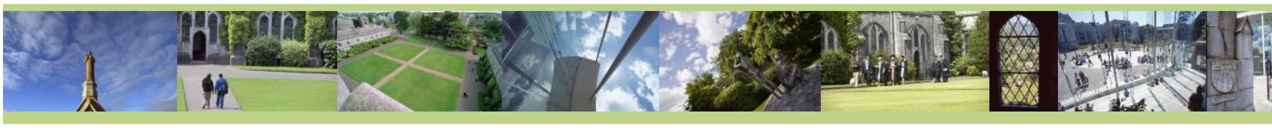


Educating Chemical Engineers for Contemporary Challenges:

The value of Context, Connection and Collaboration

Edmond Byrne

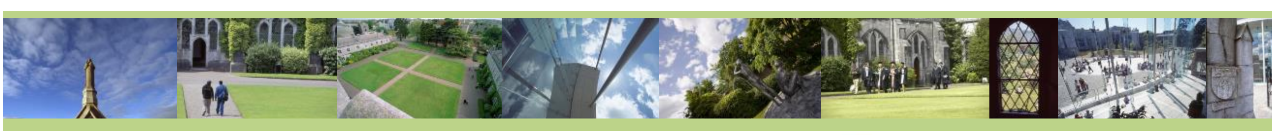
Head & Professor of Process & Chemical Engineering

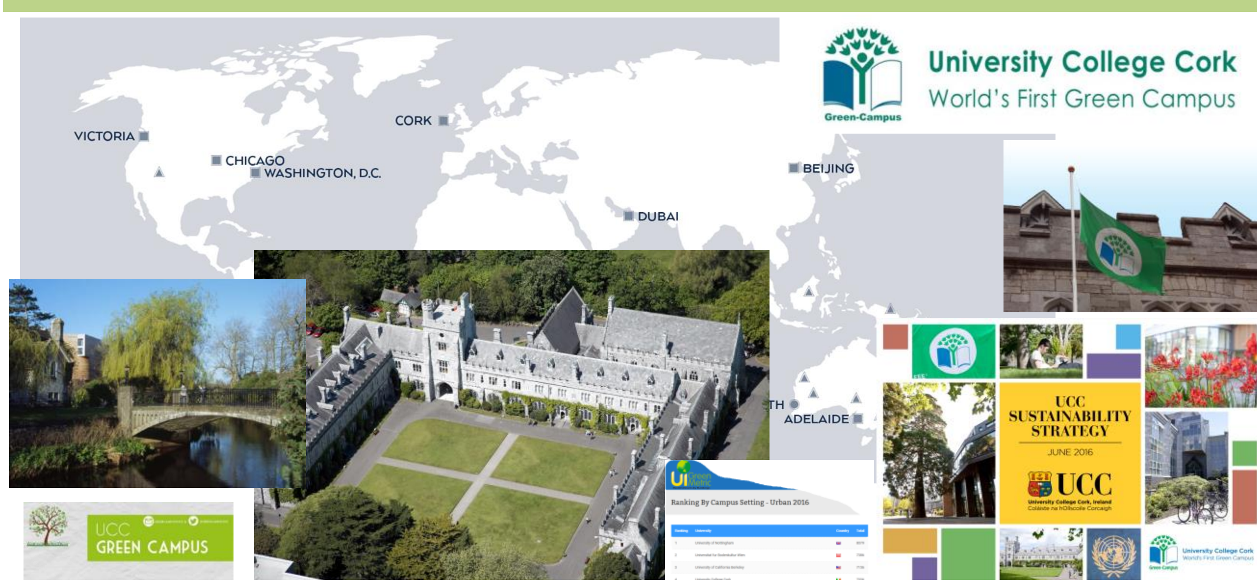
University College Cork, Ireland

University College Cork, Ireland

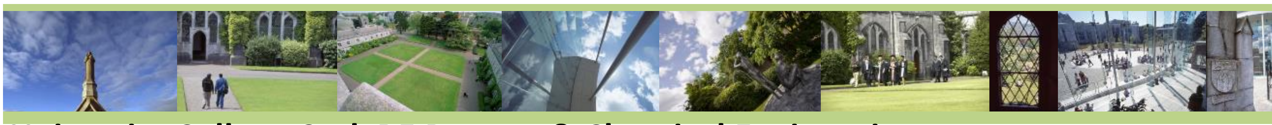
Coláiste na hOllscoile Corcaigh

International Engineering Education Forum, Tianjin University, 11-12th December 2017 E.P. Byrne





International Engineering Education Forum, Tianjin University, 11-12th December 2017 E.P. Byrne

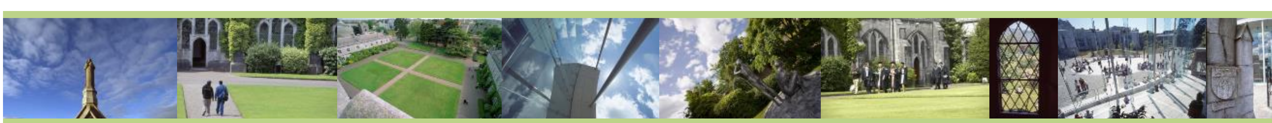


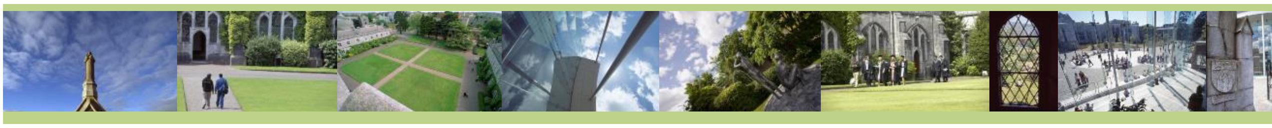
University College Cork BE Process & Chemical Engineering

Overall Winner:

IChemE Sustainability Teaching Award 2016

"University College Cork demonstrated that they could integrate sustainability teaching principles across the curriculum, which will provide their chemical engineering students with a set of values to apply to their future careers."

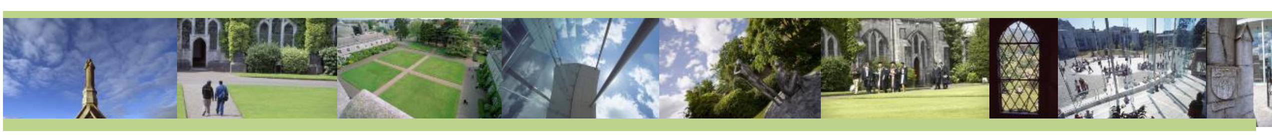




Educating **Chemical Engineers** for **Contemporary Challenges**:
The value of ***Context, Connection*** and ***Collaboration***

- *Contemporary Challenges?*
  - Considering *Context?*
  - Recognising *Connection?*
  - Seeking *Collaboration?*
- *So what?* Implications for *Chemical Engineering Education?*
- A Case Study
- University College Cork's Approach

International Engineering Education Forum, Tianjin University, 11-12th December 2017 E.P. Byrne



Business/Industry needs?

Accelerating change (Δt↓): Tech/IT environment?

Engineering Education: Reform/Evolution to produce fit-for-purpose Engineers to address Emerging and Contemporary Challenges?

Environmental degradation-climate change-food-water-energy nexus?

To (Serve) What Purpose? ..and How?

Complex socio-technical recursive interactions?

International Engineering Education Forum, Tianjin University, 11-12th December 2017 E.P. Byrne

All would agree that the:
'traditional' engineering toolbox of technical skills, while <u>absolutely required</u>, is alone, <u>insufficient</u>:

- *Soft skills* (communication, teamworking, presentation)
- *Contextualisation* of engineering social practice
- *Inter- and Transdisciplinary* approaches

…are all also necessary

change ($\Delta t\downarrow$): vironment?

lution

Connection

Context

e?

Collaboration

eractions?

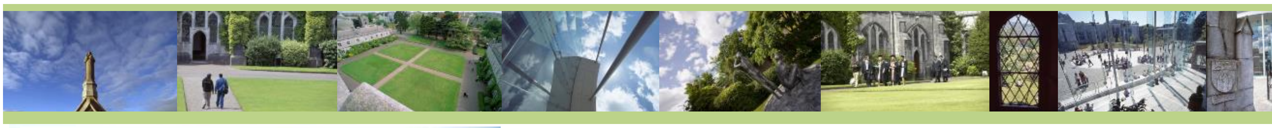
Business/Industry needs?

Accelerating change ($\Delta t\downarrow$): Tech/IT environment?

