Addressing Climate Change Through Resource Efficiency

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Contents

Background

A bit of background…

- We talk about saving the planet
- But the planet is fine, **the problem is us**
- We are the one’s that need saving
- We are a **small part of a larger system** 4.5 billion years in the making

We need to change to work with the system or accept the consequences

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“Sustainable development is development that **meets the needs of the present without compromising the ability of future generations to meet their own needs** […] In essence sustainable development is **a process of change in which exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony** and enhance current and future potential to meet human needs and aspirations.”

WCED, Brundtland Commission, 1987

Technologists and engineers have much to contribute

The principles of sustainability

Create a balance between:

- **Economic Factors**
  Creating wealth to do things and continue to do them
- **Environmental and Natural Resource Factors**
  The impact on the resources we have available
- **Societal Factors**
  That we have healthy, happy, full lives

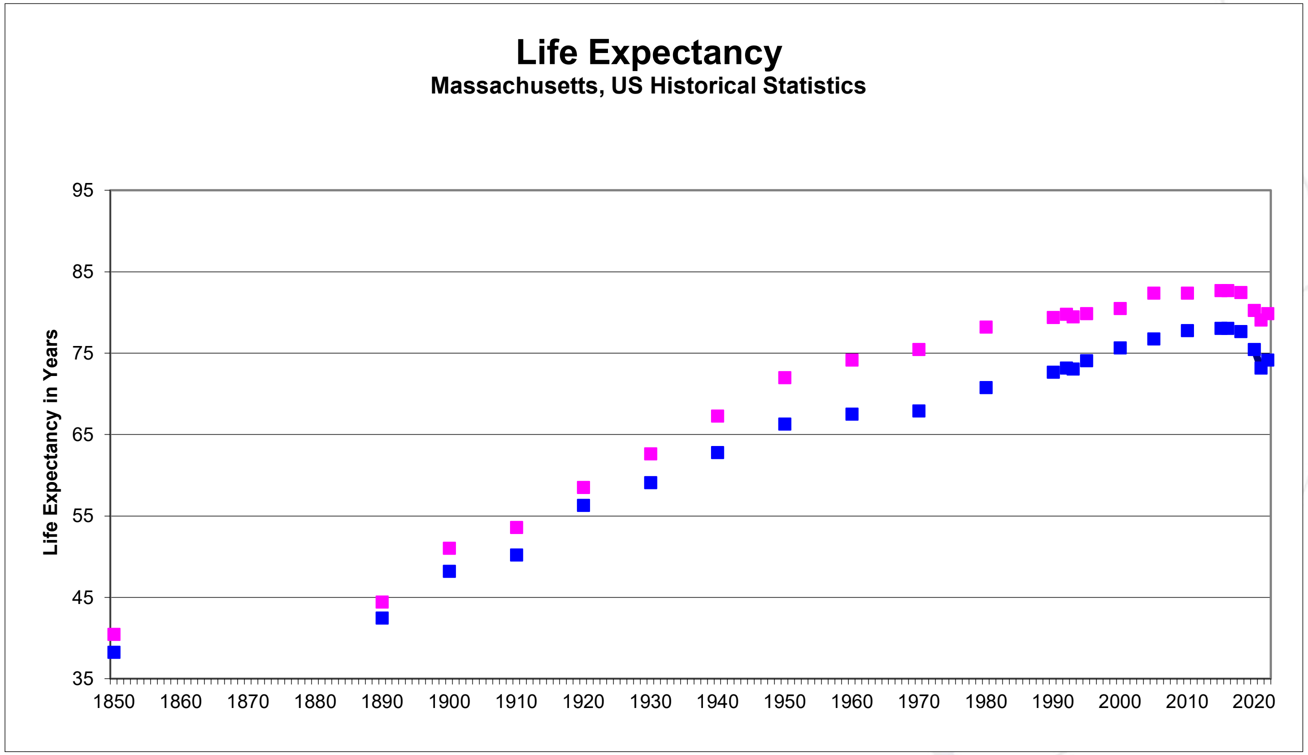
These three factors are equally important

Where we are and what we are facing

Life expectancy: Massachusetts historical data

In 150 years:

- It has **doubled** in the developed world
- Females live longer than males
- The developing world is **following close** behind
- Life expectancy in the USA fell 2.2 years in 2020

