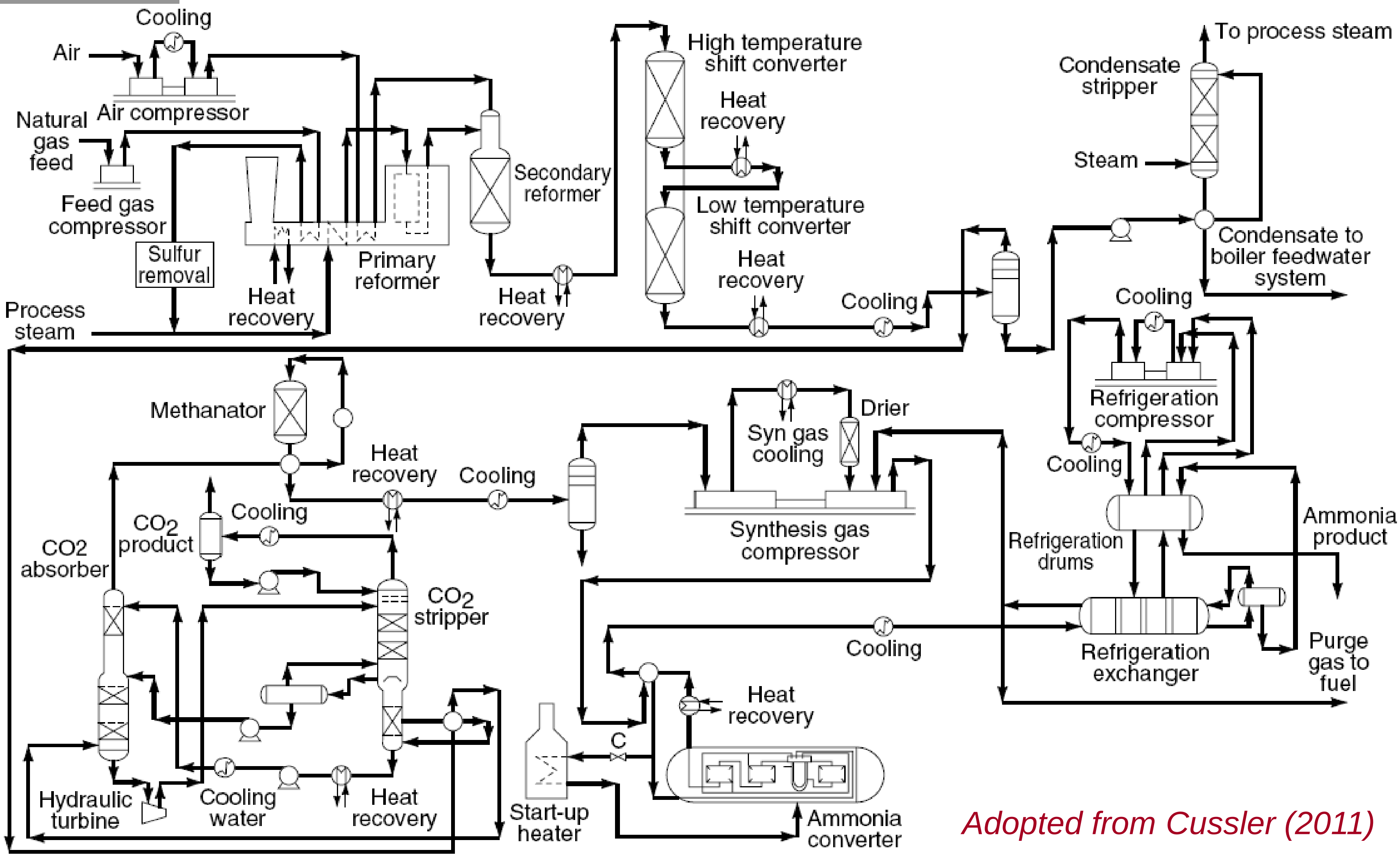
	Commodities	Molecules	Microstructures
Key	**Cost**	**Speed**	**Function**
Basis	**Unit Ops**	**Chemistry**	**Microstructure**
Risk	**Feedstock**	**Discovery**	**Science**