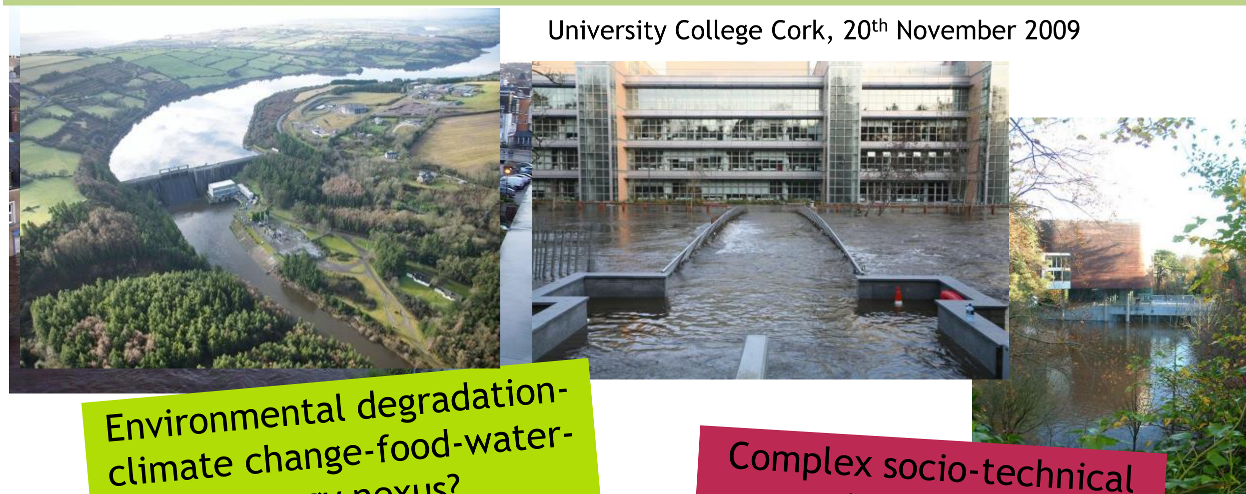
Contemporary Challenges:

Environmental degradation-climate change-food-water-energy nexus?

Complex socio-technical recursive interactions?

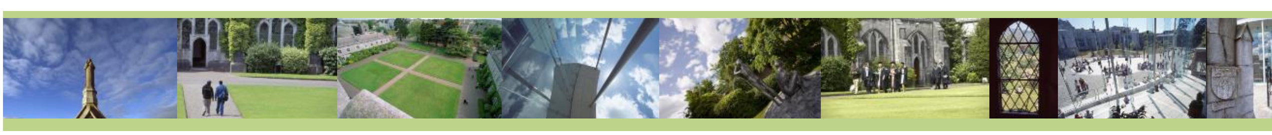


University College Cork, 20th November 2009

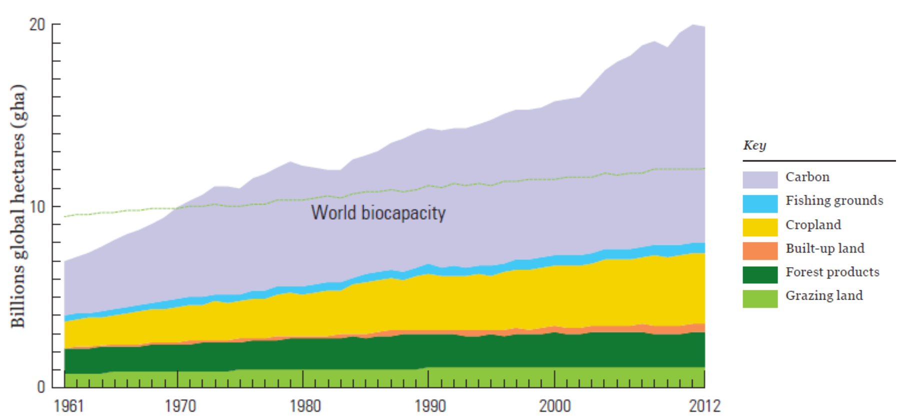


Environmental degradation-climate change-food-water-energy nexus?

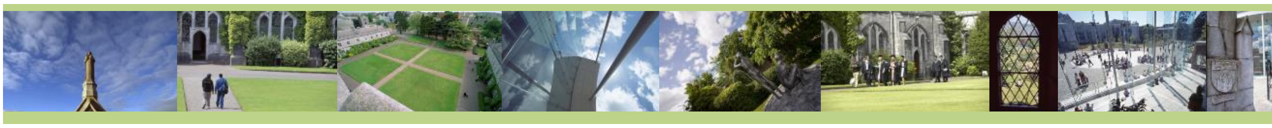
Complex socio-technical recursive interactions?



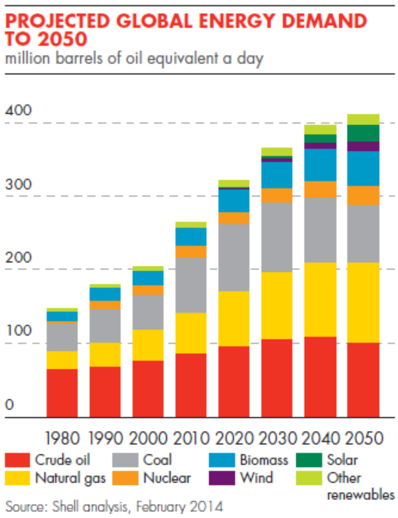
Ecological footprint by component

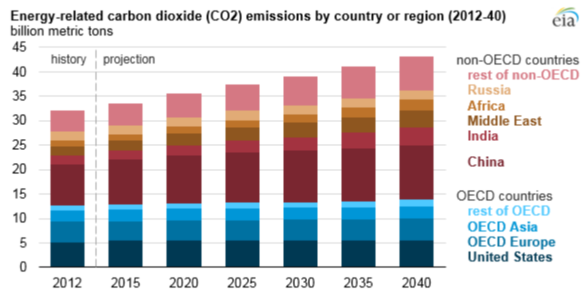


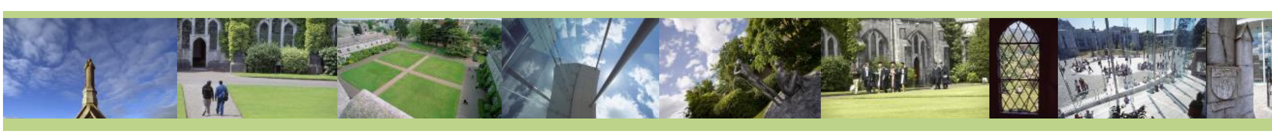
Source: **WWF Living Planet Report 2016**



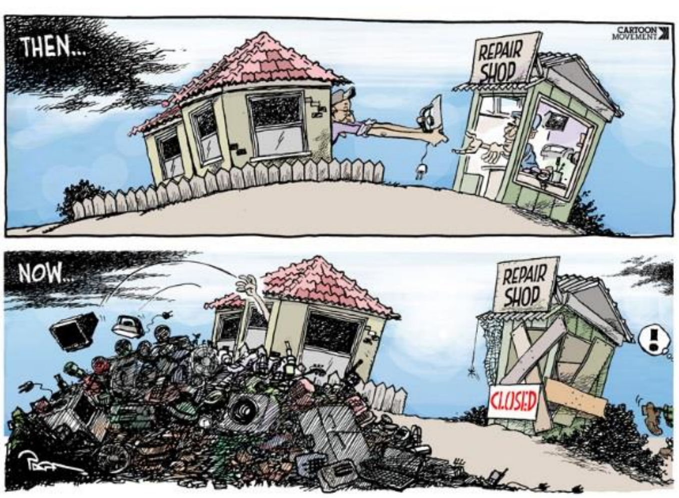
Energy Demand and resultant CO_2 emissions

