A multi-layered view of chemical & biochemical engineering

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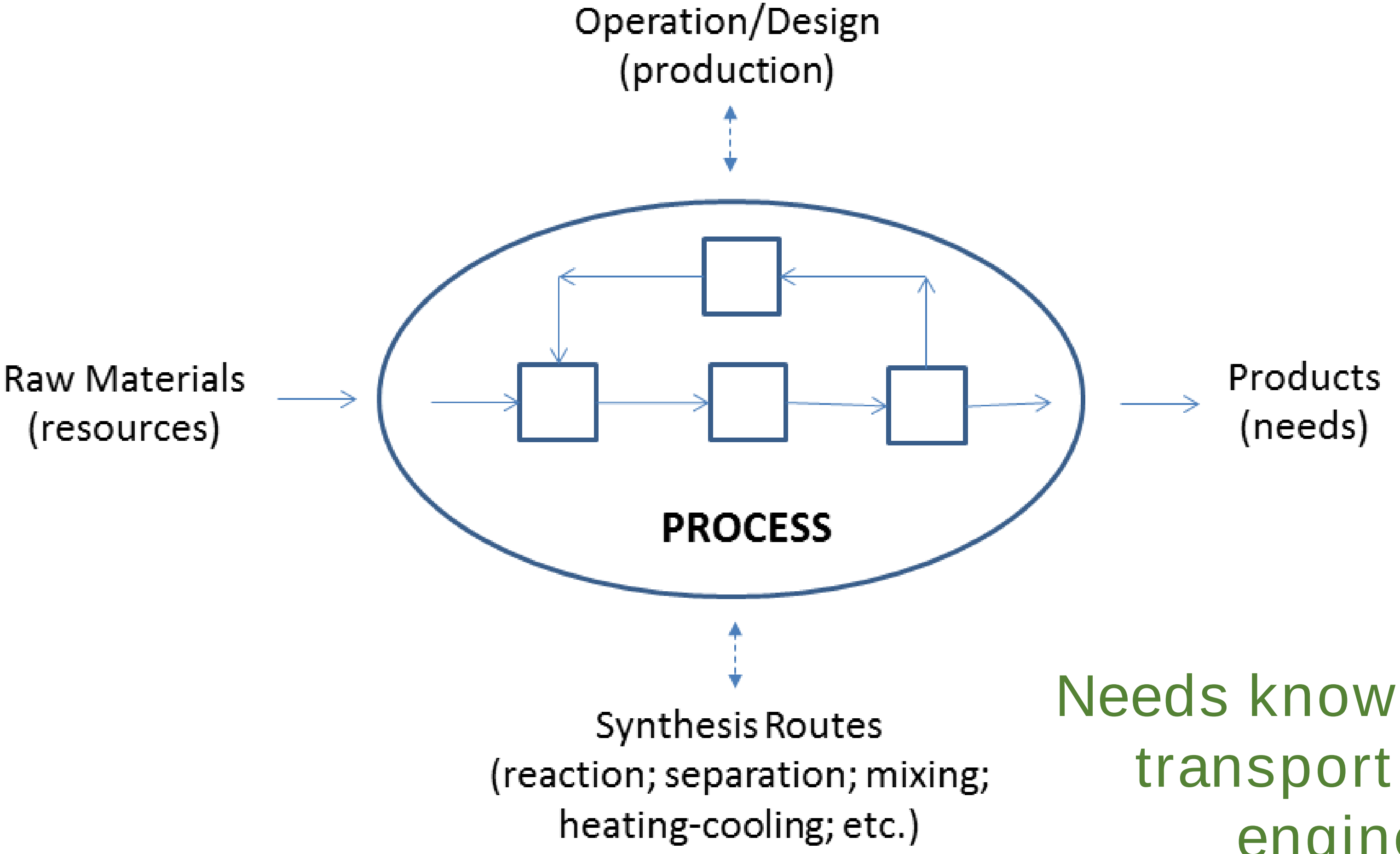
Core chemical & biochemical engineering



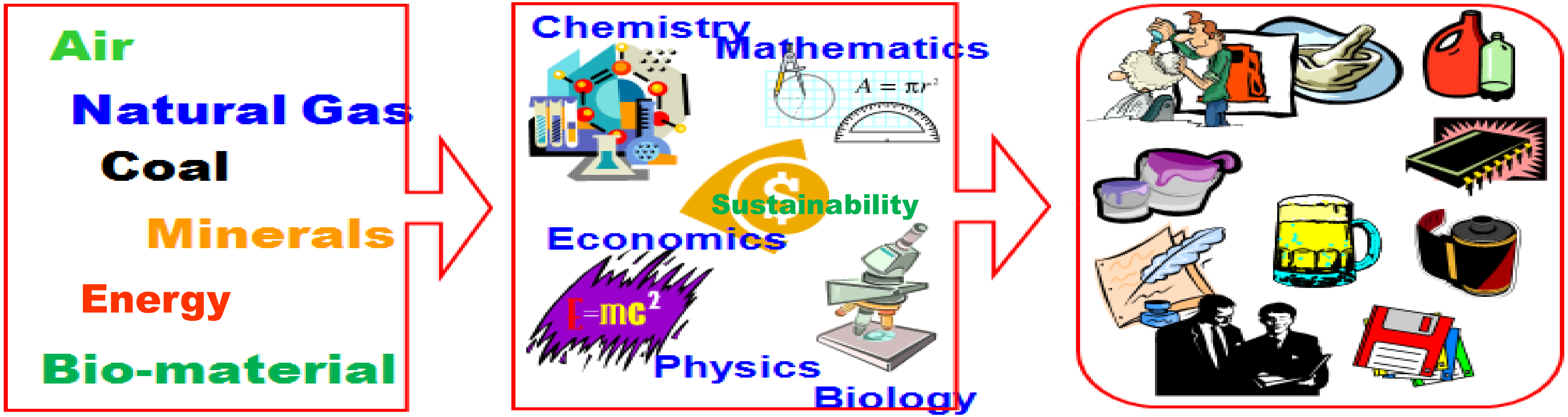
- Implements synthesis routes to convert raw materials to useful products
- Designs the process
- Determines the best operating conditions
- …..

Needs knowledge of unit operations, transport phenomena, reaction engineering, separation technologies, ****....****

What is (bio) chemical engineering?

A more modern view

Chemical & biochemical engineering is the application of science, mathematics and economics to the process of converting raw materials or chemicals into more sustainable forms. The terms economics & sustainability are very important here



What (bio) chemical engineers do? **Highlights**

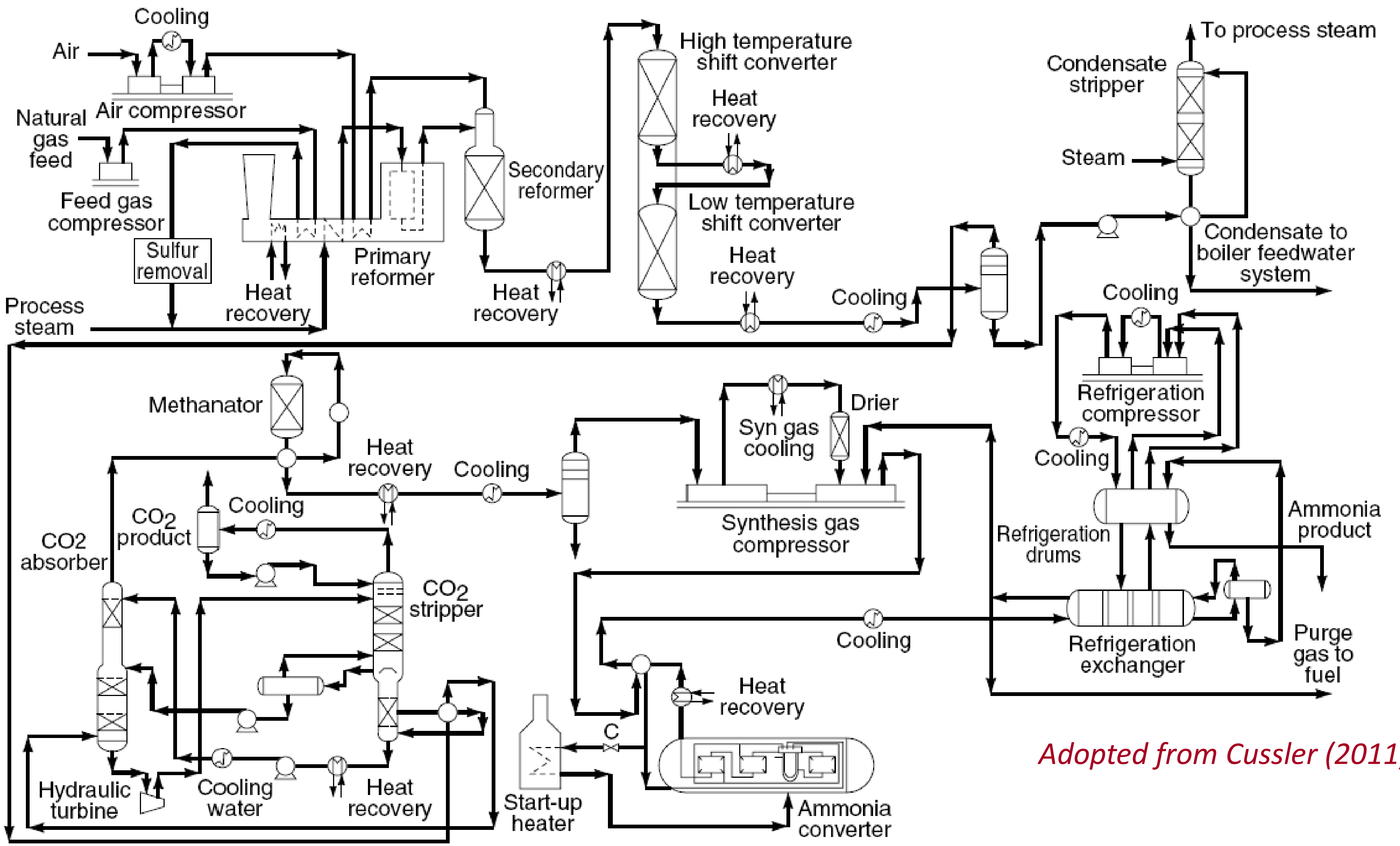
- **Work with unit operations** for purposes of chemical synthesis and/or separation (chemical reaction, mass-, heat- and momentum- transfer operations)
- **Apply physical laws** of conservation of mass, energy and momentum
- **Apply principles** of thermodynamics, reaction kinetics and transport phenomena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

Classification of the key products in Bio & ChE

	Commodities	Molecules	Microstructures
Key	Cost-Manufacturing	Speed-Selection	Function-Need
Basis	Unit Ops	Chemistry	Microstructure
Risk	Feedstock	Discovery	Science

Traditional: Convert resources to commodities?