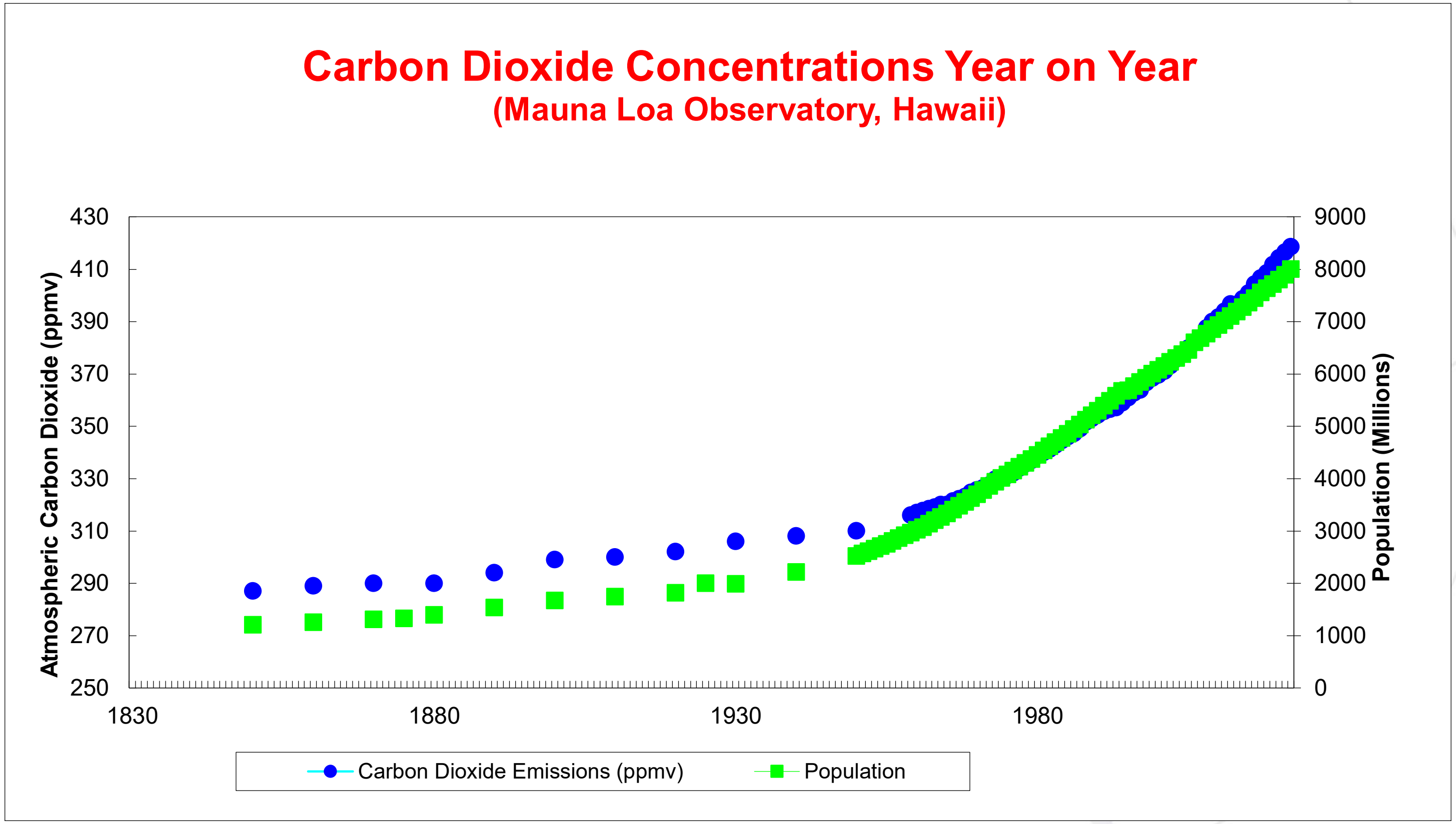


Source: *Massachusetts, US historic statistics*

CO_2 in the atmosphere

CO_2 in the atmosphere is rising rapidly

It is strongly linked to **population**



Source: *Mauna Loa Observatory plus historic data from ice cores*

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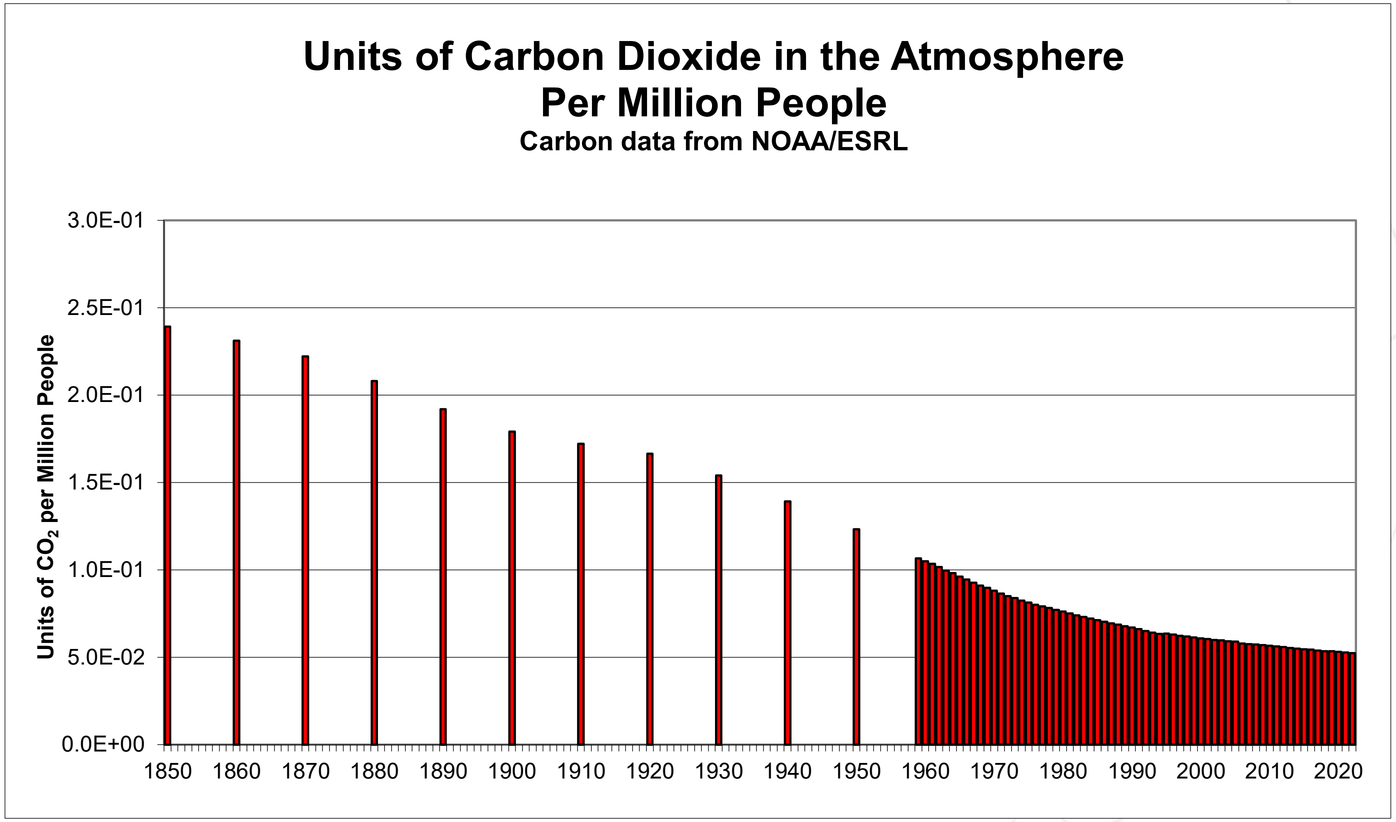