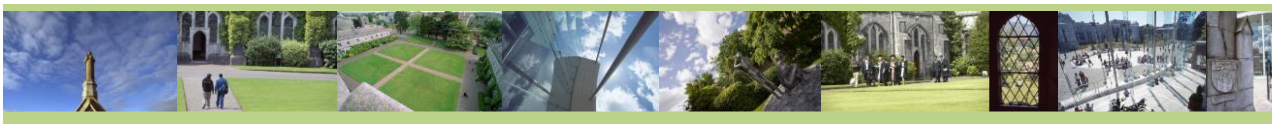




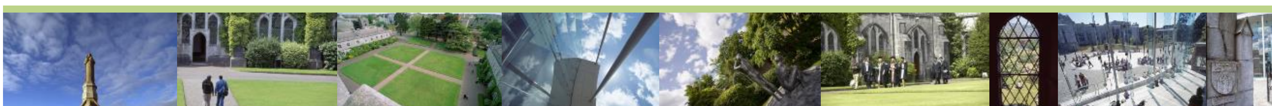


Material and Energy flows driven by Economics without Limits

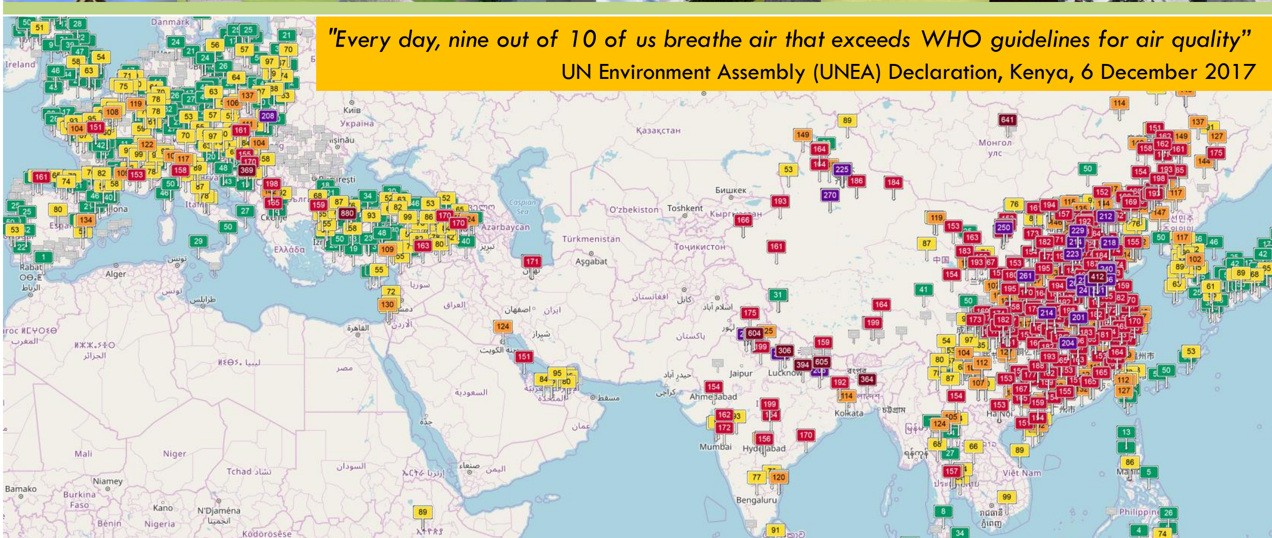




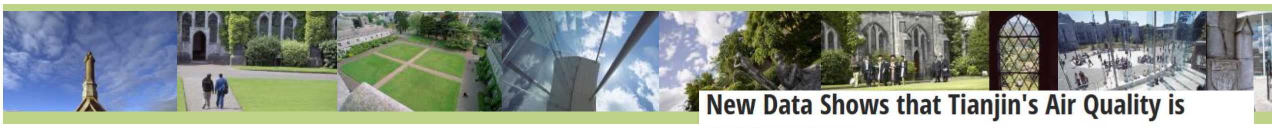
Contemporary Challenges: Considering Context

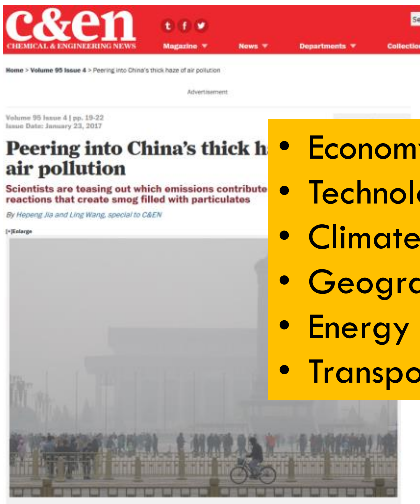


"Every day, nine out of 10 of us breathe air that exceeds WHO guidelines for air quality"
UN Environment Assembly (UNEA) Declaration, Kenya, 6 December 2017



World Air Quality Index (www.aqicn.org), Tue 5th December 2017 (20.30h GMT)

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CHEMICAL & ENGINEERING NEWS
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Home > Volume 95 Issue 4 > Peering into China's thick haze of air pollution

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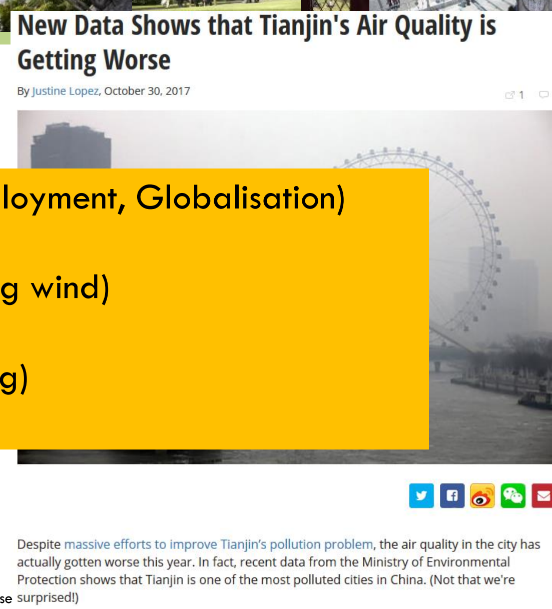
Volume 95 Issue 4 | pp. 19-22
Issue Date: January 23, 2017

Peering into China's thick h[aze of] air pollution

Scientists are teasing out which emissions contribute [to the chemical] reactions that create smog filled with particulates

By Hepeng Jia and Ling Wang, special to C&EN

Heavy air pollution enshrouded Tiananmen Square in Beijing last month.

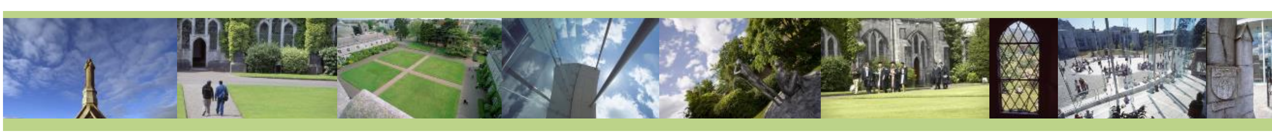

New Data Shows that Tianjin's Air Quality is Getting Worse

By Justine Lopez, October 30, 2017

Despite massive efforts to improve Tianjin's pollution problem, the air quality in the city has actually gotten worse this year. In fact, recent data from the Ministry of Environmental Protection shows that Tianjin is one of the most polluted cities in China. (Not that we're surprised!)

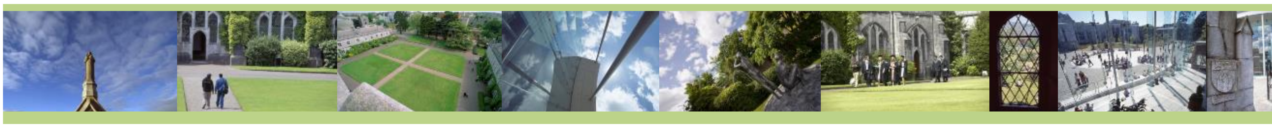
- Economy – (Industry, Employment, Globalisation)
- Technology
- Climate Change (including wind)
- Geography
- Energy (Fossil fuel burning)
- Transportation

http://www.thatsmags.com/tianjin/post/21154/new-data-shows-that-tianjin-s-air-quality-is-getting-worse

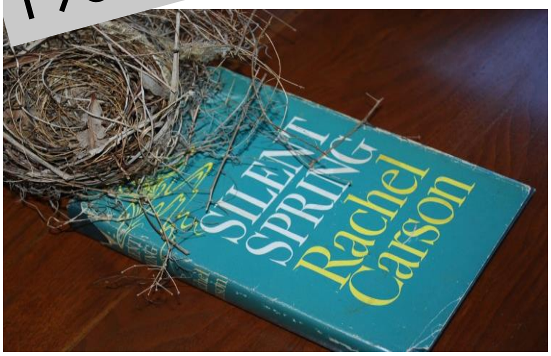


Contemporary Challenges:
Recognising
Connection

International Engineering Education Forum, Tianjin University, 11-12th December 2018 E.P. Byrne UCC