Manufacturing of commodity products – what is new?



Adopted from Cussler (2011)

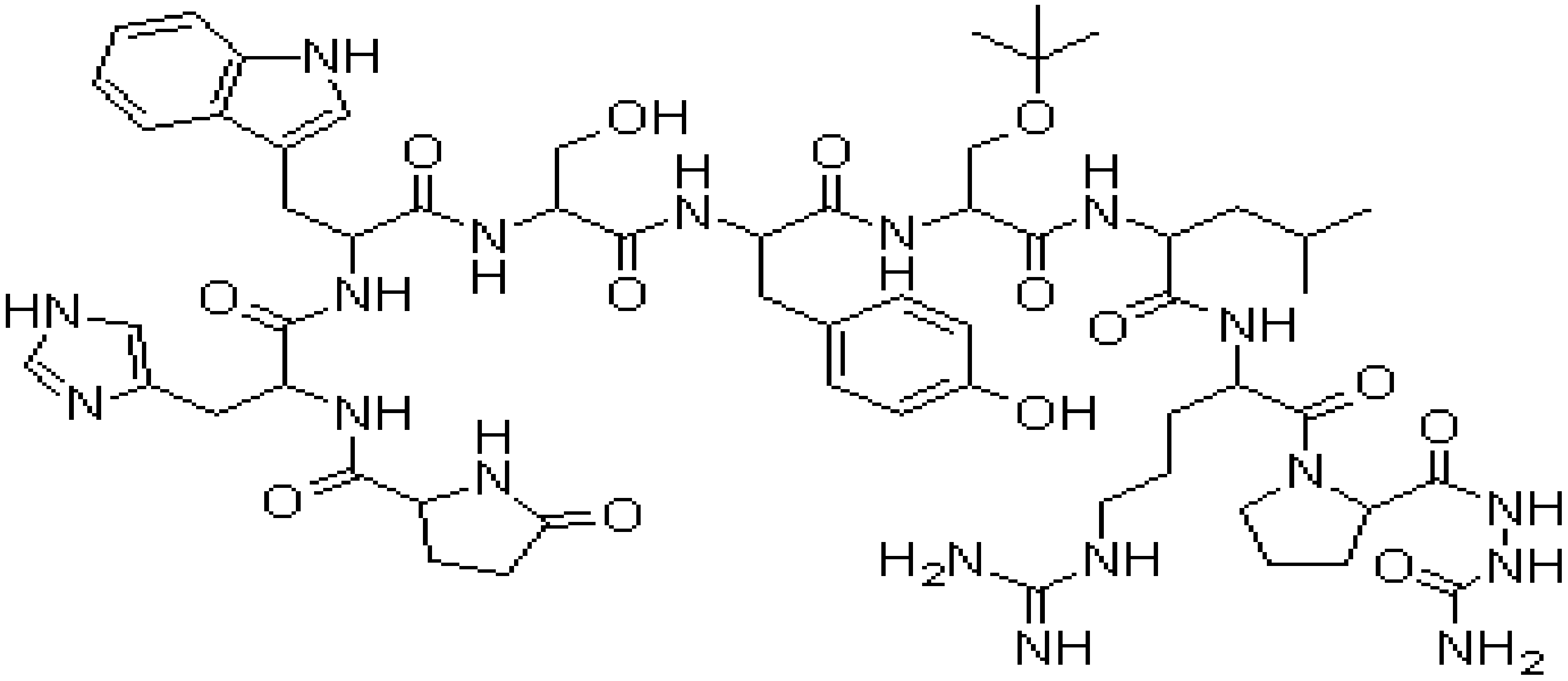
Classification of the key products in Bio & ChE

	Commodities	**Single Species**	**Multi Species**
Key	**Cost-Manufacturing**	**Speed-Selection**	**Function-Need**
Basis	**Unit Ops**	**Chemistry**	**Microstructure**
Risk	**Feedstock**	**Discovery**	**Science**

Bio & ChE are extending to design of single species products

For single species products, "selection" is the key

46 Kilos = $800 M



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

Adopted from Cussler (2011)

Classification of the key products in Bio & ChE

	Commodities	Single Species	Multi Species
Key	Cost-Manufacturing	Speed-Selection	Function-Need
Basis	Unit Ops	Chemistry	Microstructure
Risk	Feedstock	Discovery	Science

Bio & ChE are also extending to design of multi species products

For multi species products, ”need” is the key

Jet-fuel blend

Gasoline blend

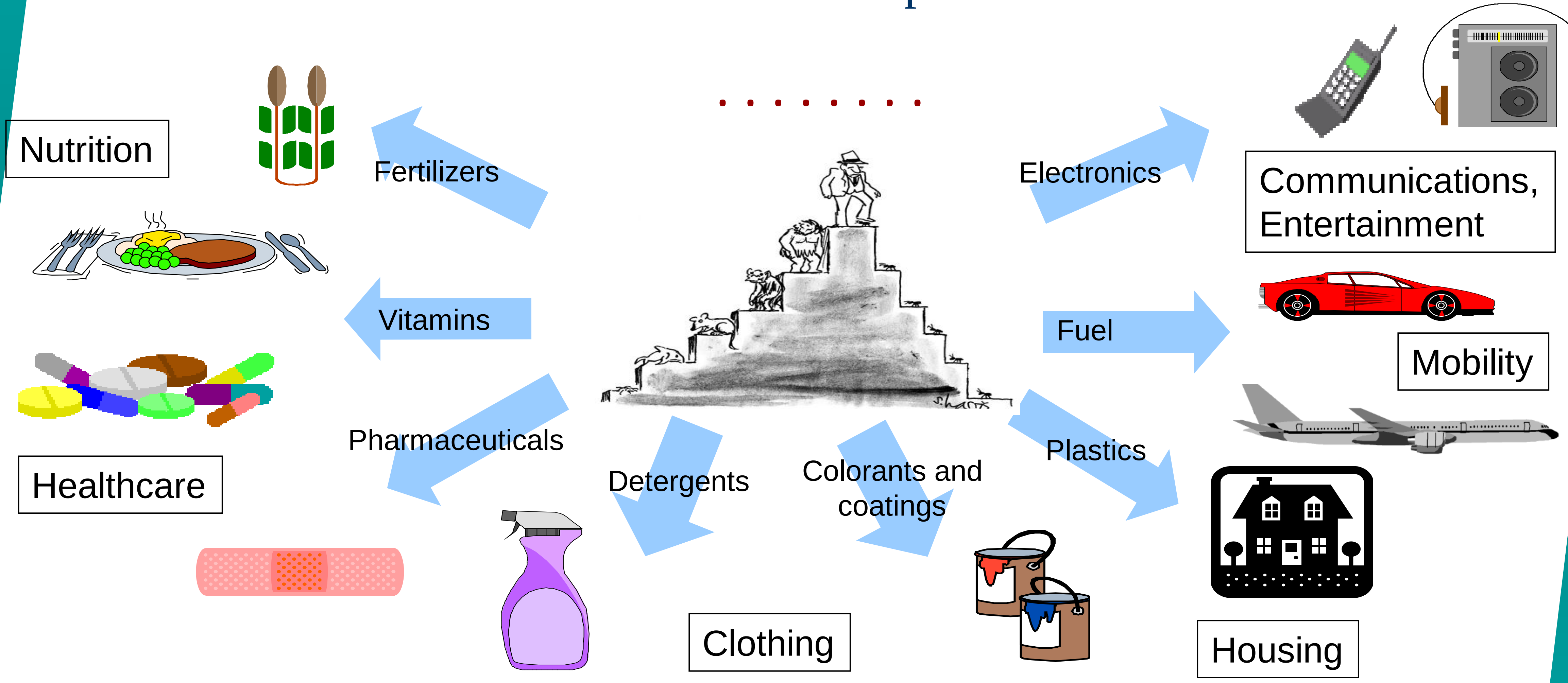
Scientifically specified needs

Liquid formulations & emulsions

Consumer reaction based needs

Where did this get us to?