Skills needed

Curriculum - harmonization

Adopted from Cussler (2011)

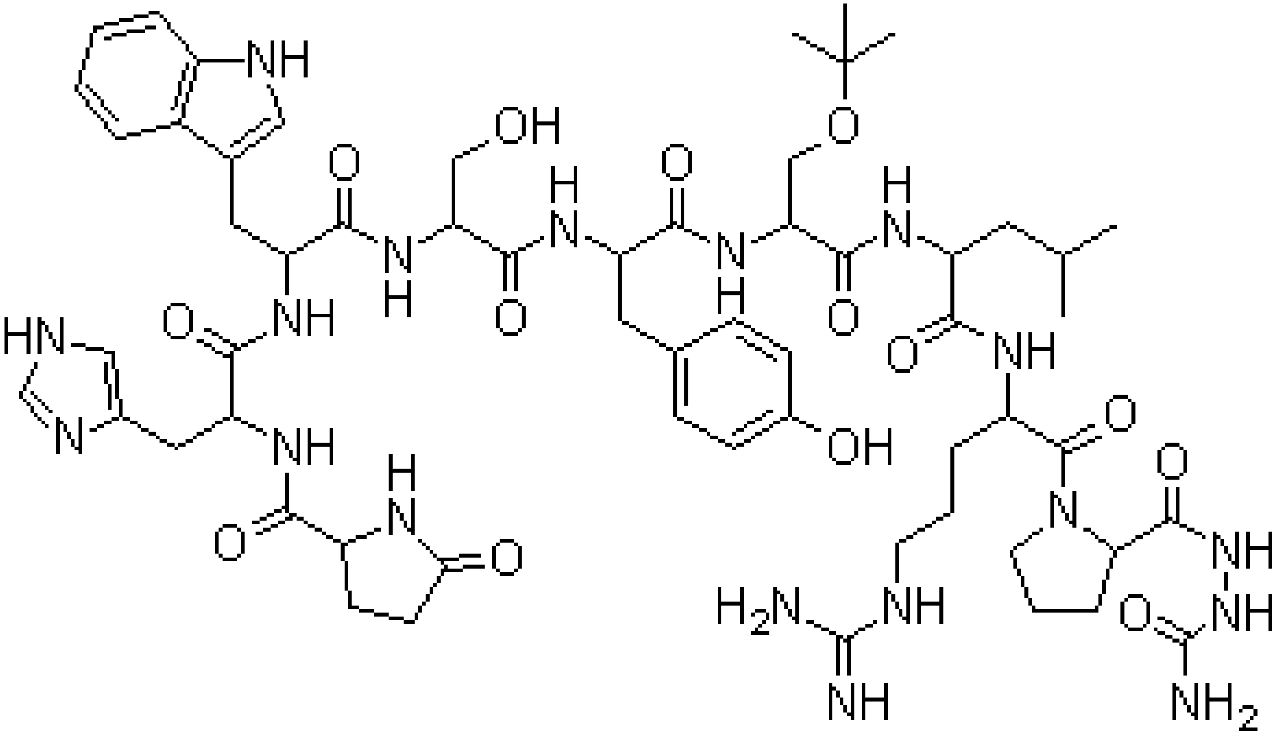
For Commodities, “Manufacture” is Key



Adopted from Cussler (2011)

For Molecules, “Selection” is Key

46 Kilos = $800 M



Pyr-His-Trp-Ser-Tyr-D-Ser(tBu)-Leu-Arg-Pro-Azagly-NH_2

Adopted from Cussler (2011)