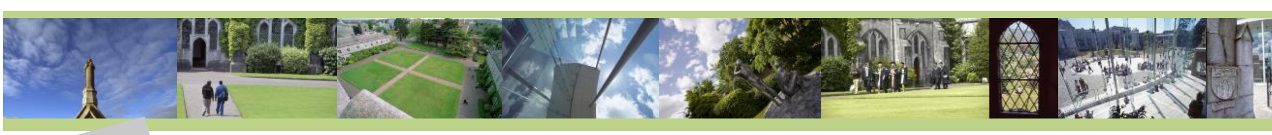


1962

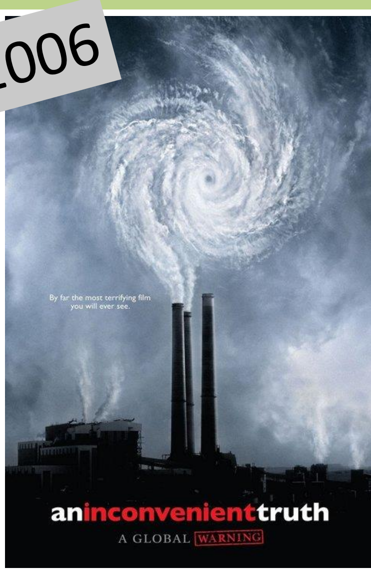


*'The history of life on earth has been a history or **interactions** between living things and their surroundings.'*

Rachel Carson,
Silent Spring

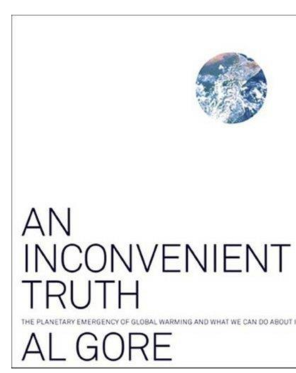


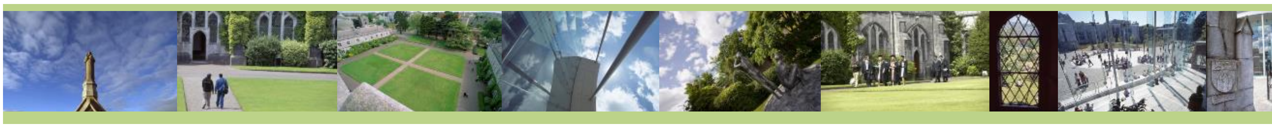
2006

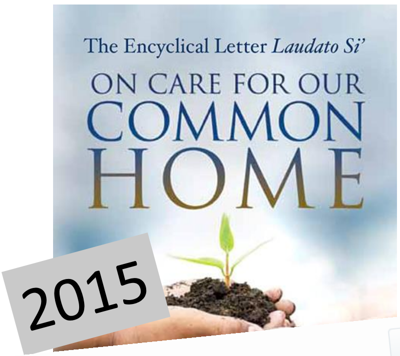


*'Our capacity for analysis sometimes leads us to an arrogant illusion: that we are so special and unique that nature isn't **connected** to us.*

But the fact is,
*we're **inextricably tied.**'*



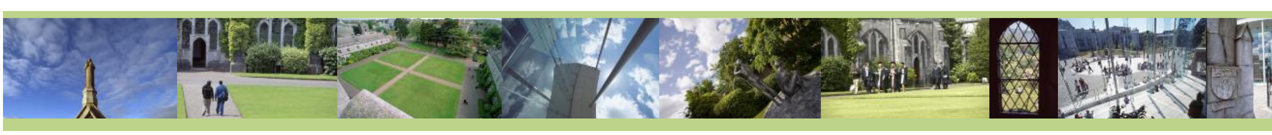




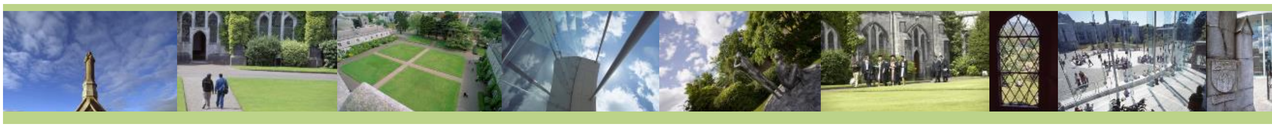
'*It cannot be emphasized enough how* ***everything*** *is* ***interconnected.***

..It follows that the ***fragmentation*** *of knowledge and the* ***isolation*** *of bits of information can actually become a form of* ***ignorance****, unless they are* ***integrated*** *into a* ***broader vision*** *of* ***reality****.'*

seek ***only*** *a* ***technical*** *remedy to each ronmental problem which comes up is to* ***separate*** *t is in reality* ***interconnected*** *and to mask the true deepest problems of the global system.'*



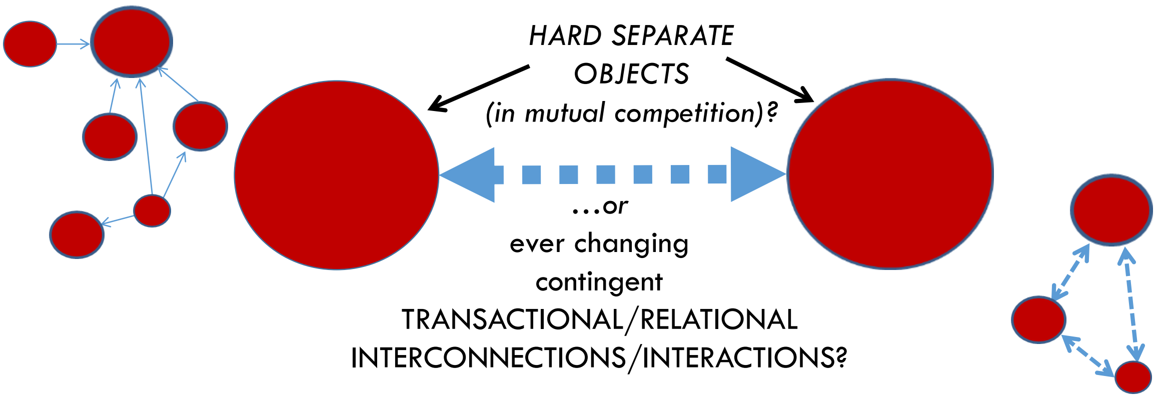
Contemporary Challenges:
Seeking
Collaboration

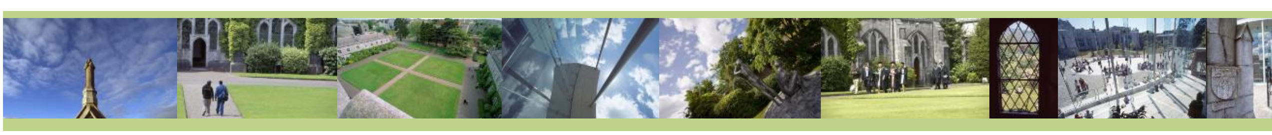


[In considering/modelling ecosystems], researchers could..

*'pay more attention to **processes** (flows) than to **objects**'*

Robert Ulanowicz, 2004, (Computational Biology & Chemistry, 28, 322)



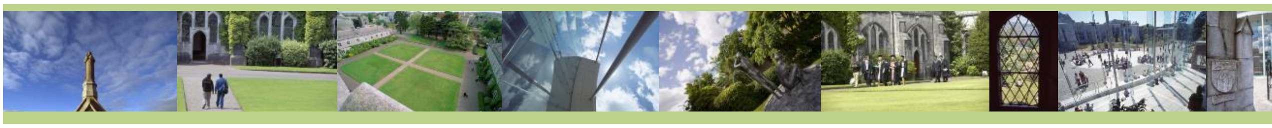


'The problems that engineers will face in the future are often unique, complex, heterogeneous, ill-defined and even wicked.
Past solutions will no longer suffice.
In order to solve these problems, engineering education must develop a new 'breed' of engineers that are innovative, cross-disciplinary, collaborative, and holistic.'

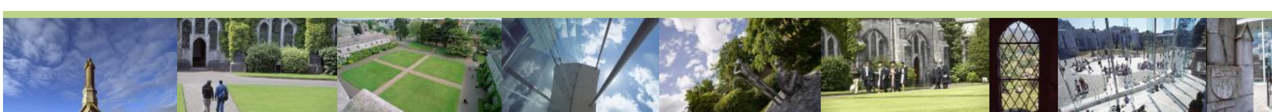
[Such engineers] *'..just want to solve <u>real problems</u>, <u>not just</u> some technical part of problems.'*

Anders Buch (2016)

(In: Jørgensen & Brodersen (Eds.), *Engineering Professionalism*, 147–169)

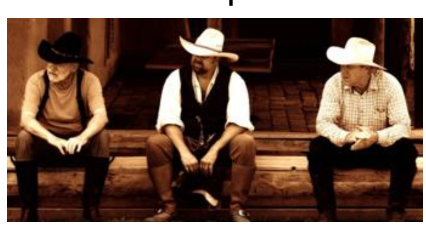


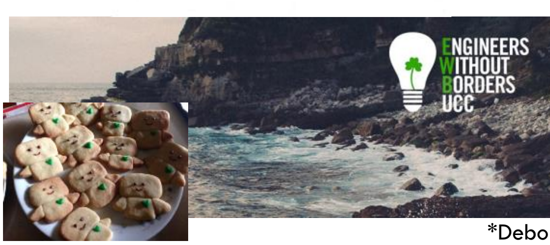
Context, *Connection* and *Collaboration:* in (Chemical) Engineering Education?