We are the master of the planet earth



Positive contribution to the development of our society

Is our future sustainable? The challenge facing us

Convert resources to products

↓

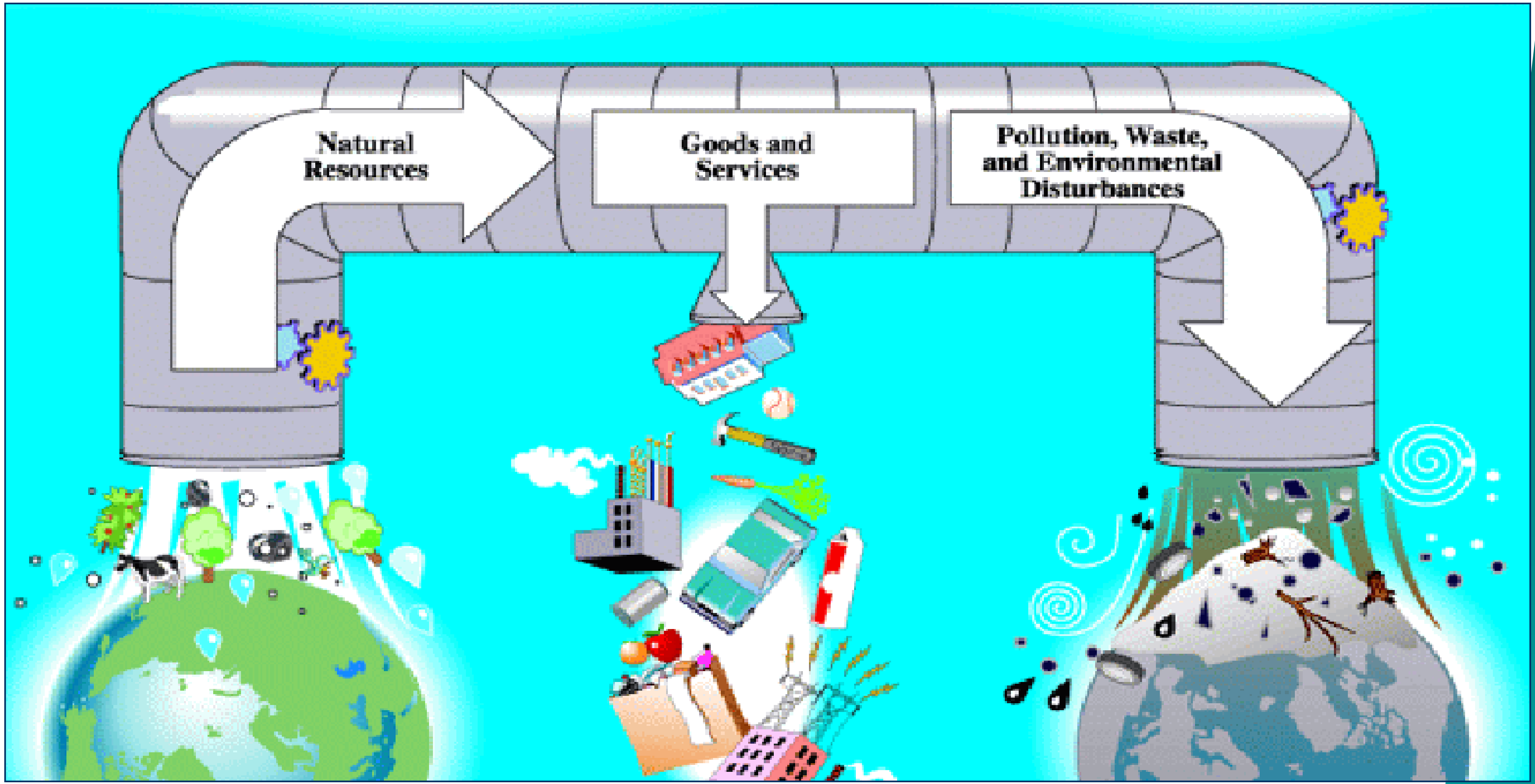
Use energy, **water, ….**

↓

Environmental Impacts (GWP, **OD, HTTP, …)**

↓

Produce waste



Only 25% converted; must be > 40% (Driolli 2007)

Current & future challenges

Sustainability Issues: Current and future survival

World population is expected to reach 11 billions by 2050

Increase in water, energy & commodities demand

6-7 x Global GDP growth over next ~50 years (in constant dollars)

5-6 x Production capacity for most commodities (steel, chemicals, lumber, etc.)

3.5 x Energy demand **7 x** Electricity demand

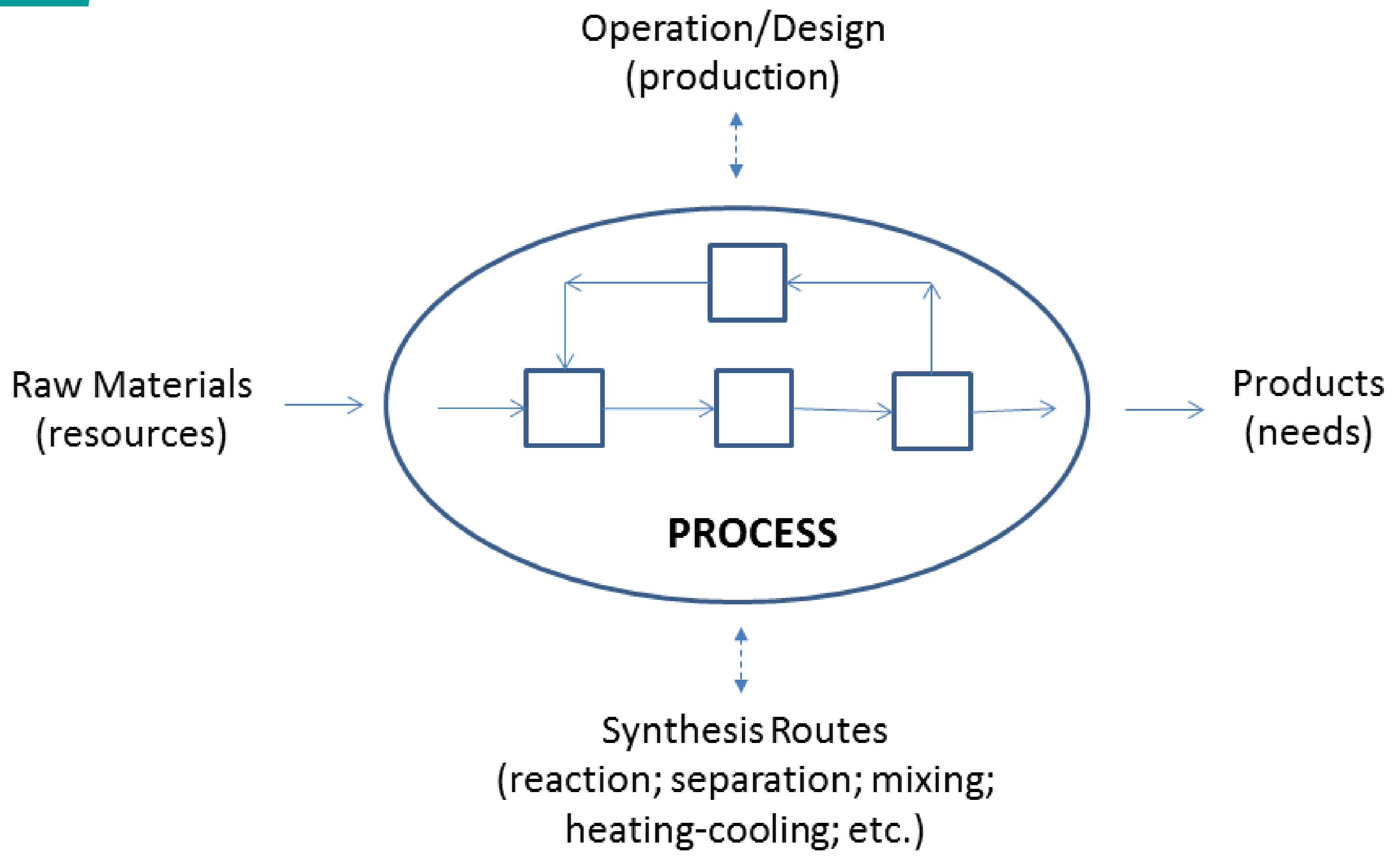
Increase Water demand

Increase 

GHG emissions

Adopted from Siirola, PSE-2012

Is the core layer sufficient to describe Bio & ChE?



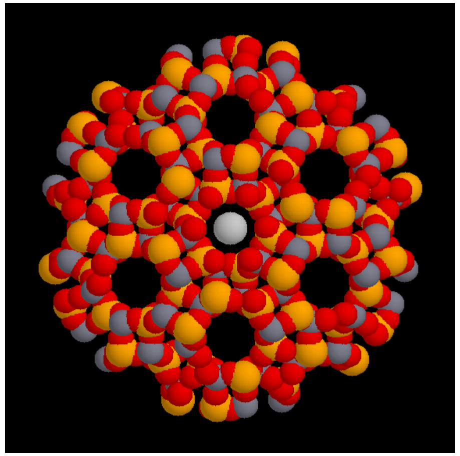
Core of chemical & biochemical engineering - does it include:

* Learn about value preservation versus value creation
* How much of science to add?
* How to innovate?
* How to address the grand challenges?
* …….

Role & scope of Bio & ChE

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

Value preservation vs. Value creation



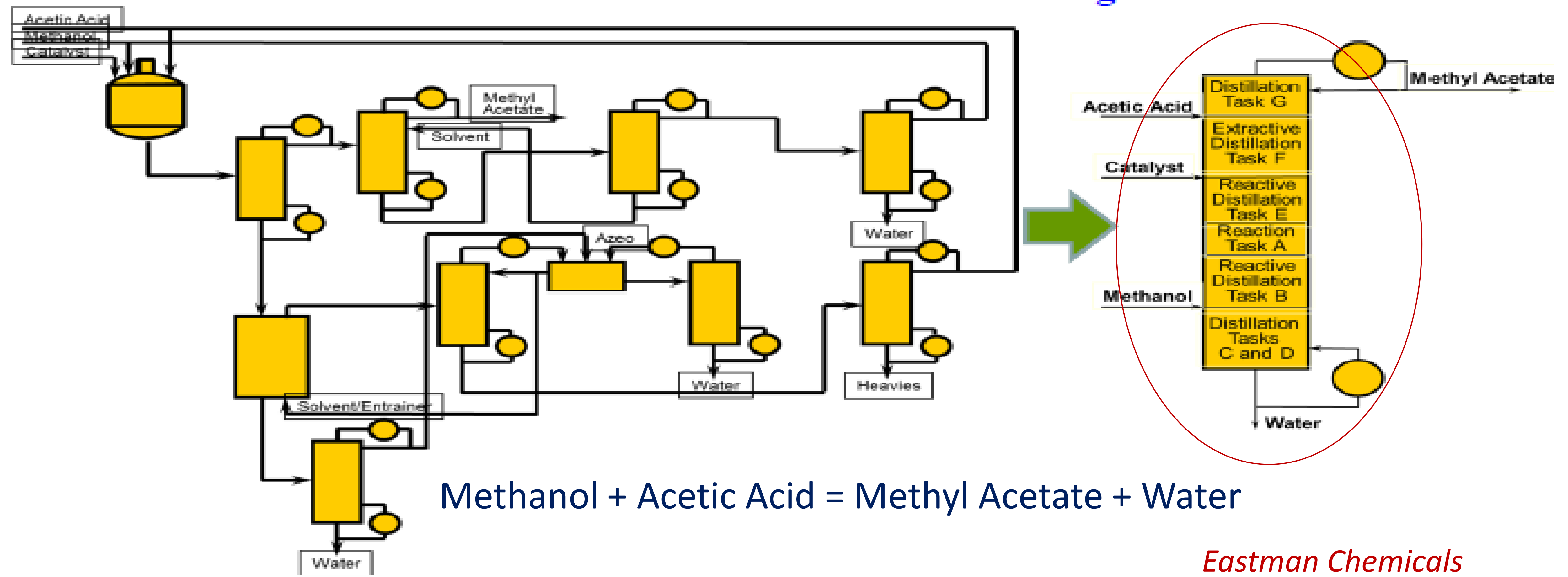
2. What is the future scope for fundamental contributions in Chemical & Bio-Chemical Engineering ? ***Engineering vs. Science***

3. Need to innovate and ensure sustainability

New ideas, methods & tools

Need for innovation in process-product design

How to find new and significantly better unit operations?