For Microstructures, “Needs” is Key

Jet-fuel blend

Gasoline blend

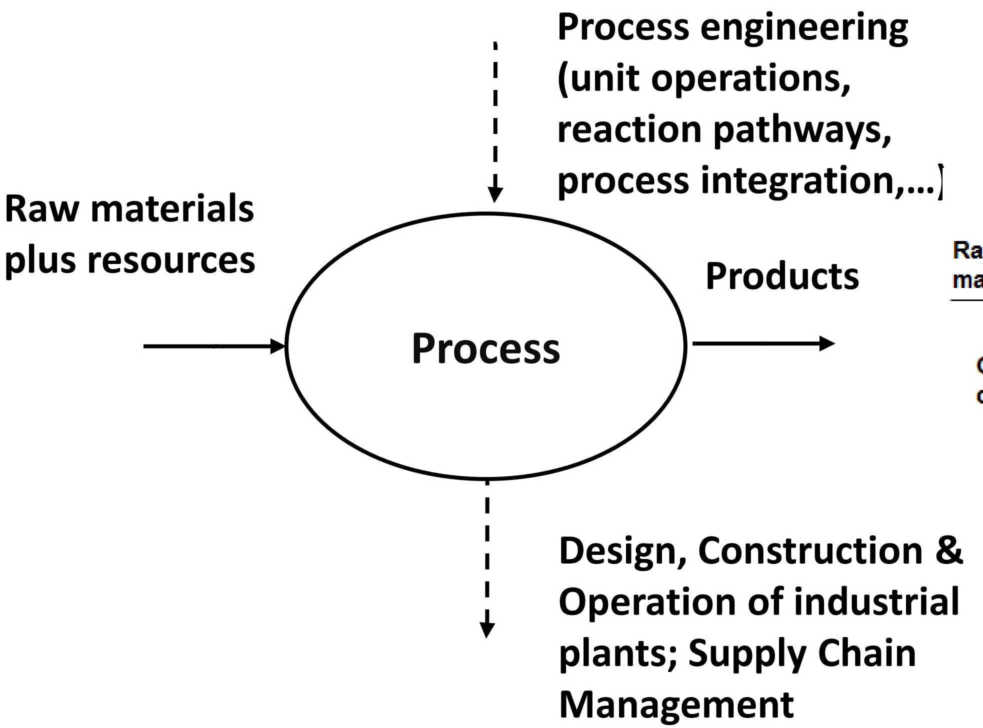
Liquid formulations & emulsions

Scientifically specified

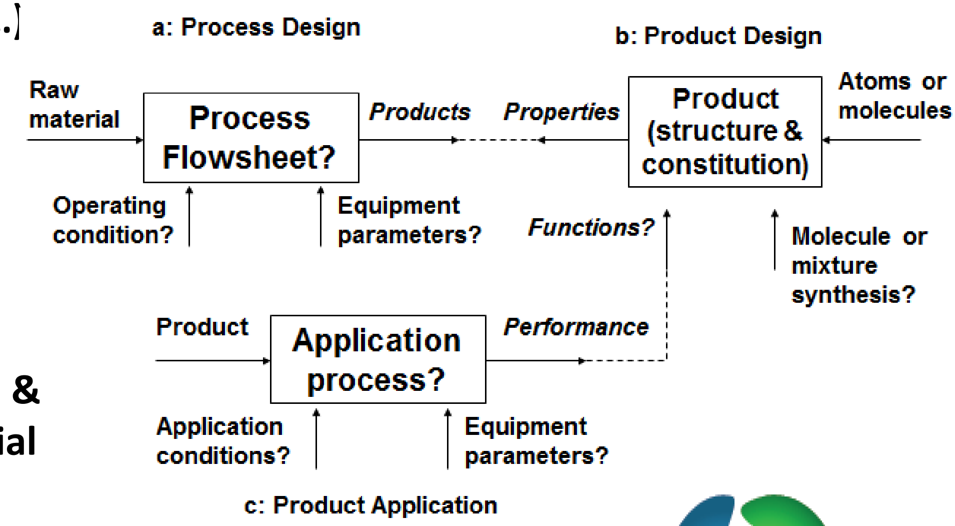