Competing Conceptions of Engineering*

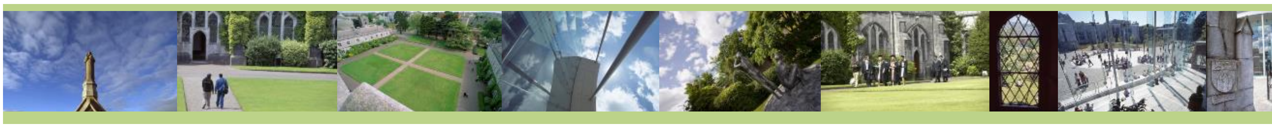
1. Engineers as value neutral 'guns for hire' or 'paid hands'





2. Engineers as committed to a social good thus being constrained in some ways, privileged in others to achieve this*

*Deborah Johnson, 'The Social/Professional Responsibility of Engineers' (1989)



Kick-off Reflection PE1006 Professional Engineering Communication & Ethics (2017-18):

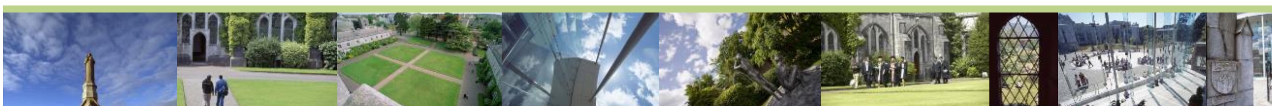
What *social* and *ethical* commitments should engineering have?..

MACRO-ETHICAL (Societal good)

- Enhance people's lives
- Protect the environment
- Safety of others
- Be aware of consequences of one's actions
- Do not infringe on rights
- Enhance communication between nations/communities, etc.
- Take others ideas on board to enhance overall project

MICRO-ETHICAL (Individual morals)

- Honesty regarding one's work/products
- Do not plagiarise
- Pride in one's work



THE MELBOURNE COMMUNIQUÉ

We, the representatives of twenty organisations representing chemical engineers world-wide, subscribe to the following statement.

Entering the Twenty-First Century, we in the chemical engineering profession renew our commitment to using our skills to strive to improve the quality of life, foster employment, advance economic and social development and protect the environment through sustainable development.

Chemical engineering uses the principles of science to develop and provide technologies that improve the lives of people everywhere. From chemical engineering come materials: minerals, metals, ceramics, polymers, paper and composites. Food production and processing and water purification rely on chemical engineering. To enhance the health of the world's peoples, chemical engineering makes possible vaccines, pharmaceuticals and biotechnology. Shelter, clothing, transport and information technology all rely on chemical engineering. We develop and deliver the energy resources on which communities depend.

In meeting society's needs we are committed to designing processes and products that are innovative, energy-efficient and cost-effective, and that make the best use of scarce resources. We are committed to the highest standards of personal and product safety. We seek to eliminate waste and adverse environmental effects in the development, manufacture, use and eventual disposal of the products of society.

In an increasingly global society, we are committed to meeting the collective needs of the world's growing population while working to avoid and eliminate practices that are unsustainable. We recognise the profound concern relating to climate change. We must promote a better understanding of the complex science surrounding climate change, while also striving to develop and implement sound technologies to mitigate its effects.

We commit to developing public understanding of the challenges and choices facing our world, and the role chemical engineering can play. We will use our talents, knowledge and organisational skills for the continued betterment of humanity to protect the public welfare. We will practice our profession according to its high ethical standards. We will promote lifelong professional development and will enthuse the brightest young people so that they enter our profession.

We will take this Communiqué to our members, reinforcing their awareness of their obligations to serve society. We also commit to working with industries, governments, universities and other organisations that shape the future of the world.

We acknowledge both our professional responsibilities and the need to work with others as we strive to meet the challenges facing the world in the Twenty-First Century.

AGREED IN MELBOURNE AT THE SIXTH WORLD CONGRESS OF CHEMICAL ENGINEERING

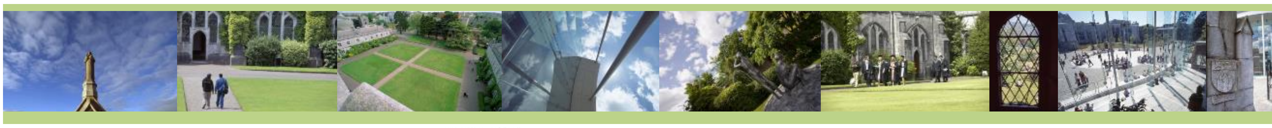
27th September, 2001

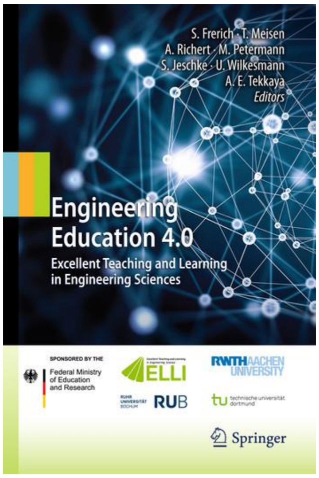
MELBOURNE COMMINIQUÉ, 2001:

[20 global chemical engineering institutions]

"We acknowledge both our <u>professional responsibilities</u> and the need to <u>work with others</u> as we strive to meet the <u>challenges</u> facing the world in the Twenty-First Century."

AGREED AT THE 6th WORLD CONGRESS OF CHEMICAL ENGINEERING MELBOURNE 2001





The Globally Competent Engineer – What Different Stakeholders Say About Educating Engineers for a Globalized World May et al. (pp. 895-910, 2016)

3.2.3 China

1. a knowledge of humanities and an understanding of social, professional and ethical responsibility;

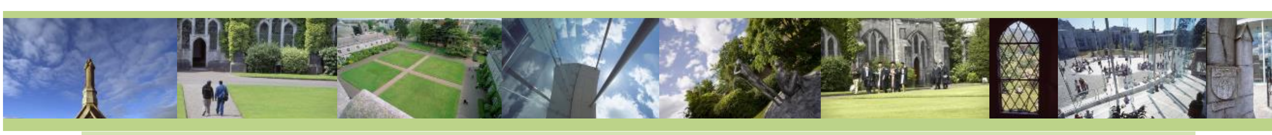
5. an ability to innovate; an attitude and awareness of innovation; an ability to synthesize theories and techniques to design a system and process within the economic, environmental, legal, safety, health and ethical constraints;

7. a knowledge of policies, laws and regulations on the production, design, research and development, environment protection and sustainable development related to the profession and industry; a recognition of the impact of engineering to the external world and society;

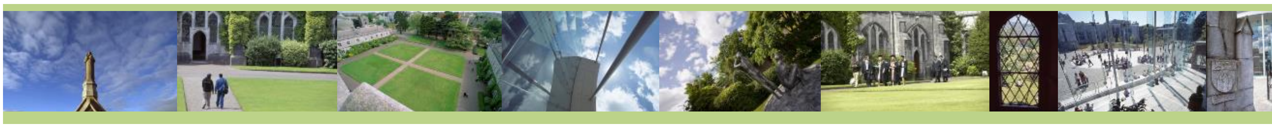
8. an ability to manage, communicate and function in teams;

external world and society;
8. an ability to manage, communicate and function in teams;

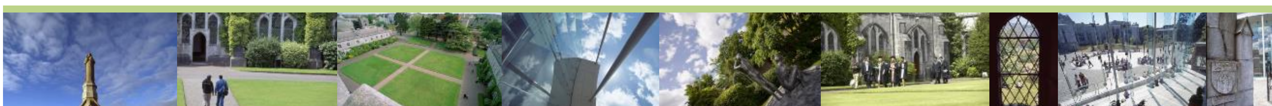
10. an global vision; an ability to communicate, compete and cooperate in the multicultural context.