Methanol + Acetic Acid = Methyl Acetate + Water

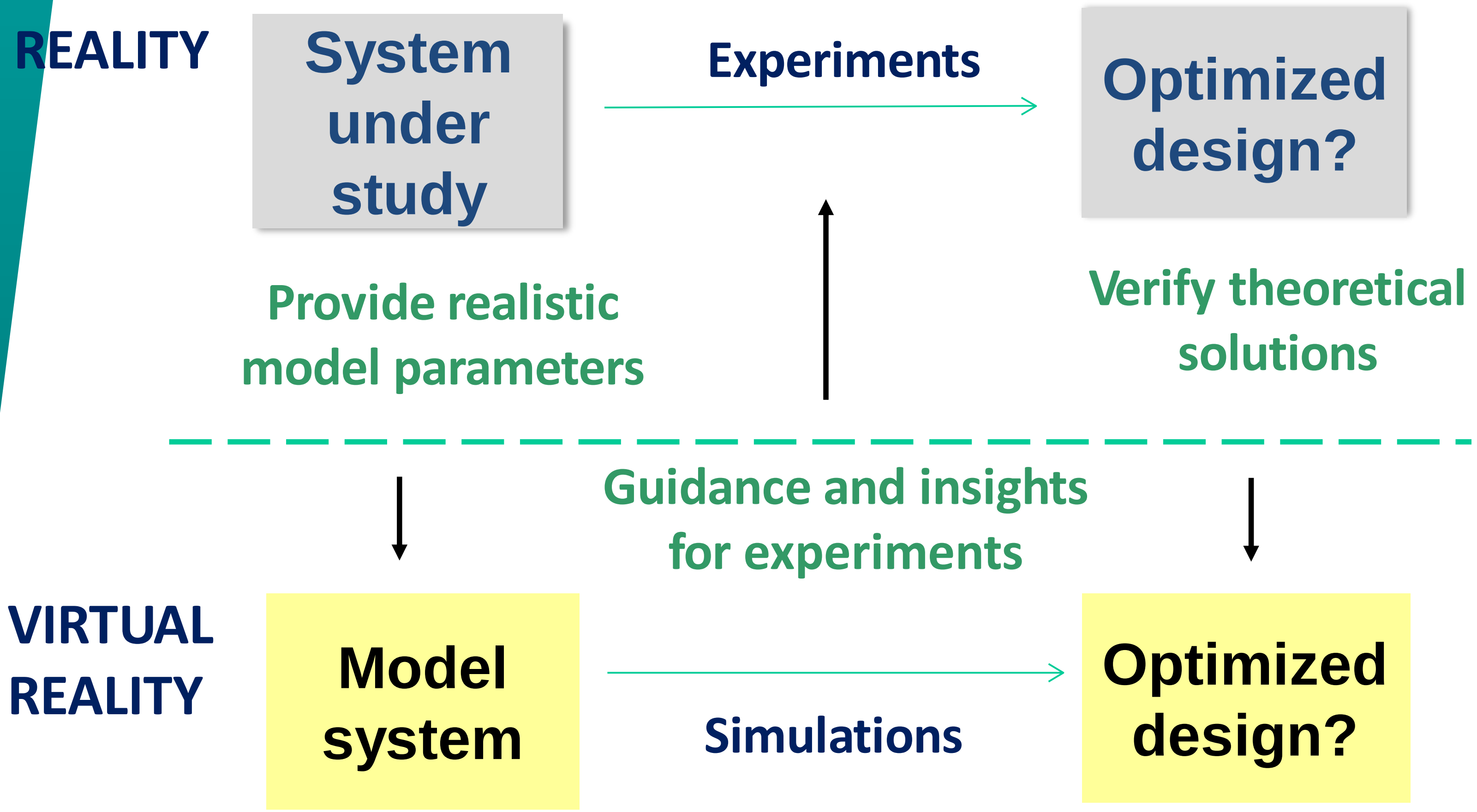
Eastman Chemicals

Can our current methods, tools & technologies deliver?

Well-known PSE tools: ASPEN, gPROMS, HYSIS, PROII, ChemCad, ….(design, optimization, control, plan-schedule operations, …)

Can our current methods and tools solve the problems of our interest? Or, do we need a new class of software tools that promote innovation?

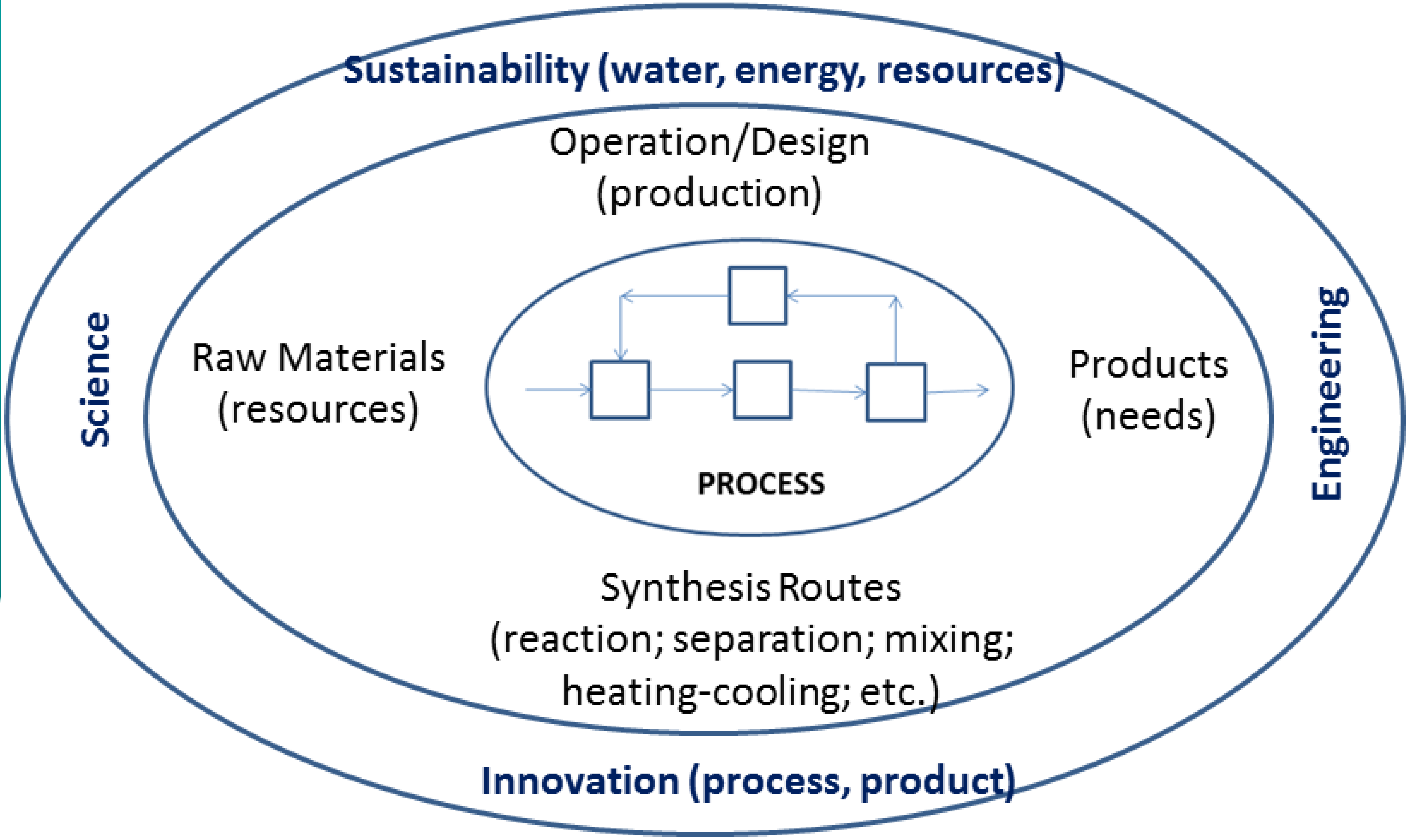
Need to extrapolate (think outside the box?)



Solution approaches

Ability to find predictive, innovative & more sustainable solutions

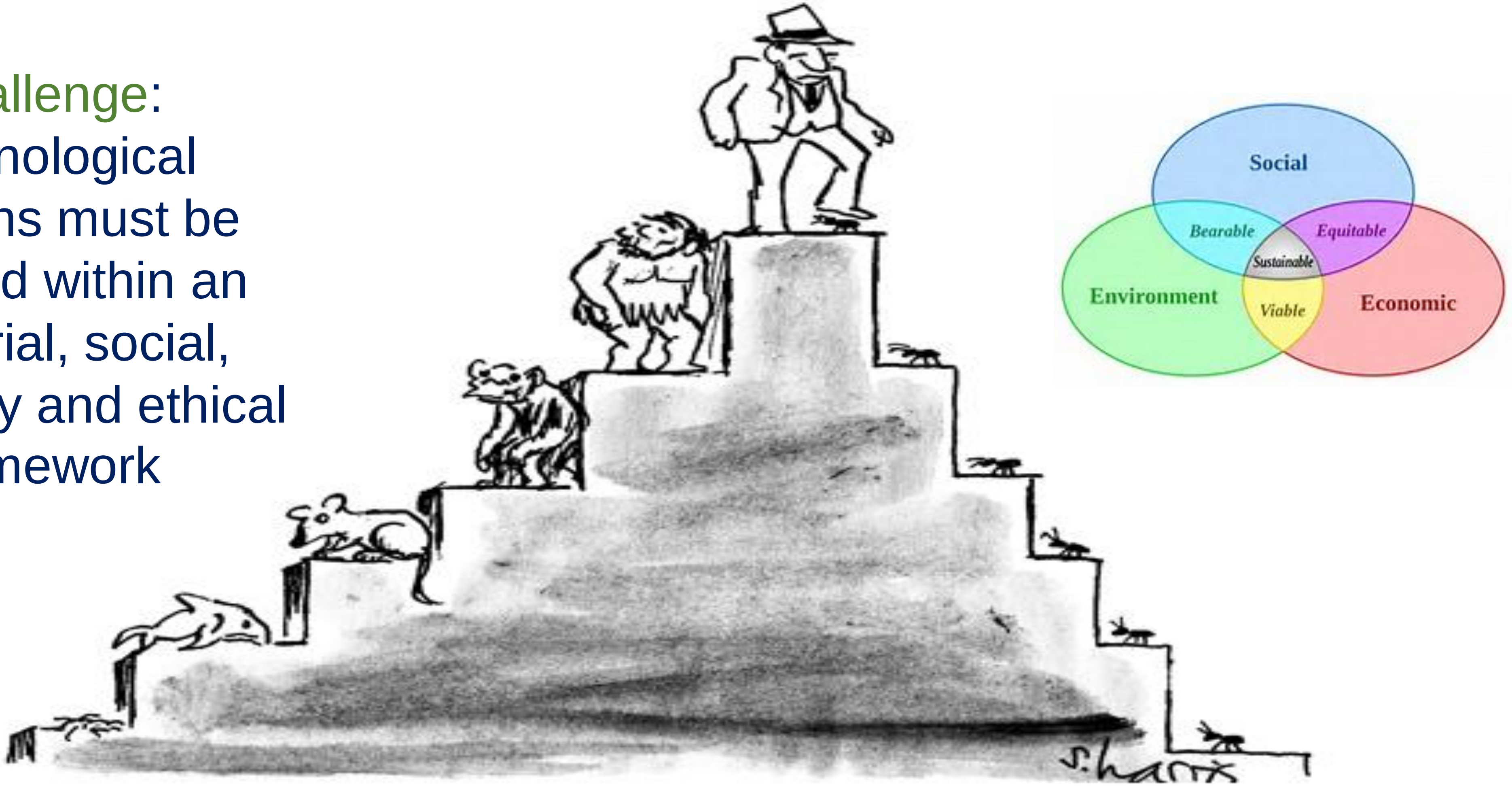
Add an Interface Layer to the Core



The core, however, needs to be supplemented by appropriate levels of science and engineering to find sustainable and innovative solutions. Sustainable and innovative solutions can be found through an appropriate mix of science-engineering