Consumer reactions

The Multi Layered View

Inner Core Layer

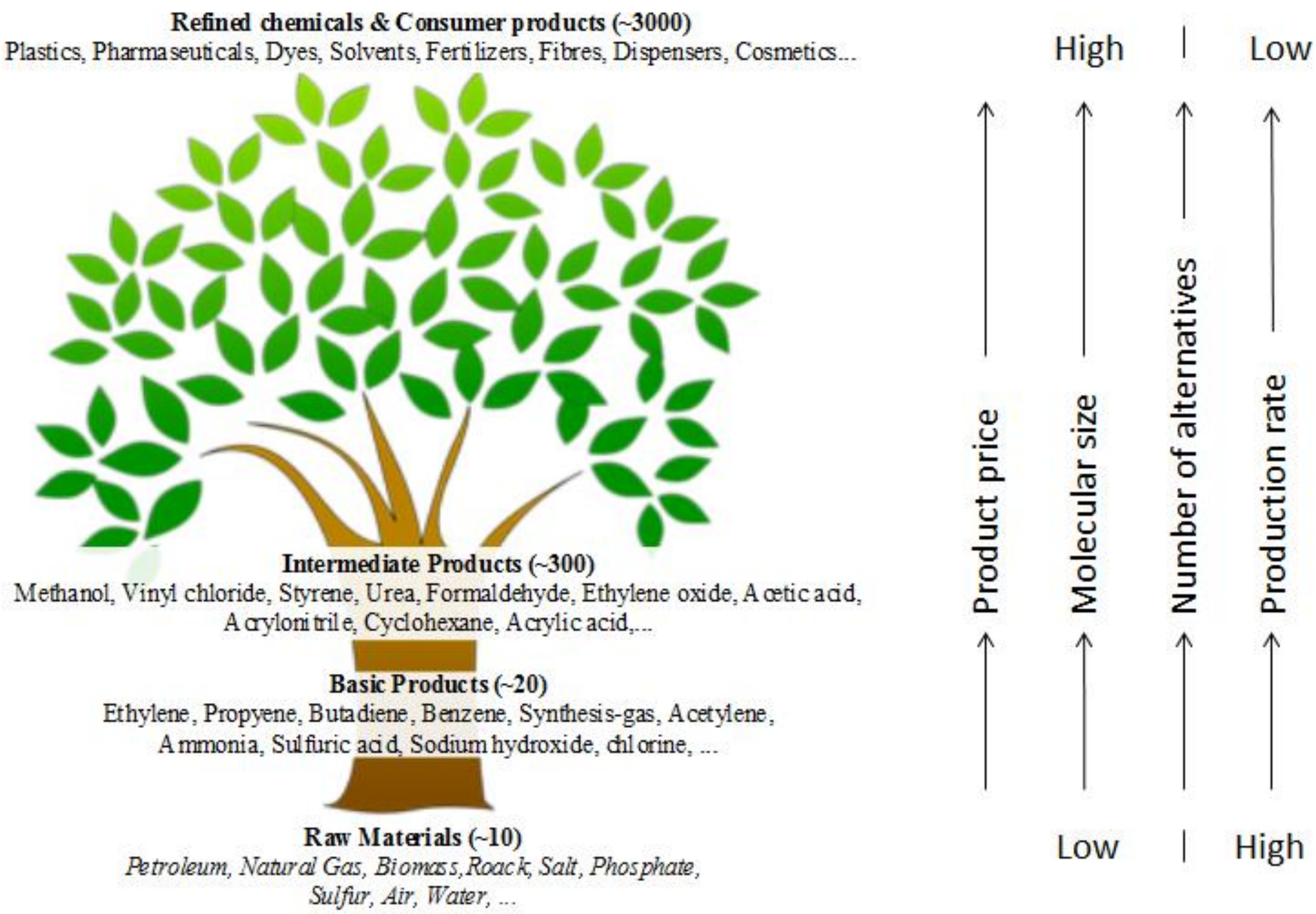


The product-process connection

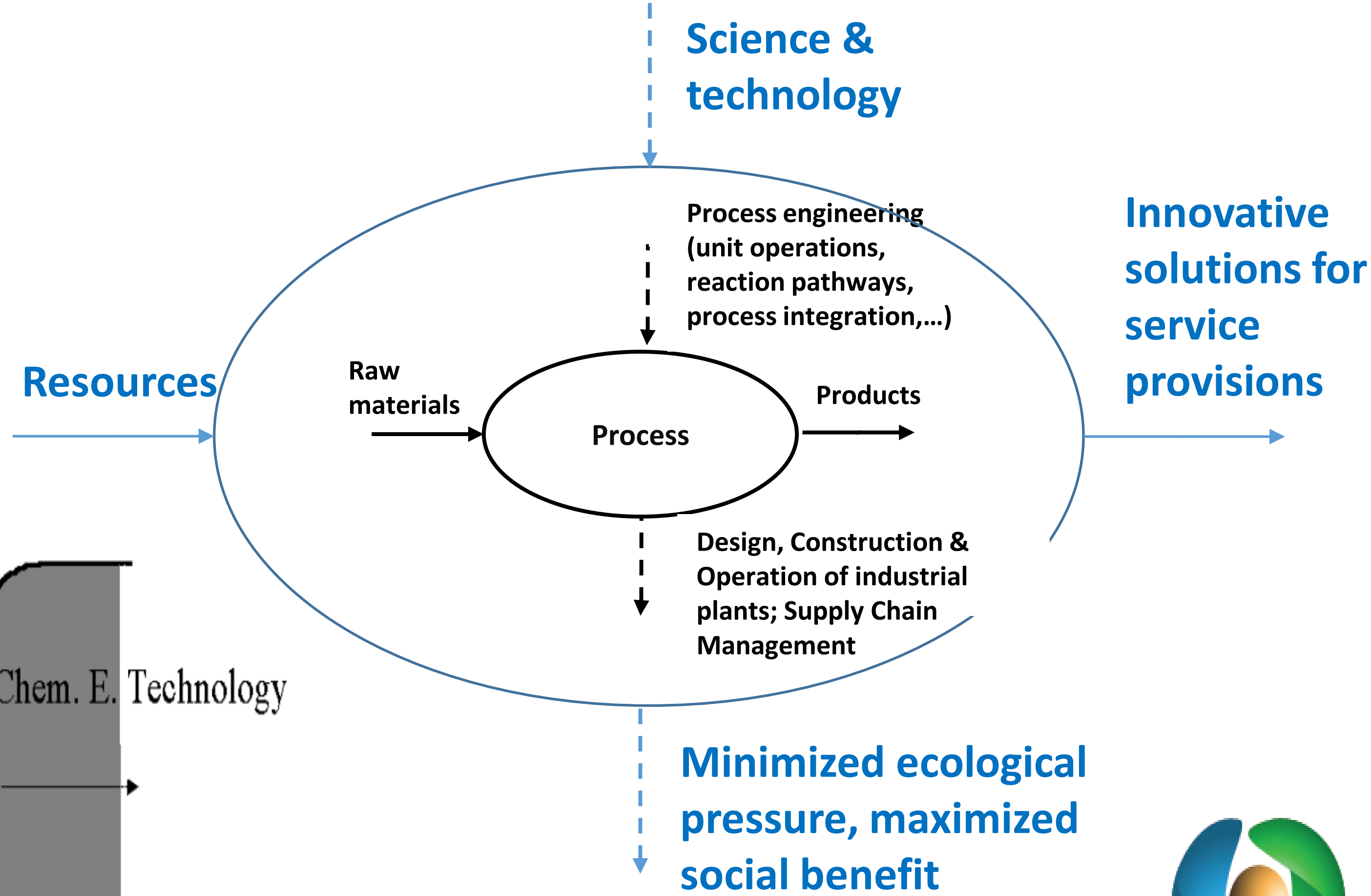