CO_2 in the atmosphere

CO_2 concentration per million people in the atmosphere is **falling**



Source: Mauna Loa Observatory plus historic data from ice cores

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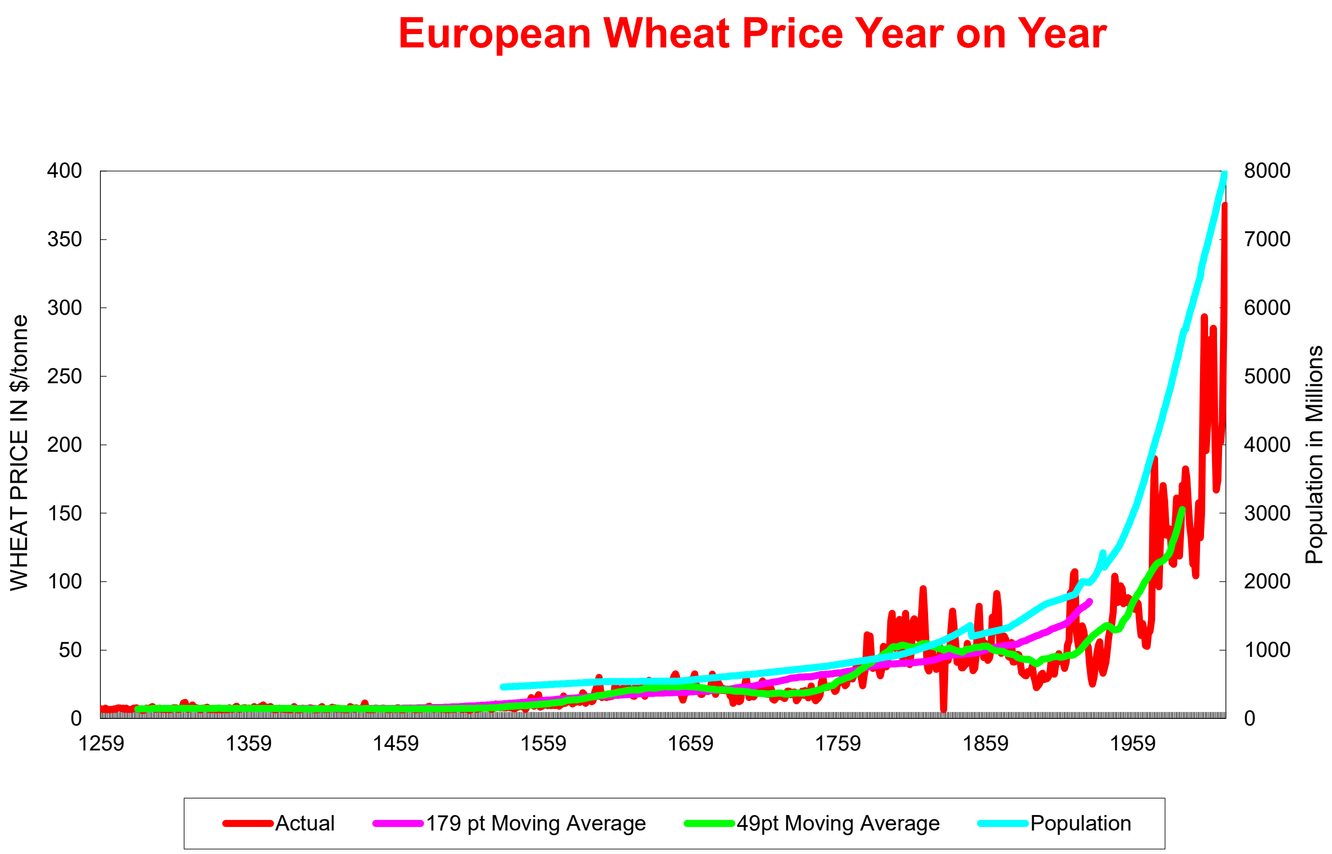
Food prices are rising

Wheat price in $/tonne is **rising**

It appears to be linked to rising population

It is affected by the weather

There are cycles that have an impact



Source: Historical Cycles plus United Nations and recent data series

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It is often a lack of efficiency that lets us down

- For example:
  - The UK **loses 55% of the fuel** it uses for electricity generation in conversion, transmission and distribution loses
  - A considerable amount of these **losses are heat**
  - Using gas to generate heat can be up to **90% efficient**
  - Electricity production does not average much above **34% efficient**
  - Electricity is often **turned back into heat**
  - Incentives can drive inefficiency by **rewarding the wrong behaviour**

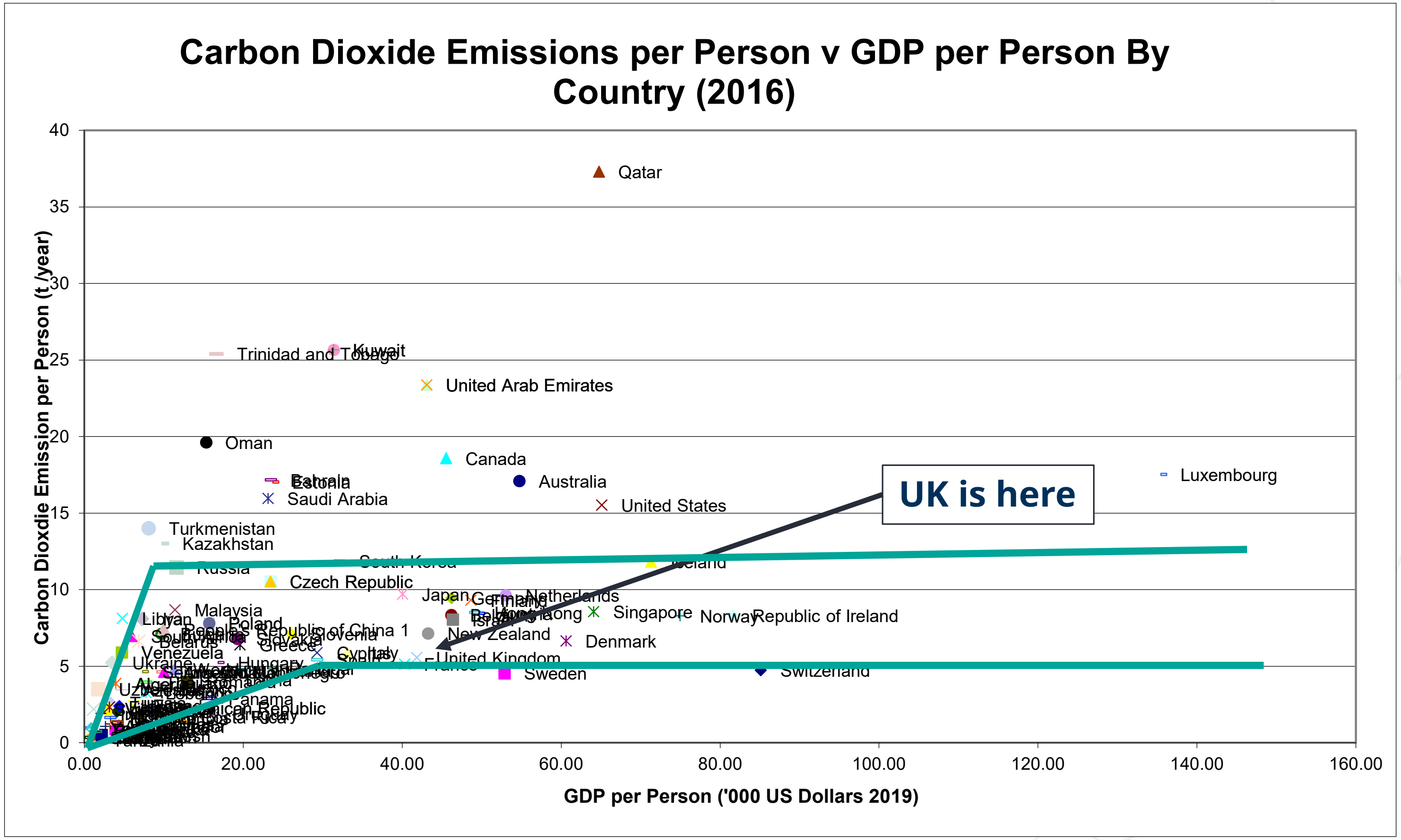
Improving efficiency in general is a significant technical and political opportunity to reduce carbon emissions

CO_2 emissions by country

CO_2 emissions **rise** with GDP…

But there seems to be a levelling out at **5 t/person/yr - 11 t/person/yr** above a GDP/person of about $20k/person (2019)

There are a lot of special cases



How population growth and affluence are affecting CO_2 emissions

Case	Population (billion)	Average CO_2 emissions per person (t/yr)	Total annual human CO_2 emissions (bn t / yr)	Increase over 2018 base case (bn t/yr)
Base Case 2021 Population	7.9	4.7	37	-
Rich World 2021 Population	7.9	7.5	59	22 (59%)
Base Case 2050 Population	9.7	4.7	45.5	8.5 (23%)
Rich World 2050 Population	9.7	7.5	73	36 (97%)

Dealing with this much carbon dioxide is a challenge
Catching it is not a viable option
Long Term Trend is Improving as Emissions per Person are Reducing and Population Forecast is Falling

Based on UN, EDGAR and IEA Figures

Selected Changes in CO_2/capita and GDP/capita by Country 2007 to 2021

Country	2007 CO_2/Person (t)	2007 GDP/Person ('000 $)	2021 CO_2/Person (t)	2021 GDP/Person (' 000 $)	2021 Population (Millions)
USA	**19.5**	41.2	**14.24**	69.2	337
Germany	**9.88**	35.3	**8.06**	51.1	83.4
China	**5.6**	**2.7**	**8.73**	**12.4**	**1426**
Italy	**7.4**	31.2	**5.41**	35.6	69.2
UK	**9**	**38.1**	**4.95**	**46.5**	**67.3**
France	**5.9**	34.6	**4.58**	44.2	64.5
India	**1**	1.1	**1.9**	2.3	1408
EU	**7.44**	28.1	**6.25**	38.5	447
World	**3.7**	6.7	**4.8**	12.2	7890

Patterns are Changing, but Not Consistently

Based on UN, EDGAR and IEA Figures

The challenge of sustainability

Growing Population

- Inexorably increasing the need for food and shelter
- Doubled life expectancy since 1850
- 8bn now 9.7bn in 2050

Growing Affluence

- The amount of emissions rise with affluence

Resource Consumption

- There is only a finite resource it will not last for ever
- More affluence equals more waste
- Carbon dioxide in the atmosphere rises in proportion to population

This puts immense stress on a finite system

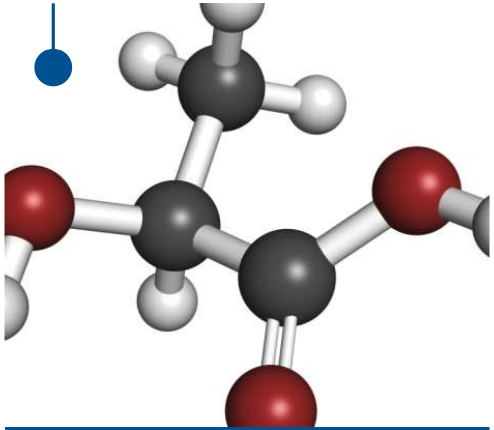
What could we do?

Resource demand in a simple equation

CO_2 emissions & wastes = Number of People × Affluence × Efficiency with which an individual uses resources × Efficiency with which industry uses resources

We need to become more efficient in our use of resources

What the world needs from industry



Low carbon products with increased functionality

Processes that use less water and recycle more fresh water

Processes that use fewer virgin resources and recycle more

Zero carbon, energy self-sufficient manufacturing

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What the world needs from industry

Pollute less | **Consume less** | **Deliver more**

What the industry needs from the wider community

Demand and adopt environmentally better performing products

Appetite for financing in a high-risk environment

Proven complimentary technologies across the supply chain

Approaches to low carbon sustainable manufacturing

Drop in

Replace fossil material with the same molecule manufactured through a more sustainable route.

New Processes

Replace the original material with a different material from a more sustainable route.

New Product

Create a new product/formulation/system that completely replaces the original route and delivers an enhanced effect.

Akzo Nobel 2017

New technology is only a partial answer

Hydrogen

- Making storing and distributing it is a challenge.
- Producing hydrogen requires as much energy as it yields in use so the energy requirement for a hydrogen economy is double that for a fossil one
- Each tonne of hydrogen produced from natural gas produces c.9.3 tonnes of CO_2

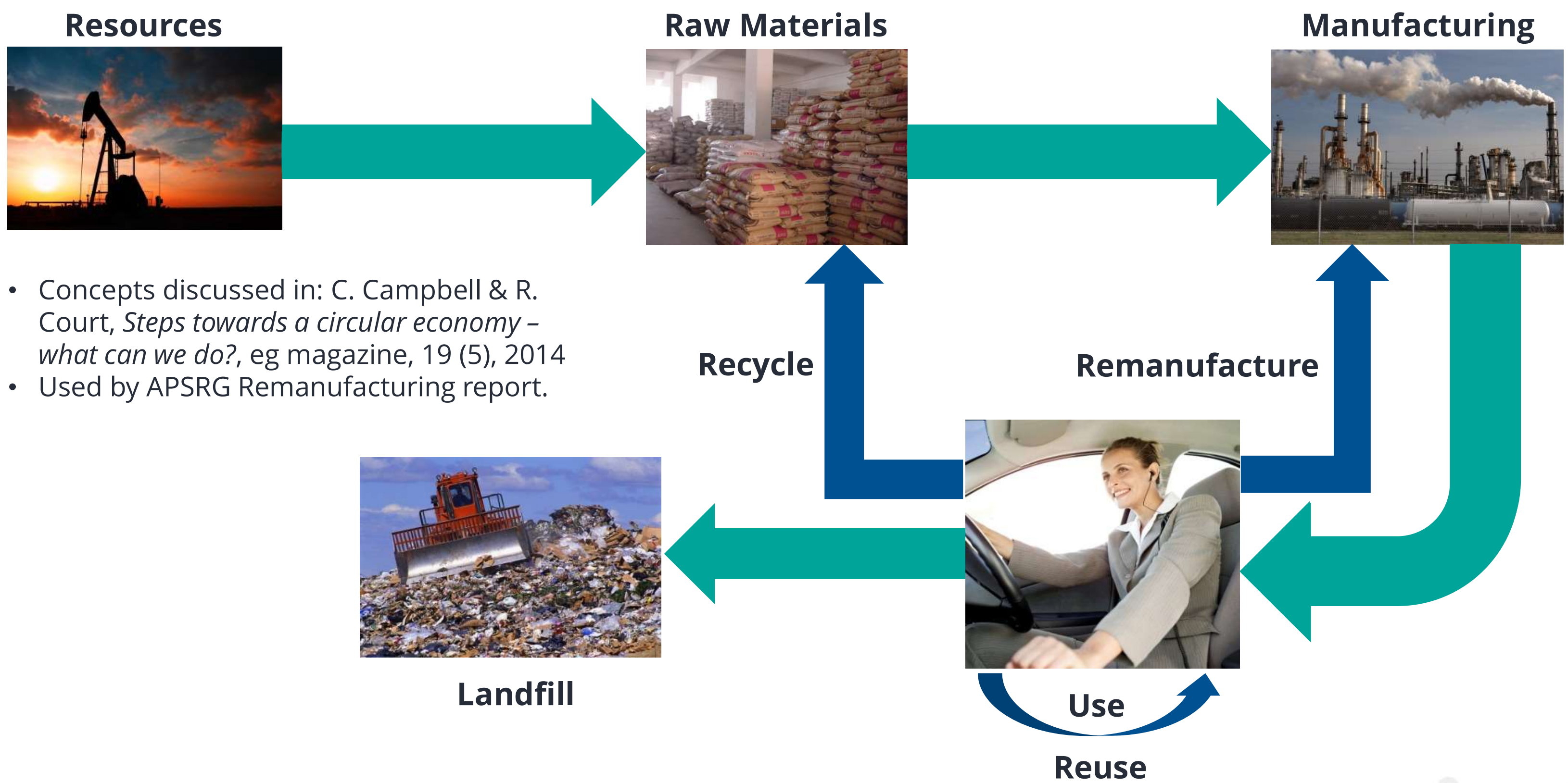
Electric Vehicles

- There are 31.7 million cars in the UK and the average driver travels 7000 miles/year
- My plug in hybrid used 10kWh for every 25 miles it travelled
- If all UK cars were electric that would require 88TWh of electricity
- UK generating capacity produced 330TWh of electricity in 2020
- This would need 21GW of additional generating capacity just for cars.

We need to become more efficient in our use of resources

Forbes, personal data, DVLA, UK Gov Energy Stats

Resource efficient systems



- Concepts discussed in: C. Campbell & R. Court, *Steps towards a circular economy – what can we do?*, eg magazine, 19 (5), 2014
- Used by APSRG Remanufacturing report.

Quite a challenge for our economic system which is driven by consumption and growth

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Becoming more resource efficient

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Ashden Rwandan prison anaerobic digestion example

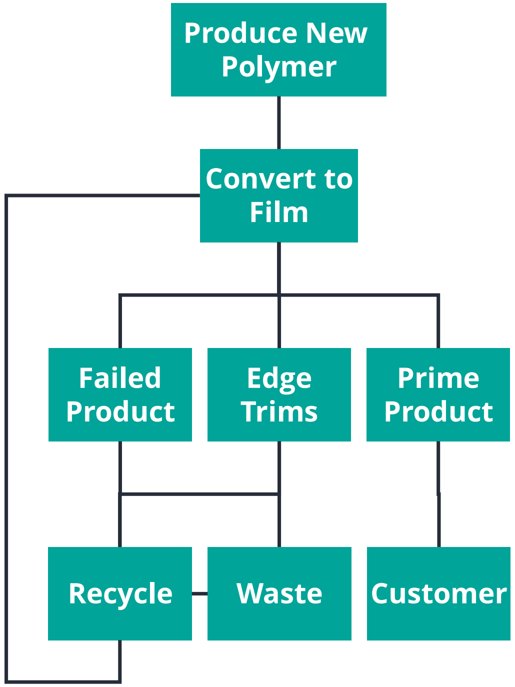
- Influx of people to a resource poor community,
- Burn all the firewood, generates untreated sewage,
- Prisoners built anaerobic digestion plant in the gardens
  - Excludes air from pit of sewage and natural bacteria producing methane
- No need to denude firewood
- No sewage problem
- By-product is digestate for use as a fertilizer

The Ashden Awards for sustainable energy

True sustainable intervention: eliminates 2 problems, create solutions and educate people to use their skills to repeat the benefit. Close loops: use wastes as resource

Source: *Ashden Awards, AD Section*

Plastic film production



100t polymer feed		40% Prime			60% Prime		
Stage	**Value, £/t**	**% Pass**	**Tonnes**	**Value, £**	**% Pass**	**Tonnes**	**Value, £**
New polymer	(20)		46	(920)		64	(1280)
Prime product	100	40	40	4000	60	60	6000
Edge trim	(10)	10	10	(100)	10	10	(100)
Failed product		50	50		30	30	
Recycle	(10)	90	54	(540)	90	36	(360)
Waste	5	10	6	30	10	4	20
Total value				**2470**			**4280**

20% operational improvement gives 75% value increase

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Baffle reactor example

Batch to continuous

- Lower inventory
- Make what you need
- Plug flow is so easy to clean
- Highly efficient mixing
- Capital down up to 50%
- Operating cost reduced by up to 90%

Lower capital and operating cost
Less resource use and less waste

A Systems approach

In whole systems, materials, manufacturing and use are **integrated**

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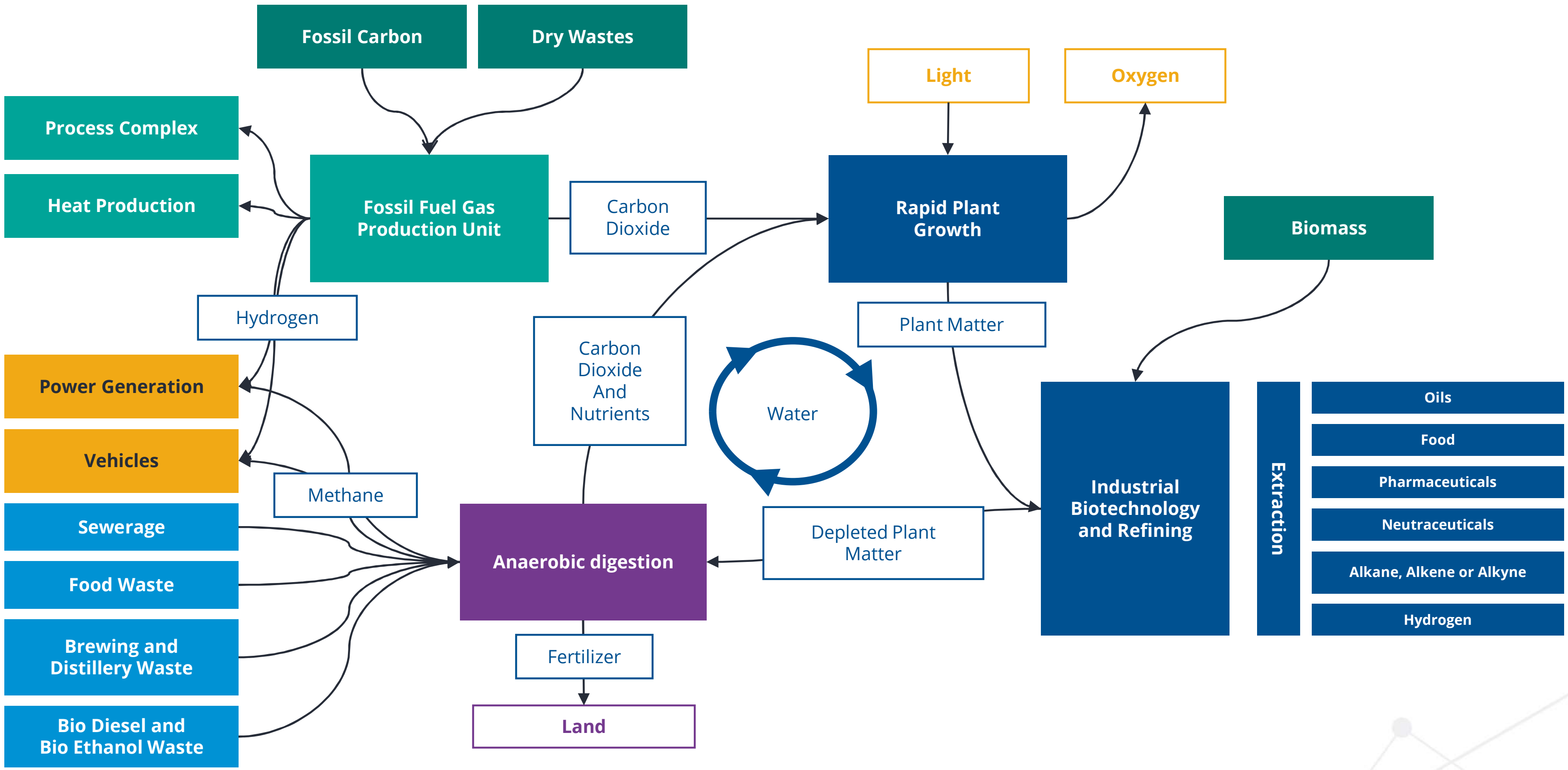
Case Study of a Bio-renewable Innovation Challenge



Based on: *Entering the Ecological Age: The Engineer's Role. Work done jointly by CPI and Arup*

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What could we do?

Create 'low carbon resource efficient communities' based on an integrated set of projects

that

combine industrial, residential, agricultural and transport applications

to

exploit the inherent strengths of communities and regions

and

Deliver economic well being

To do this we need to:

- Facilitate links between research, development and commercial interests to create value through application development.
- Create a range of supply partnerships appropriate to end users to increase adoption.
- Build supply chain networks that develop the UK industry base.

Final thoughts

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The best response

- More recycling?
- Longer time in-use?
- More re-use?
- More remanufacturing?
- Near net shape manufacturing?

There is no single correct answer

It is a combination of things
Depends on common sense, economics, social environment and manufacturing process

Principles for next generation processes

- It's **impossible to fully decarbonise** as life and many products are based on carbon
- It is possible to **improve the efficiency** and **improve the use** of products to reduce carbon consumption
- There is a significant opportunity in using or reusing **naturally derived or waste feedstocks**
- **Growing plants** consumes CO_2
- There are **chemical processes** that can consume CO_2
- CO_2 is very stable, so process developers need to be **very creative** to create economically viable processes

Making chemicals and materials in a lower carbon economy is challenging

Big challenges to adopting sustainable principles

Global drivers and trends favour a resource efficiency approach, but we must:

- Look at engineering problems differently
- Make sure policy makers, business leaders and engineers understand change is needed and is possible
- Aspire to deliver the benefits
- Work collaboratively across technical and social disciplinary boundaries
- Create a favourable legislative and regulatory environment
- Take account of the value of finite resources in our economics
- Make attractive, reliable and useable products and demonstrate there are benefits

There is a large opportunity for economic, social and environmental benefit

We need to change our behaviour and do something

Future Challenges

- Develop more sustainable processes – **Lower Impact**
- Use resources more efficiently – **Don't Throw Stuff Away**
- Improve the efficiency of our processes – **Don't waste resources**
- Look at the efficiency of integrated systems – **Think about how processes link together**
- Convert wastes to products – **Reduce use of new raw materials**
- Convert batch processes to continuous ones – **Where it is more efficient**
- Create more flexible processes – **Means smaller plants are effective**
- Make better use of bio systems and mimic natural processes – **Evolution can tell us a lot**

Closed loop systems

Efficient process steps

End to end process knowledge

Link raw materials to the product, to use, and to end of life

Conclusions

- Design things that use little energy
- Make or build them as efficiently as possible, preferably with reuse in mind
- Think about resource flows before you design
- Think about resource flows through communities and systems
- Think how wastes can be eliminated or used as fuels or feedstocks
- Drive collaborative interdisciplinary working
- Take action!

Reduce, Reuse, Recycle, Relate

4 Industrial Revolutions Changed the World Forever, the Next Must Make Sure it Lasts that Long

Thank you

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