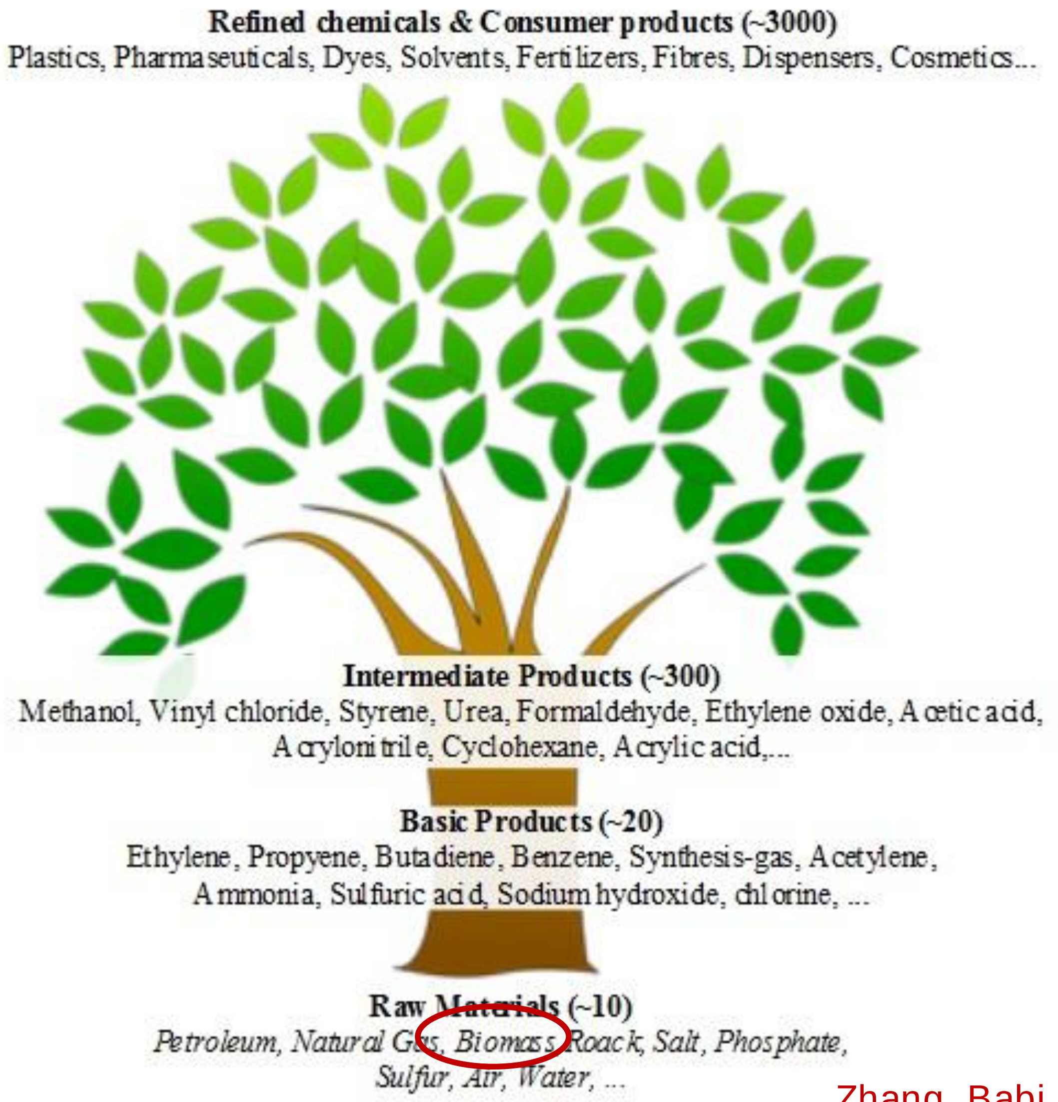
Is our position as the master of planet earth threatened?

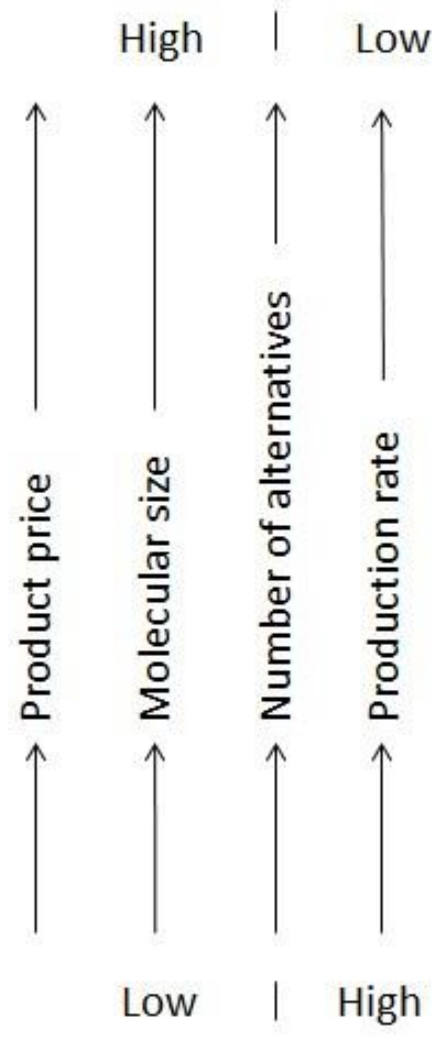
Challenge:
Technological solutions must be provided within an industrial, social, regulatory and ethical framework



Not threatened but our survival maybe is threatened unless we do something!

New issues: Why & when to make (products)?





Questions:

what, how are addressed but what about:

why & when?

Zhang, Babi & Gani, Annual Rev of Chem & Biomedical Eng, 2016

We need to develop new directions

Unique opportunities and formidable challenges

Probe the frontiers of technological innovations to bring

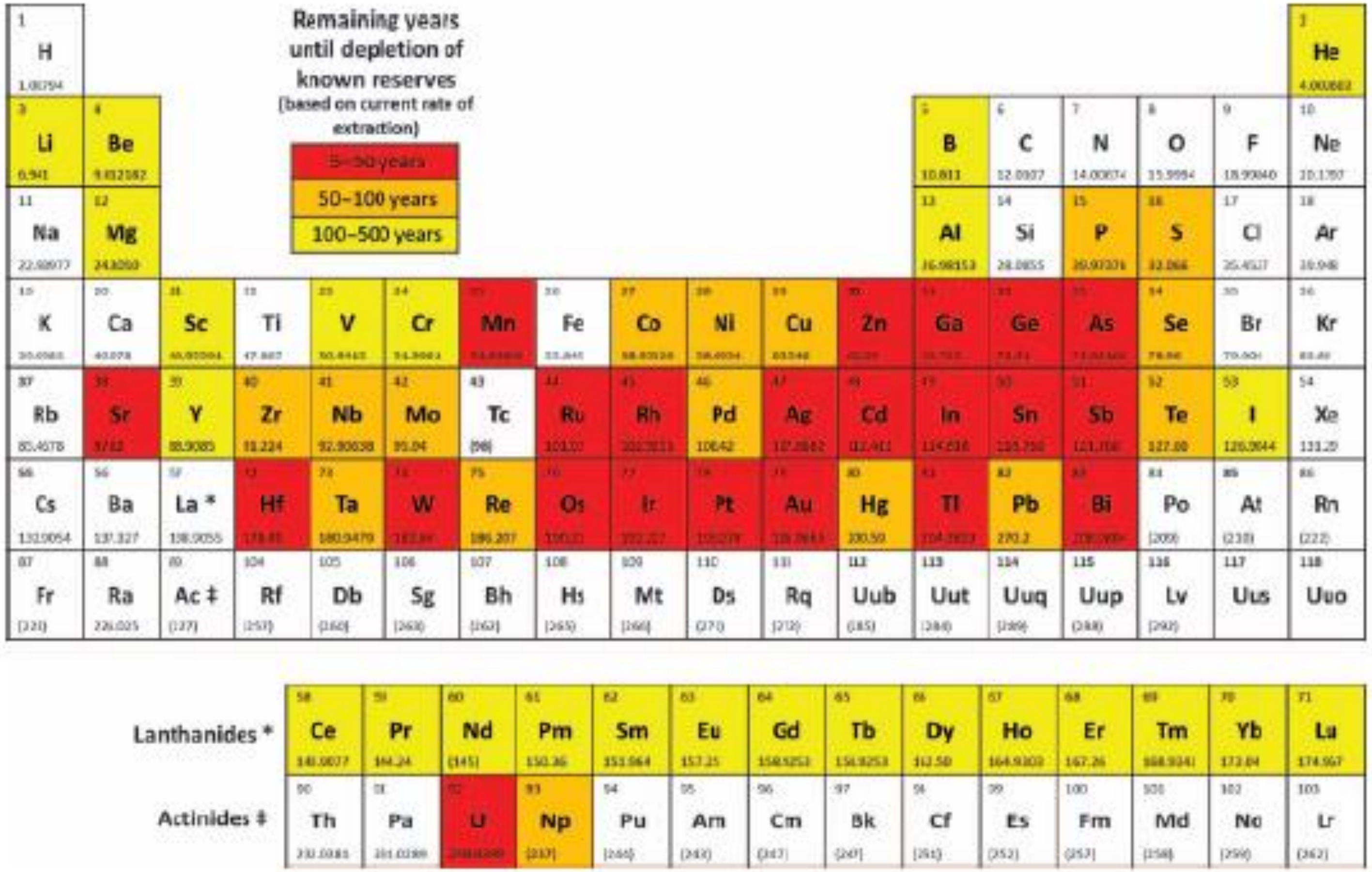
- New categories of abundant resources
- Substitute and/or improve resources that become scarce
- Deliver sustainable solutions (energy, water, food …)
- Contribute to staving off disasters (global climate change, a viral pandemic, oil spills, …)
- 3rd Paradigm (Integration of process-product-phenomena)

Risky feedstocks that need to be secured

Fight for survival!