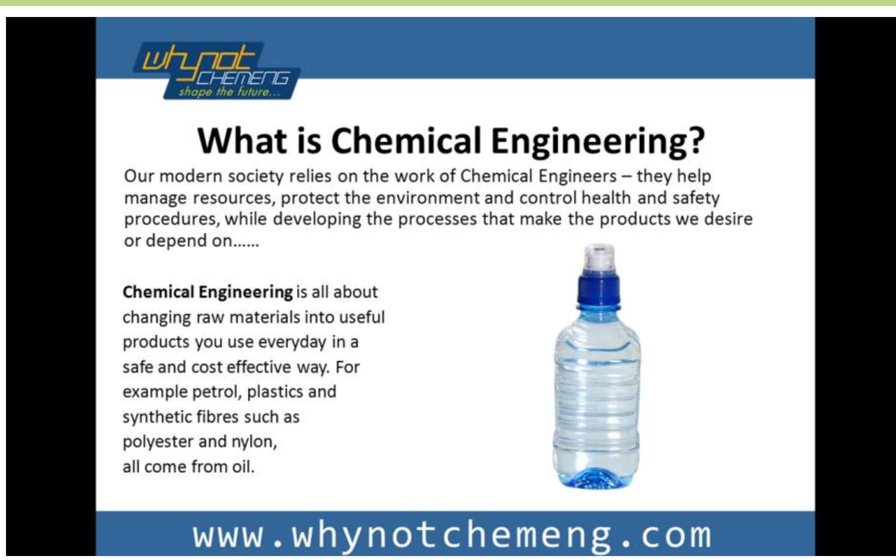


Contemporary Challenges Case Study: Plastics



- Chemical Engineering: emanated end 19th Century from need to understand both:
  - the **processes** & **chemistry** around fractionation of oil
  - the **design** and development of **safe** industrial-scale **processes** to carry this out.
- Chemical engineers are justly proud of their achievements in helping fuel the **industrial** and **social revolution** through the 20th Century with respect to **oil,** but also **food, drugs, chemicals,** etc. concurrent with a rapidly growing global population.
- One such product that chemical engineers are proud of is an oil derived product with a huge range of uses: **Plastic**





- **Environmentally** though, plastics are deeply **problematic:**
  Most end up being dumped in landfills or incinerated

- All plastics have some **residual contaminants,** no recycled plastics are suitable as food grade product

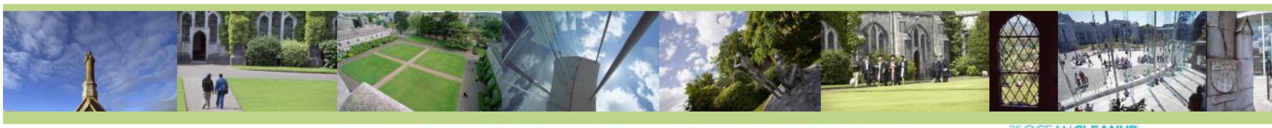
- **Poor degradability** means they have become an environmental scourge, on the natural land and seascapes, where they **accumulate** as a hazardous material to wildlife and can enter the food chain.

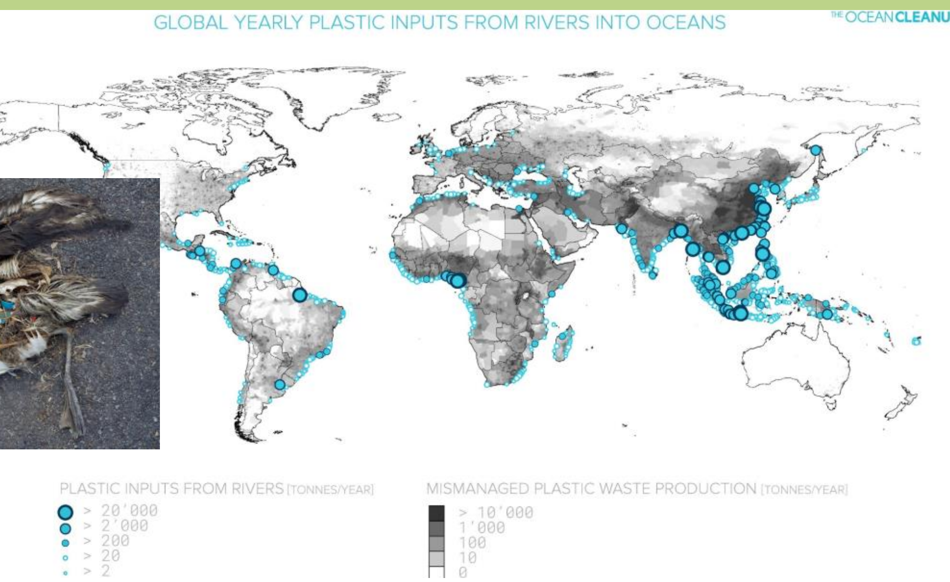
UN Ocean Conference: Plastics Dumped In Oceans Could Outweigh Fish by 2050, Secretary-General Says

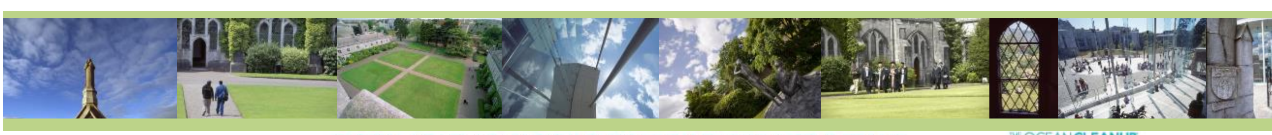
By Pam Wright · June 06 2017 02:45 PM EDT · weather.com

"Consumers around the world buy a million plastic bottles a minute.
Plastic production is set to double in the next 20 years and quadruple by 2050.
Around the world, more than 8m tonnes of plastic leaks into the oceans, and a recent study found that billions of people globally are drinking water contaminated by plastic."

(Graham Ruddick, The Guardian, 15 October 2017)







GLOBAL YEARLY PLASTIC INPUTS FROM RIVERS INTO OCEANS
THE OCEAN CLEANUP

Science & Environment

UN commits to stop ocean plastic waste

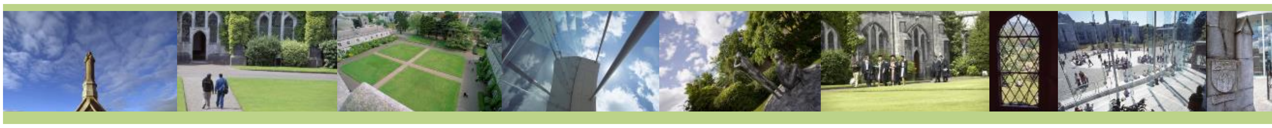
By Roger Harrabin
BBC environment analyst, Nairobi

5 December 2017 | 90 Share

Nations have agreed that the world needs to completely stop plastic waste from entering the oceans.

The UN resolution, which is set to be sealed tomorrow, has no timetable and is not legally binding.

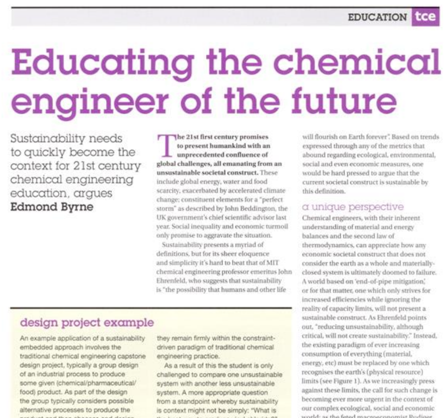
But ministers at an environment summit in Kenya believe it will set the course for much tougher policies and send a clear signal to business.



Points to ponder:

- Do chemical engineers bear a **moral** and **ethical responsibility** for the **'unintended' consequences** plastic bring?

- Do we have a responsibility to take a **broader** view e.g. develop and promote **alternative** materials to oil based plastics? *e.g. biodegradable plastics produced from polymerized lactic acid bacteria?*



EDUCATION tce

Educating the chemical engineer of the future

Sustainability needs to quickly become the context for 21st century chemical engineering education, argues **Edmond Byrne**

The 21st first century promises to present humankind with an unprecedented confluence of global challenges, all emanating from an unsustainable societal construct. These include global energy, water and food scarcity, exacerbated by accelerated climate change; constituent elements for a "perfect storm" as described by John Beddington, the UK government's chief scientific advisor last year. Social inequality and economic turmoil only promise to aggravate the situation.