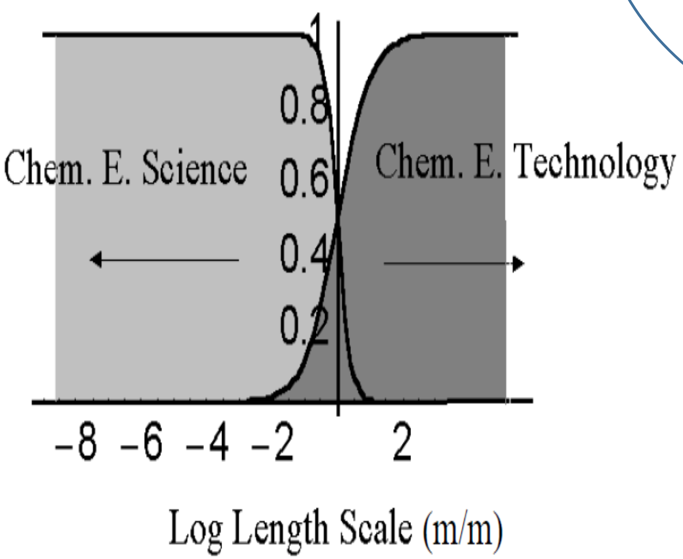
The general idea can be understood through the following logic: Left: input, right: output; upper part: (intellectual) input from C&BE, lower part: Impact on the world.

Product-Process Connection



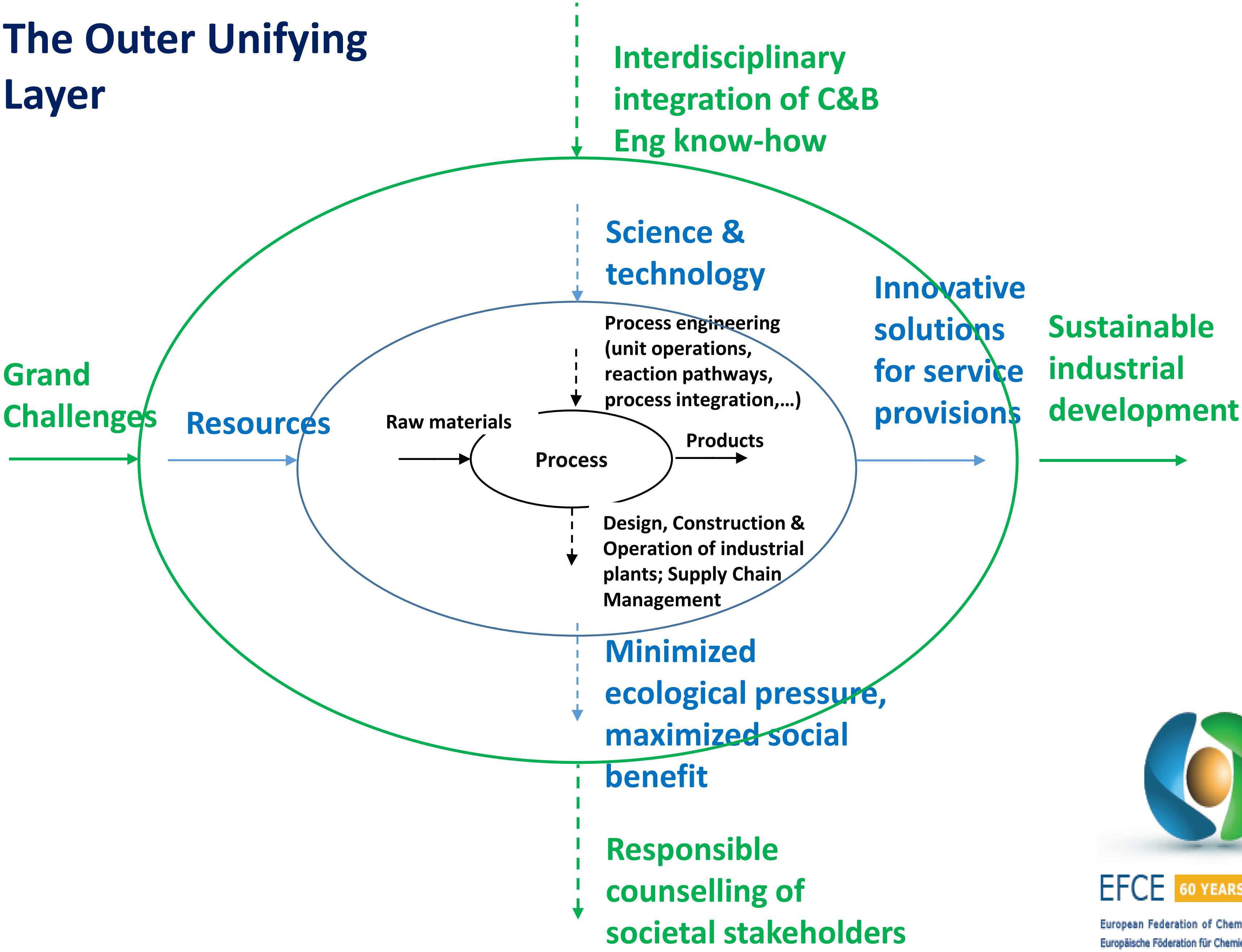
Middle Interface Layer





Science versus Technology

The Outer Unifying Layer



EFCE 60 YEARS 1953-2013
European Federation of Chemical Engineering
Europäische Föderation für Chemie-Ingenieur-Wesen
Fédération Européenne du Génie Chimique

Example of Curriculum Harmonization

Bologna Declaration

- **Bologna Declaration signed in 1999 (for implementation by 2010)**
- **Harmonization of European higher education**
- **Basic role of the universities**
  - **Introduction of a three cycle degree system**
  - **Objective should be more than passing knowledge to the students (High priority - Create the new knowledge; High importance - Research at the doctoral level)**
- **Changes/amendments added – 2009**
- **EFCE recommendations (2005, 2010, new)**

Two questions asked in preparing the recommendations

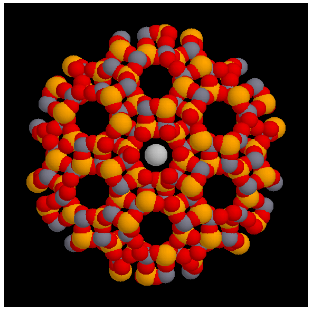
Which skills, outcomes and knowledge are common and should not be ignored in new study programs?

Which are other, non-traditional topics, engineering fields and non-engineering knowledge necessary for engineers to manage problems of specific current and future chemical and bio-chemical processes and related industries?

Curriculum vs Role and Scope of Chem Eng

1. What is the role of Chemical & Biochemical Engineering in "commodity" industry vs. "new emerging" technologies?

Value preservation vs. Value creation



2. What is the future scope for fundamental contributions in Chemical & BioChemical Engineering ?

Engineering vs. Science

3. What are the major real world challenges

Globalization, energy, environment, health

Issues

- **Industrial production (products needed to sustain the modern society)**
- **Raw material resources (which raw material to use?)**
- **Utilities requirements (energy, water, …needs)**
- **Environmental impacts (negative impact to air, water, land, …)**
- **Ethics (does this need to be taught?)**

EFCE recommendations - 1

First cycle (BS) core curriculum

Recommended 2/3

Science: 20-30%

Engineering 40-50%

Non-technical 10%

Left open 1/3

Core curriculum Chemical Engineering (first cycle)	*Credits (minimum requirements)*
Fundamentals of science and natural sciences mathematics, computer science, physics, chemistry, biology	45
Chemical Engineering fundamentals material and energy balances, thermodynamics, fluid dynamics, heat and mass transfer, separations, chemical reaction engineering, bio molecular and biological engineering	35
Chemical Engineering applications e.g. basic product engineering, safety, health and environment, design and process analytical techniques	15
Non-technical subjects e.g. economics and management	10
First Cycle ("Bachelor's") thesis project	15
Total of the recommended core curriculum	120
Chemical engineering sciences or natural sciences according to the main emphasis of the degree course of the university	60
Total of a first cycle chemical engineering degree programme (minimum requirement)	**180**