Adopted from Cussler (2011)

Resources scarcity: need to reuse the metal



Question: What will happen if a large percentage of the population in China decide to have a car?

Azapagic, WCCE 2013, Seoul, Korea

We need to be problem solver not problem creator!

Chemical engineer

If I change one molecule of this useless & polluting product, we can make an excellent hair-spray!

Necessary shift in education - 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

Necessary shift in education - 2

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

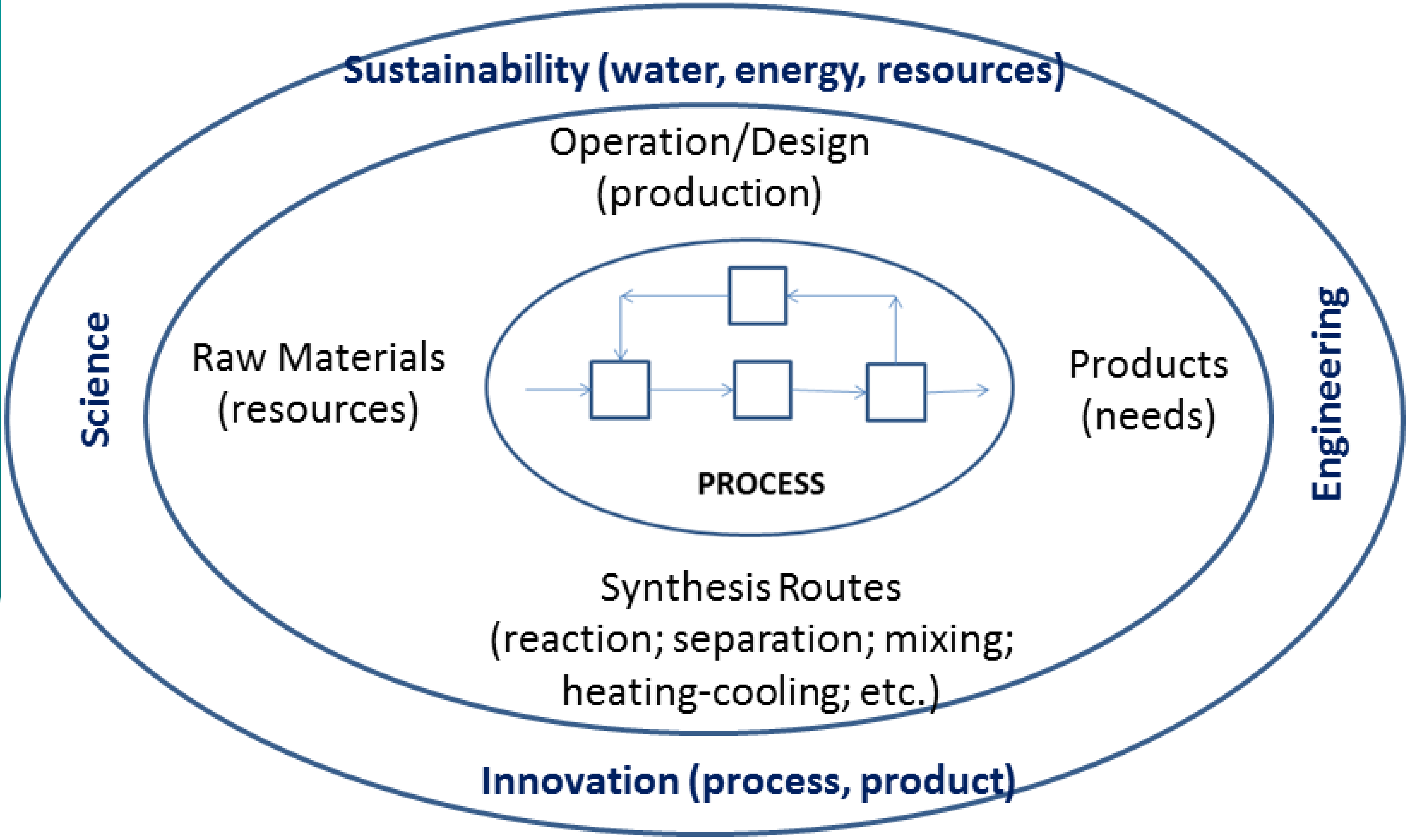
4. Environmental Engineering increasingly important and requires chemical engineering (water use efficiency, pollution control, chemical substitution, …) : Civil Eng. ownership?

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

Are the core & interface layers sufficient?



* How to understand ecology? Is it important?
* How to serve the society?
* How to make the right decisions; become the decision makers or influence them?
* How to encourage development?
* …..

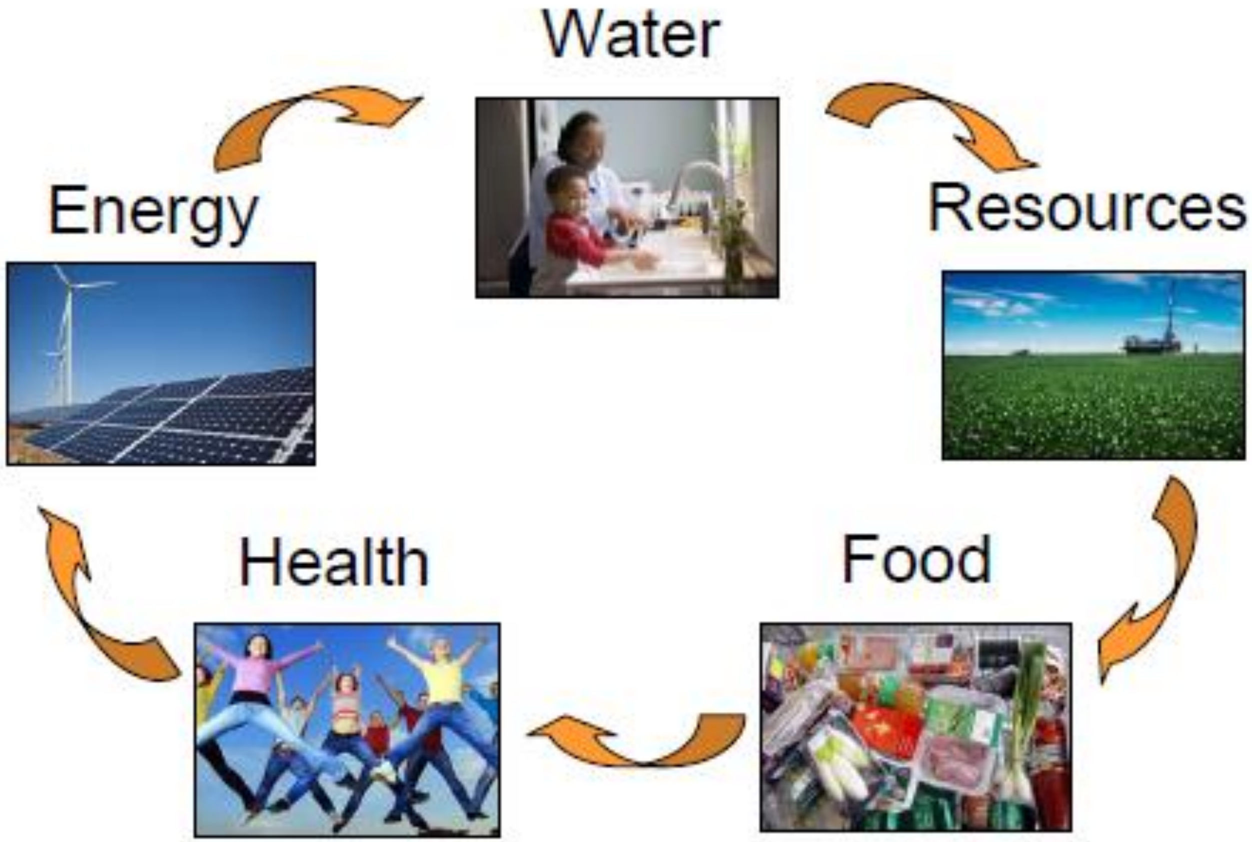
We are now in a golden age for Bio & ChE?

Adopted from Phil Westmoreland's* 5 reasons

- Manufacturing's shift to emphasize processes and properties (**smart manufacturing**)
- New abundance of hydrocarbon resources in USA, China & other locations (**a game changer**)
- Biology's turning into a molecular science (**multi-disciplinary**)
- Computing, evolved into a cyberinfrastructure (**knowledge and data management – big data**)
- ChEs' breadth and problem-solving approaches (**contribute to the society**)

** President of the AIChE, 2013*

Turn challenges into opportunities: some key areas (human needs)

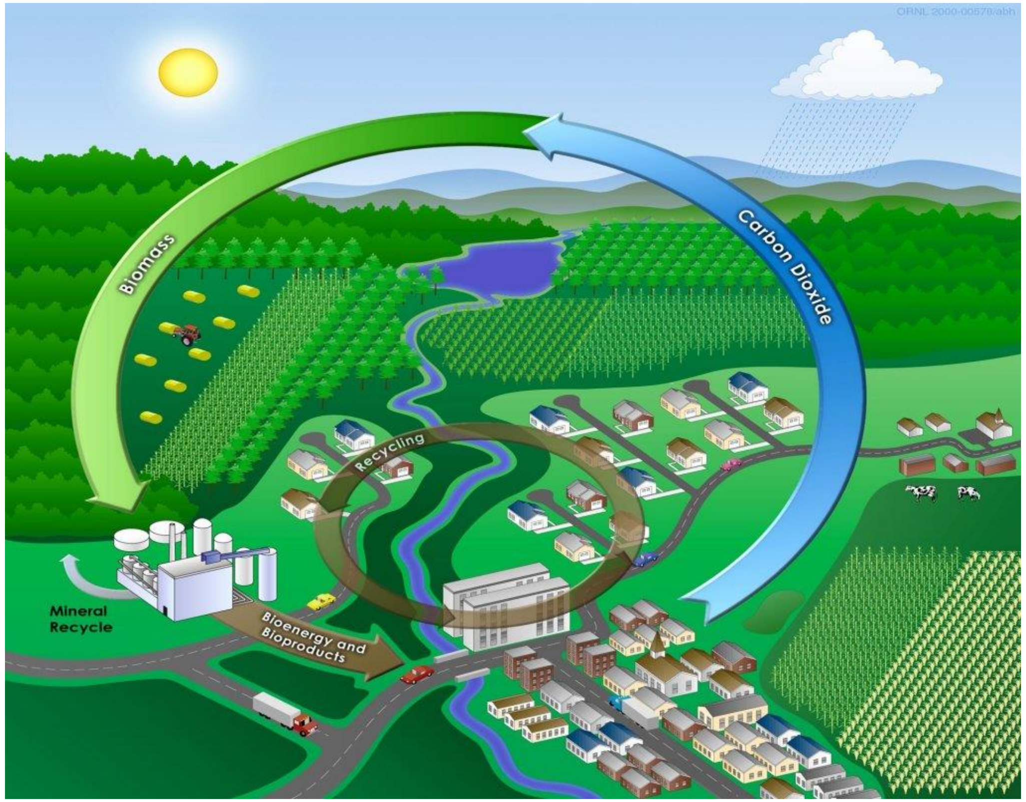


How can we achieve sustainability or sustainable development?

A Azapagic, WCCE 2013, Seoul, Korea

The need for cleaner and renewable technologies*

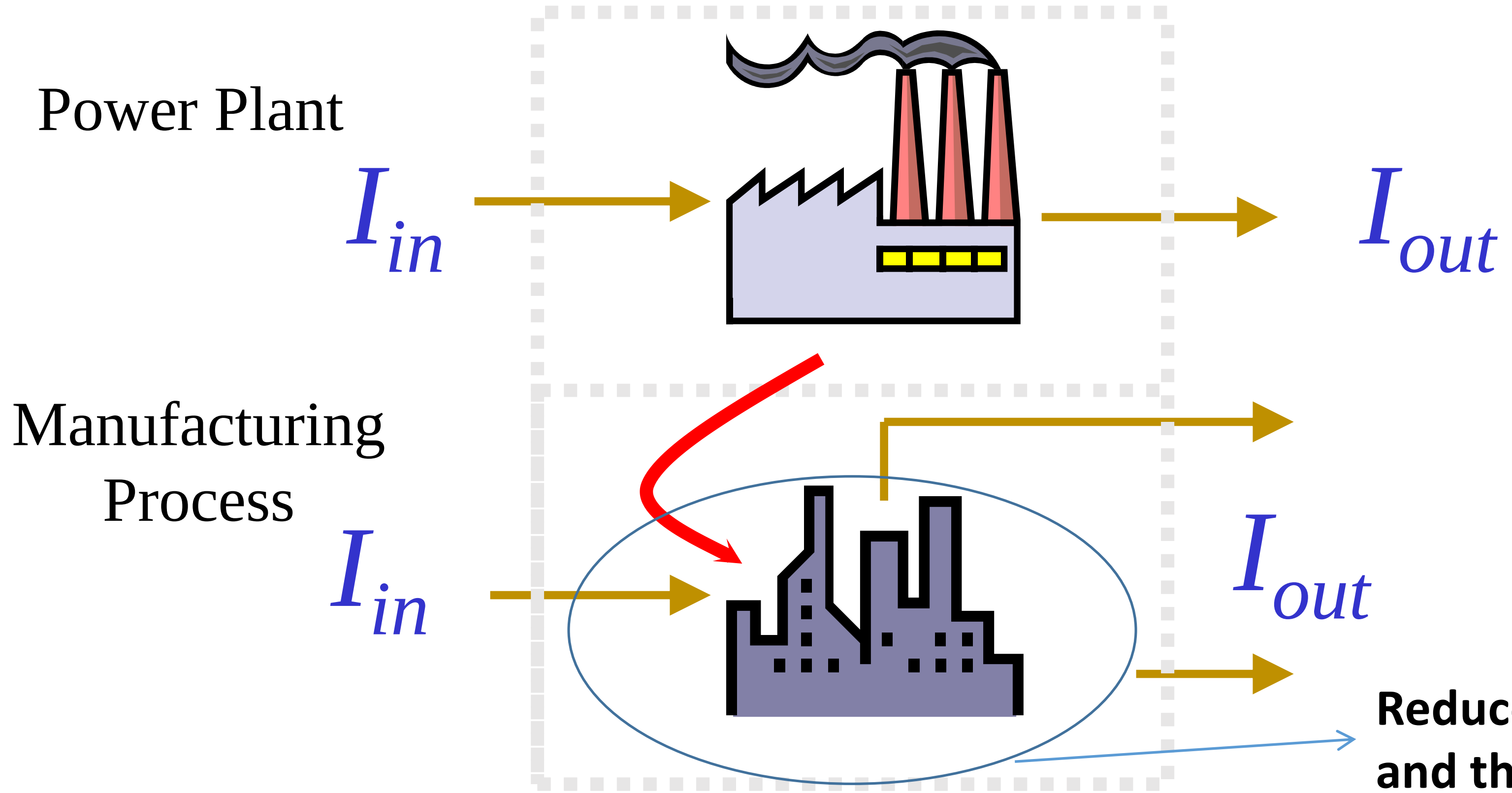
Uncontrolled manufacturing negatively impacting the atmosphere negatively & causing great harm!



Totally integrated system with recycle of resources leading to a circular economy – green engineering!

We have a responsibility to control our emissions and reduce our waste

Sustainable development & impact on global warming?

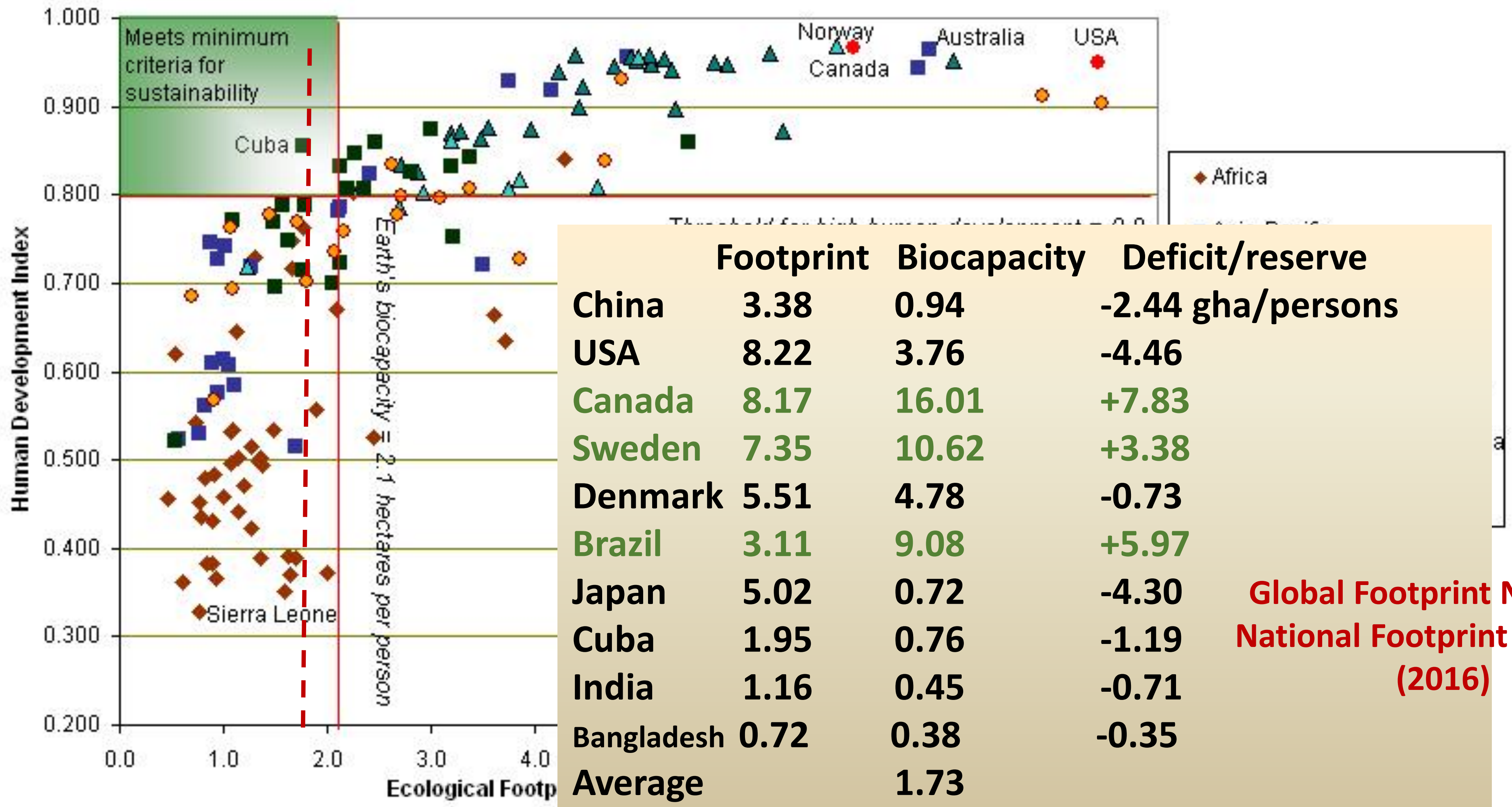


Where is the real boundary of our system?