Sustainability presents a myriad of definitions, but for its sheer eloquence and simplicity it's hard to beat that of MIT chemical engineering professor emeritus John Ehrenfeld, who suggests that sustainability is "the possibility that humans and other life will flourish on Earth forever". Based on trends expressed through any of the metrics that abound regarding ecological, environmental, social and even economic measures, one would be hard pressed to argue that the current societal construct is sustainable by this definition.

a unique perspective

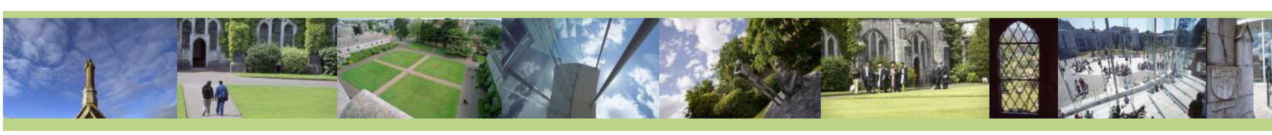
Chemical engineers, with their inherent understanding of material and energy balances and the second law of thermodynamics, can appreciate how any economic societal construct that does not consider the earth as a whole and materially-closed system is ultimately doomed to failure. A world based on 'end-of-pipe mitigation,' or for that matter, one which only strives for increased efficiencies while ignoring the reality of capacity limits, will not present a sustainable construct. As Ehrenfeld points out, "reducing unsustainability, although critical, will not create sustainability." Instead, the existing paradigm of ever increasing consumption of everything (material, energy, etc) must be replaced by one which recognises the earth's (physical resource) limits (see Figure 1). As we increasingly press against these limits, the call for such change is becoming ever more urgent in the context of our complex ecological, social and economic world; as the feted macroeconomist Rudiger

design project example

An example application of a sustainability embedded approach involves the traditional chemical engineering capstone design project, typically a group design of an industrial process to produce some given (chemical/pharmaceutical/food) product. As part of the design the group typically considers possible alternative processes to produce the product and then chooses and design they remain firmly within the constraint-driven paradigm of traditional chemical engineering practice.

As a result of this the student is only challenged to compare one unsustainable system with another less unsustainable system. A more appropriate question from a standpoint whereby sustainability is context might not be simply: "What is the best way to produce vinyl chloride?"

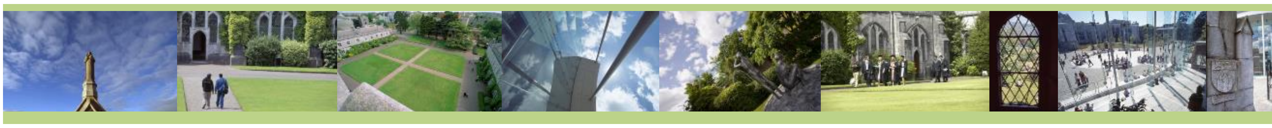
See: Byrne, E. (2011) *Educating the chemical engineer of the future, The Chemical Engineer, 833, 27-29. (Nov. 2010)*
http://www.ucc.ie/en/processeng/staff/academic/ebyrne/publications/thechemicalengineerarticlenov10educatingchemengofthefuture/TCENov2010Educatingthechemicalengineerofthefuture.doc



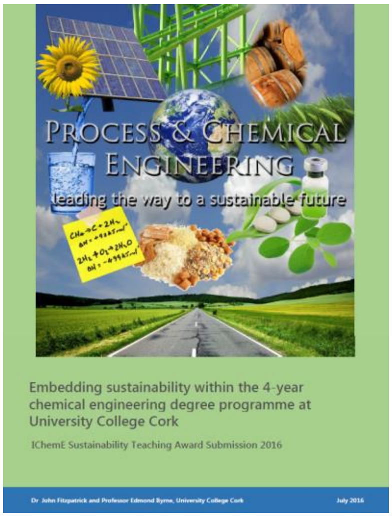
Contemporary Challenges:

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

University College Cork Approach



UCC BE Process & Chemical Engineering: "IChemE Sustainability Teaching Award 2016"



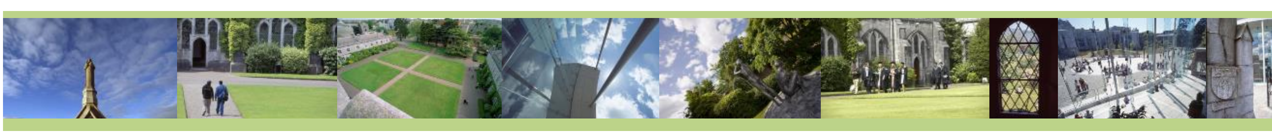
*"Dedicated **modules** and elective streams **alone** are not in themselves sufficient to demonstrate how sustainability should be the **context** through which **21st Century chemical engineering** must be practiced.*

*To do this programmes must **inherently** and consistently demonstrate the need for **sustainable practice.**"*

Byrne & Fitzpatrick* (2009)

*Byrne E.P. and Fitzpatrick, J.J. (2009) Chemical engineering in an unsustainable world: Obligations and opportunities. *Education for Chemical Engineers,* 4, 51-67.

International Engineering Education Forum, Tianjin University, 11-12th December 2018 — E.P. Byrne — UCC



"A sustainability context and ethos pervades the UCC programme through dedicated 'primary' modules concerning sustainability, scaffolded by a series of 'secondary' modules at each stage (one to four) of the programme."

'Primary' Sustainability Modules	*'Secondary' Sustainability Modules*
PE1006 Professional Engineering Communication & Ethics	PE1003 Intro. to Process & Chemical Engineering
	PE2005 Introduction to Biochemical Engineering PE2011 Plant Design and Commissioning
PE3011 Sustainability in Process Engineering PE3008 Safety & Environmental Protection I	PE3001 Applied Thermodynamics and Fluid Mechanics
PE4004 Safety & Environmental Protection II PE4006 Design Project	PE4001 Advanced Process Design

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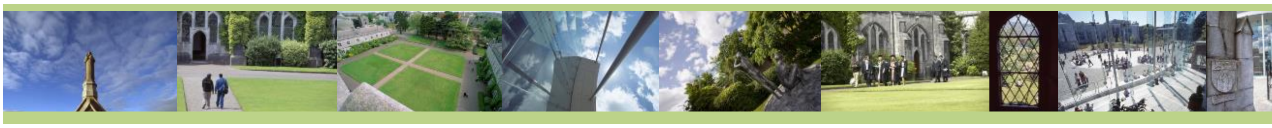
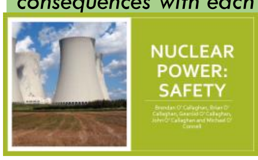


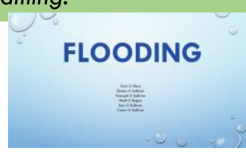
Year 1: PE1006 Professional Engineering Communication & Ethics

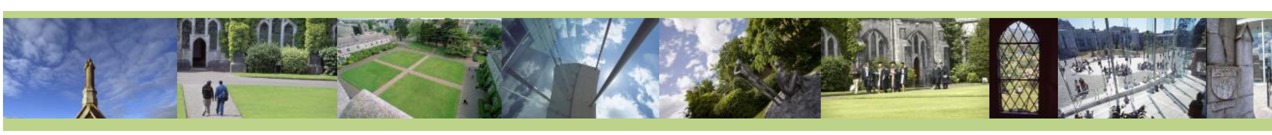
Wicked Problem Group Assignment

Wicked Problems: *Complex messy societal problems where people often cannot agree on what the problem is (framing) and which do not lend themselves to solving through simple deterministic interventions.*

Task: *Research. Frame problem according to different perspectives (techno-optimistic, local/community, global(ised), techo-critical, integrative, etc.) Identify problematic issues/potential unintended consequences with each framing.*







Year 2: PE2004 Communication in Engineering

Module Objective:

To improve students' skills in communicating and presenting complex technical information both to technical audiences and to the public at large.

News

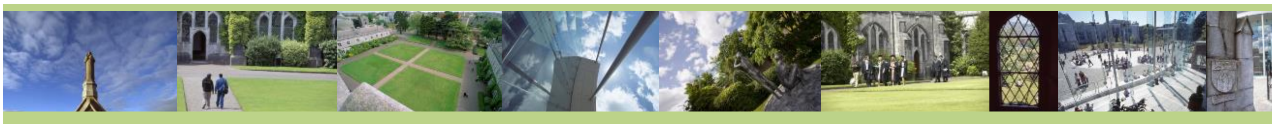
Process II triumph again! This time at Climathon

Winners 2017 UCC Climaton: Competition to devise low-carbon transport and mobility schemes for UCC

News

Process II are 1st runners up in the ESB Inter-Colleges Challenge - WOW!

'Energy Futures' Innovation Challenge 2017: Team of 3 Process & Chem. Eng. + 1 Finance student



Year 3: PE3011 Sustainability in Process Engineering

PE3011/SC3029 Assignment: Reflection on Sustainability
A collaborative exercise undertaken by students of:
- PE3011 Sustainability in Process Engineering
- SC3029 Sociology of the Environment

Transdisciplinary Group Assignment

Task: Consider and present on any aspect of 'sustainability'. Can include contrasting perspectives, framings or angles, and disciplinary norms. Also, how it has potential to change the way we do things, how it might be achieved, potential consequences, difficulties or problematic issues, etc.