EFCE recommendations - 2

Second cycle (MS) core curriculum

Recommended 2/3

Left open 1/3

Core curriculum Chemical Engineering (second cycle)	*Credits (minimum re-quirements)*
Mathematics and science Extension of mathematical and scientific subjects	15
Chemical Engineering topics e.g. advanced courses in multphase reactor engineering, catalysis, transport phenomena	40
Second Cycle (“Master’s”) thesis project	20
Total of the recommended core curriculum	75
Chemical engineering sciences or natural sciences according to the main emphasis of the degree course of the university	15-35
Total of a second cycle chemical engineering degree programme	**90-120**

Student Mobility Program supported by the EU

Harmonization of activities within the area of ChE has been conducted by EFCE <http://www.efce.info/>

Development of ChE – New directions?

Unique opportunities and formidable challenges

Develop skills to:

- **Discover new categories of abundant resources**
- **Substitute and/or improve resources that become scarce**
- **Deliver sustainable & innovative solutions (energy, water, food …)**
- **Contribute to staving off disaster (global climate change, a viral pandemic, oil spills, …)**
- **……**

A global and collaborative effort needed - 1

1. **Need to keep core Chemical Engineering Knowledge; Need to emphasize fundamentals: basis is life-long learning**

2. **Need to modernize curriculum and add flexibility**
   - **Increase exposure at molecular level**
   - **Increase exposure to energy (alternative/renewable) and sustainability issues**
   - **Expose students to new process technology**
   - **Introduce product design as complement of process design**
   - **Emphasize process operations, enterprise planning**
   - **Increase link to other industrial sectors (pharma, electronics)**

Adopted from Grossmann 2014

A global and collaborative effort needed - 2

3. Need to recognize that "bio-area" & "nano-area" will be important but not dominant force in Chemical Engineering

4. Environmental Engineering increasingly important and requires chemical engineering (water use efficiency, pollution control) : Civil Eng. ownership?

5. Need closer interaction with industry; otherwise risk being irrelevant

6. Need to provide excitement to recruit the very best young people to join Chemical Engineering

Adopted from Grossmann 2014

Paradigm and Paradigm shift

Paradigm is a constellation (of ideas) that defines a profession and an intellectual discipline

The Structure of Scientific Revolution: scientific advancement is not evolutionary, but rather a "series of peaceful interludes punctuated by intellectually violent revolutions", and in those revolutions "one conceptual world view is replaced by another"

Thomas Kuhn 1962

Scientific revolution through paradigm shift

Paradigm Shift points to a change from one way of thinking to another. It's a revolution, a transformation, a sort of metamorphosis. It just does not happen, but rather it is driven by agents of change.

Examples:

- Agriculture changed early primitive society
- Printing press changed the culture of people
- Scientific theory changed Newtonian physics to Relativity and Quantum Physics
- Personal computer & internet is effecting personal & business environment

The quantum leaps in ChE development

Significant changes through paradigm shifts

1. **The first paradigm** - *Unit Operations*, 1923

"Unit Operations should be the foundation of chemical engineering"

2. **The second paradigm** - *Transport Phenomena*, 1960

- A new burst of creative research activities.
- The chemical industry dominated world, companies like DuPont, ICI, and Exxon content to recruit academically educated graduates, willing to teach them technology.

Conclusions & future directions

Curriculum should reflect ChE's contribution to the society

Need to adapt to the needs of the modern society (questions of energy, water, environment, sustainability, responsibility, ... should be incoporated in the study)

Courses need to adopt (introduction of new ideas, new methods, new tools, ...)

Balance between engineering-science; commodity-value added; core-new need to be found (different solutions are possible)

Has a paradign shift occured? SPPID