Reduce the energy demand and therefore CO2 emission

More efficient energy demanding technologies combined with more efficient energy producing technologies: Manufacturing processes (example)

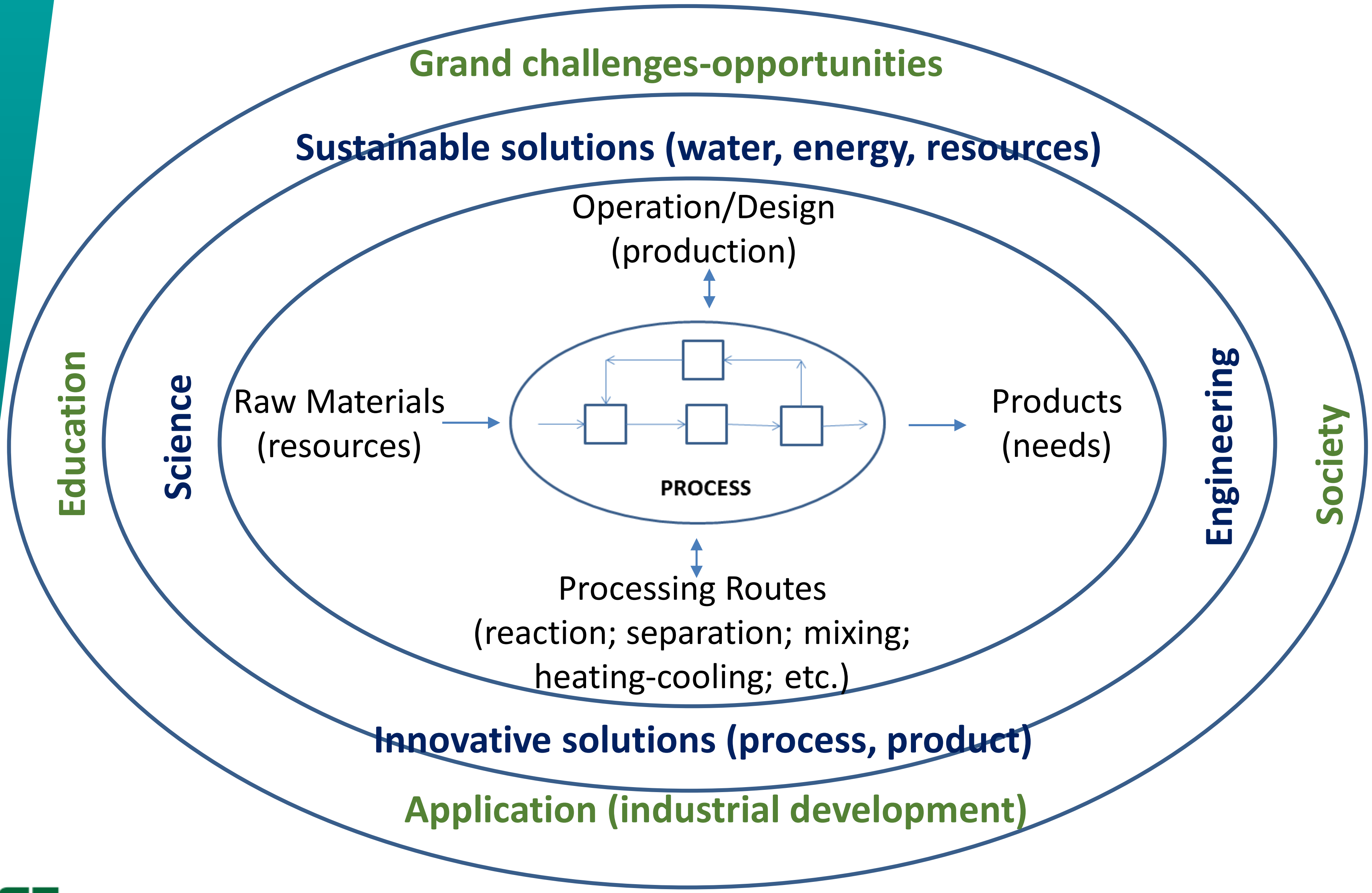
Human Welfare and Ecological Footprints compared



	Footprint	Biocapacity	Deficit/reserve
China	3.38	0.94	-2.44 gha/persons
USA	8.22	3.76	-4.46
Canada	8.17	16.01	+7.83
Sweden	7.35	10.62	+3.38
Denmark	5.51	4.78	-0.73
Brazil	3.11	9.08	+5.97
Japan	5.02	0.72	-4.30
Cuba	1.95	0.76	-1.19
India	1.16	0.45	-0.71
Bangladesh	0.72	0.38	-0.35
Average		1.73	

Global Footprint Network
National Footprint Accounts
(2016)

A multi-layered view of Bio & ChE: Core, Interface & Connecting layers



The **overall objectives** are to serve the society through educating the necessary engineers who can apply their education-training for industrial development taking advantage of the opportunities available and addressing the challenges being faced

Conclusions & future directions

Contents lists available at ScienceDirect

Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

Barcelona Declaration – 10th World Congress of Chemical Engineering, 1–5 October 2017

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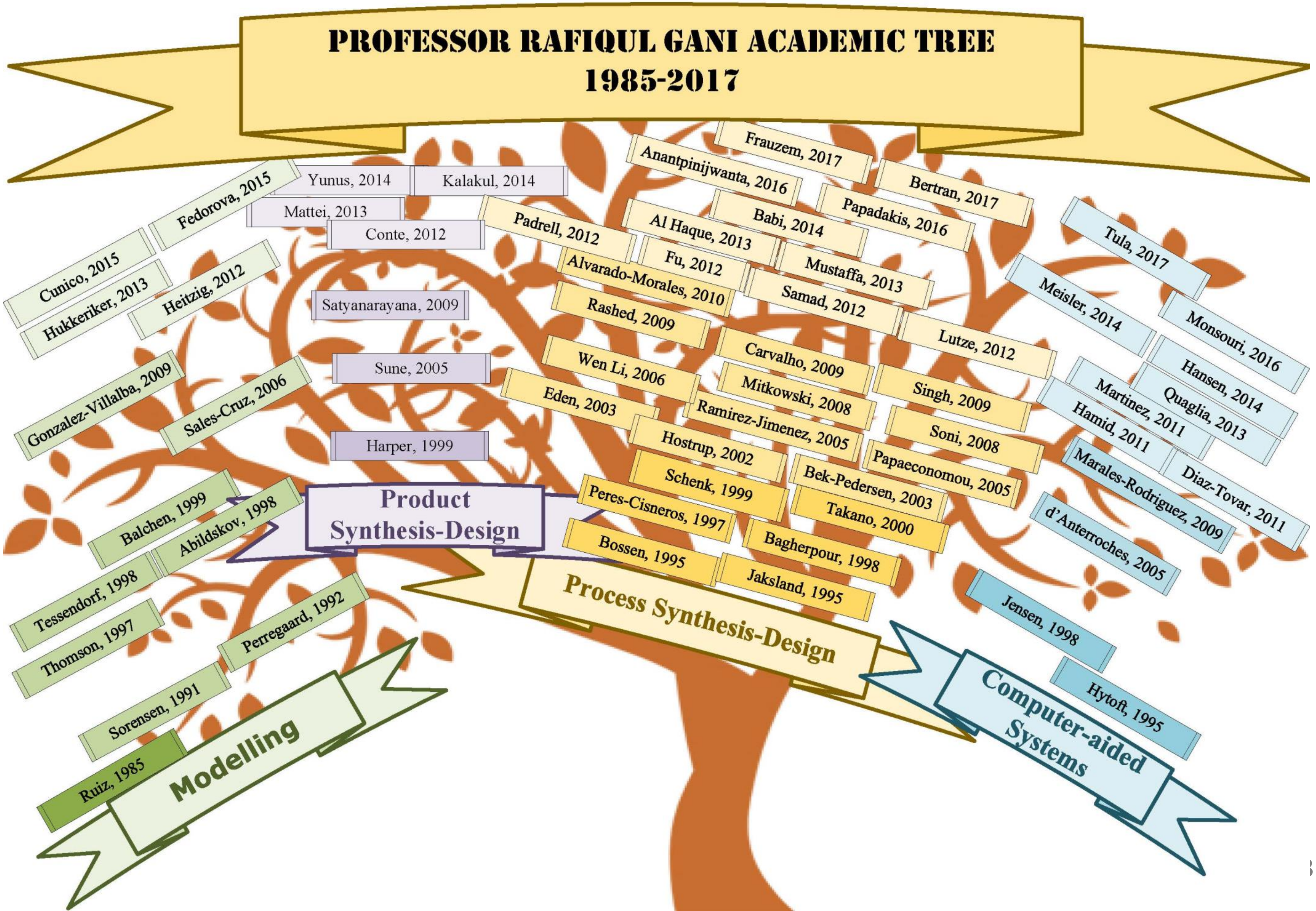
Conclusions & future directions

Barcelona Declaration, 2017 (ChERD, 2018)

We should agree to:

- Promote research and development as a fundamental pillar and encourage technology development to achieve a planet able to sustain a growing population, while improving quality of life.
- Facilitate global dissemination of chemical and biochemical engineering technical knowledge and industrial best practices, striving to bring together academia and industry worldwide.
- Promote conservation and care of global resources, health, safety, and the environment.
- Promote the highest standards of professional ethics and conduct for chemical engineers worldwide, to safeguard the public.


PROFESSOR RAFIQUL GANI ACADEMIC TREE
1985-2017
Modelling
Ruiz, 1985
Sorensen, 1991
Perregaard, 1992
Thomson, 1997
Tessendorf, 1998
Abildskov, 1998
Balchen, 1999
Sales-Cruz, 2006
Gonzalez-Villalba, 2009
Heitzig, 2012
Hukkeriker, 2013
Cunico, 2015
Fedorova, 2015
Product
Synthesis-Design
Harper, 1999
Sune, 2005
Satyanarayana, 2009
Conte, 2012
Mattei, 2013
Yunus, 2014
Kalakul, 2014
Process Synthesis-Design
Bossen, 1995
Jaksland, 1995
Peres-Cisneros, 1997
Bagherpour, 1998
Schenk, 1999
Takano, 2000
Hostrup, 2002
Bek-Pedersen, 2003
Eden, 2003
Ramirez-Jimenez, 2005
Papaeconomou, 2005
Wen Li, 2006
Mitkowski, 2008
Soni, 2008
Carvalho, 2009
Singh, 2009
Rashed, 2009
Alvarado-Morales, 2010
Fu, 2012
Padrell, 2012
Samad, 2012
Lutze, 2012
Mustaffa, 2013
Al Haque, 2013
Babi, 2014
Papadakis, 2016
Anantpinijwanta, 2016
Frauzem, 2017
Bertran, 2017
Computer-aided
Systems
Hytoft, 1995
Jensen, 1998
d'Anterroches, 2005
Marales-Rodriguez, 2009
Diaz-Tovar, 2011
Hamid, 2011
Martinez, 2011
Quaglia, 2013
Hansen, 2014
Meisler, 2014
Monsouri, 2016
Tula, 2017