Sustainability in a more solar powered society

Consumerism

Concepts of Progress

The Socio-Environmental Impacts of Plastic

Sustainability And The Green Belt Movement

Entropy and Sustainability

Quality vs Quantity

Globalisation

Sustainability through Community Projects

Sustainability and Behaviour Patterns

Consumerism and Energy

Sustainable Food Production

Unsustainability on a global scale

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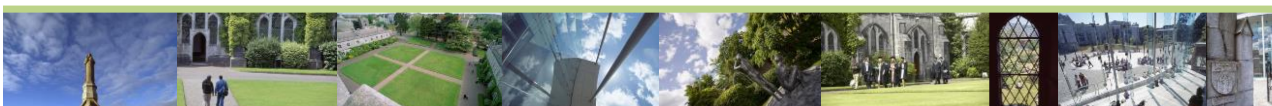

Year 4: PE4006 Design Project

'Embedding Sustainability' into the final year capstone Design Project

Traditional 'end of pipe' approach

Do the design first → Then perform sustainability assessment at the end

This philosophy seems to be somewhat 'upside down':
Sustainable assessment should NOT just be a "bolt-on" activity, but should be incorporated throughout the design process in a way that recursively influences design decisions and the final outcome.

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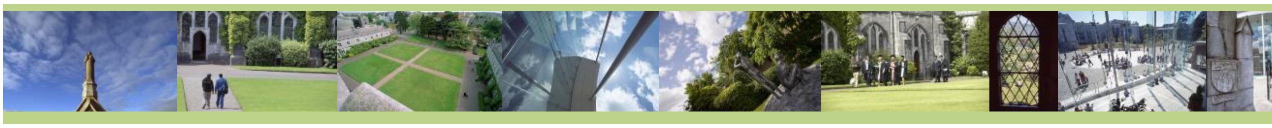


Revised approach to placing sustainability as context of design project requires:

a) Considering sustainability throughout a (semi open ended) design process

-Thus feed into design decisions from start, including framing

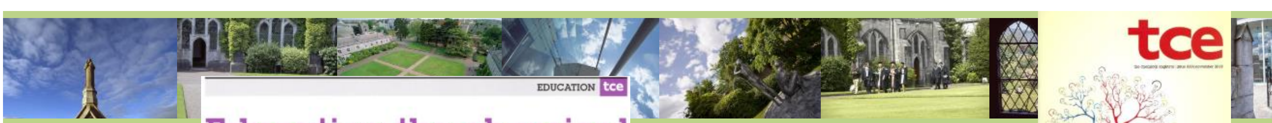
b) Environmental aspects

-Employ scientific/engineering tools and methods which can have a real impact and can directly influence the design (e.g. LCA, EIS, material and energy balances)

c) Socio-economic aspects

- More difficult and possibly outside scope (e.g. societal structural issues).

It could be argued that the key sustainability 'game-changers' lie in the broader socio-economic domain; aim is to challenge to consider broader sustainability education and at least identify key problematic issues. Ideas?



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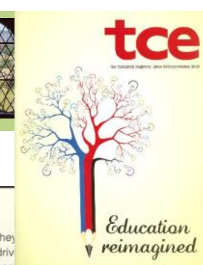
a unique perspective

Chemical engineers, with their inherent



Framing Considerations:

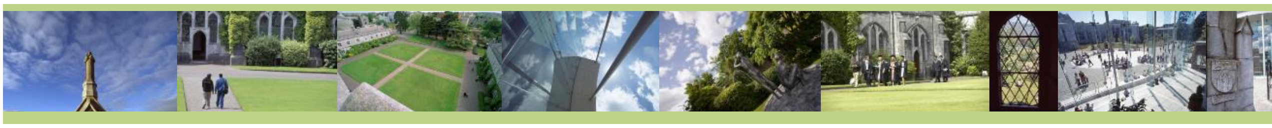
Might students propose reframing a design project which requires the production of plastics or VCM, a PVC precursor, to one which would produce inherently 'more sustainable' non-oil based plastics, such as a biodegradable plastics? This too could have longer-term positive economic (sustainability) implications for a plastics business..

design project example

An example application of a sustainability embedded approach involves the traditional chemical engineering capstone design project, typically a group design of an industrial process to produce some given (chemical/pharmaceutical/food) product. As part of the design the group typically considers possible alternative processes to produce the product and then chooses and design a suitable process having analysed and compared the available processes subject to a number of constraints, including economic, environmental, safety, availability, and so on. A commonly quoted example is the production of the vinyl chlorine monomer (VCM), the precursor to the poly vinyl chloride (PVC) polymer. Here, as part of the design exercise, students may be required to investigate two options; one with an ethylene raw material, the other using acetylene. As part of this, a number of novel unit operations may be considered which lead to a reduction in volatile organic compound (VOC) emissions in one process compared with the other. The system can then be extended to incorporate raw materials and PVC production and a lifecycle analysis can be undertaken. While these are interesting and in many ways innovative approaches,

they driv eng

challenged to compare one unsustainable system with another less unsustainable system. A more appropriate question from a standpoint whereby sustainability is context might not be simply: "What is the best way to produce vinyl chloride?" but instead: "Design a process to produce a material with the properties of PVC." This turns the design question on its head and opens up many potentially innovative possibilities while empowering the students' learning. It provokes follow-on questions among the design team, such as: "Are there materials, and corresponding processes, other than MVC/PVC that can take their place, that are sustainable, or at least, less unsustainable?" Could for example, lactic acid, and the resultant biodegradable plastic polymeric lactic acid (PLA) take the place of PVC for many applications? Or "In general, how feasible is it to produce plastics from renewable materials as opposed to oil?" "What are the technical and economic barriers preventing for example, the production of biodegradable polymeric materials to met the required specifications?"



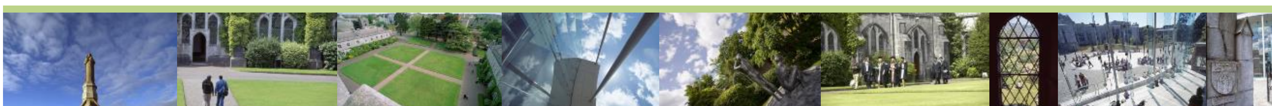
Moreover,

- In siting and designing the plant, might students consider broader issues such as low carbon/healthy **transportation** options: safe/easy walking and cycling access and/or frequent and efficient public transport routes.

Consider aspects such as:

- local **community** involvement?
- family friendly **working** shifts and practices?
- on-site natural **amenities** (wetlands, groves, walkways, etc.) ?
- on-site **renewable energy** production?

Also, what are possible economic, policy or socio-technical barriers to such initiatives?



Engineering Sustainability

Educating engineers to embrace complexity and context
Byrne and Mullally

ice | proceedings

Proceedings of the Institution of Civil Engineers

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Paper 1400005
Received 10/02/2014 Accepted 24/07/2014
Keywords: education & training/social impact/sustainability

ice Institution of Civil Engineers publishing

Educating engineers to embrace complexity and context

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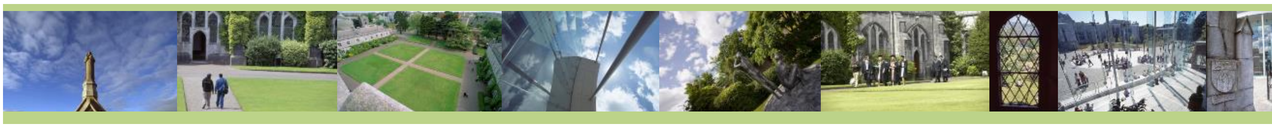
Senior Lecturer, School of Engineering, University College Cork, Ireland

Gerard Mullally MA, PhD
Lecturer, Department of Sociology, University College Cork, Ireland

"The approach taken in Cork has demonstrated that it is possible to sensitise young engineers to the dimensions of modern day challenges that lie beyond the technical realm. In my view at least, Cork's students are being prepared for a world that is ***increasingly connected*** *and* ***increasingly collaborative****; for a* ***fulfilling*** *and* ***successful public*** *and* ***private life****."*

Chris Whitehead*, Editorial, *ICE Proceedings- Engineering Sustainability,* Nov 2014.
*Group Head of Sustainability and Innovation at Balfour Beatty



Educating Chemical Engineers for Contemporary Challenges:

The value of Context, Connection and Collaboration

Edmond Byrne
Head & Professor of Process & Chemical Engineering
University College Cork, Ireland

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh