



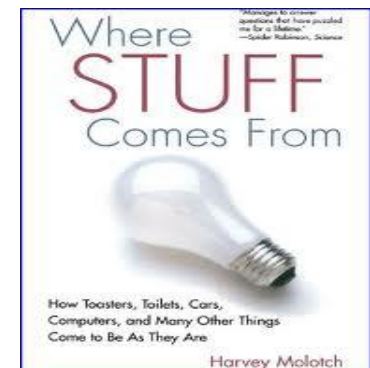
Sustainability : An uncomfortable uncertainty

Chemistry at the heart of a global crisis....and central to solutions.

Professor Roy Sandbach OBE FRSC
4 Border Abbeys U3A
October 30th 2025

Today, a journey through the sustainability landscape....

- A big picture reminder.....
- What's needed...closer to home
- Opportunities & optimism



The Big Picture

UN sustainable development goals are defined in terms of.....

Economic growth

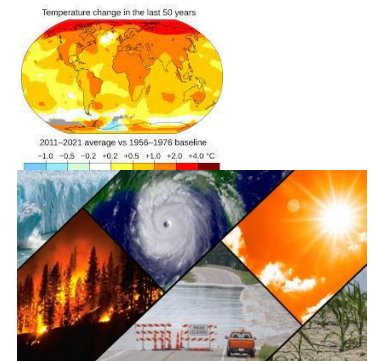
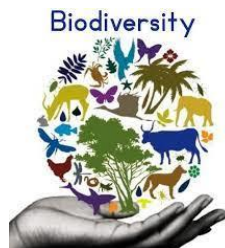
Social inclusion

Environmental protection

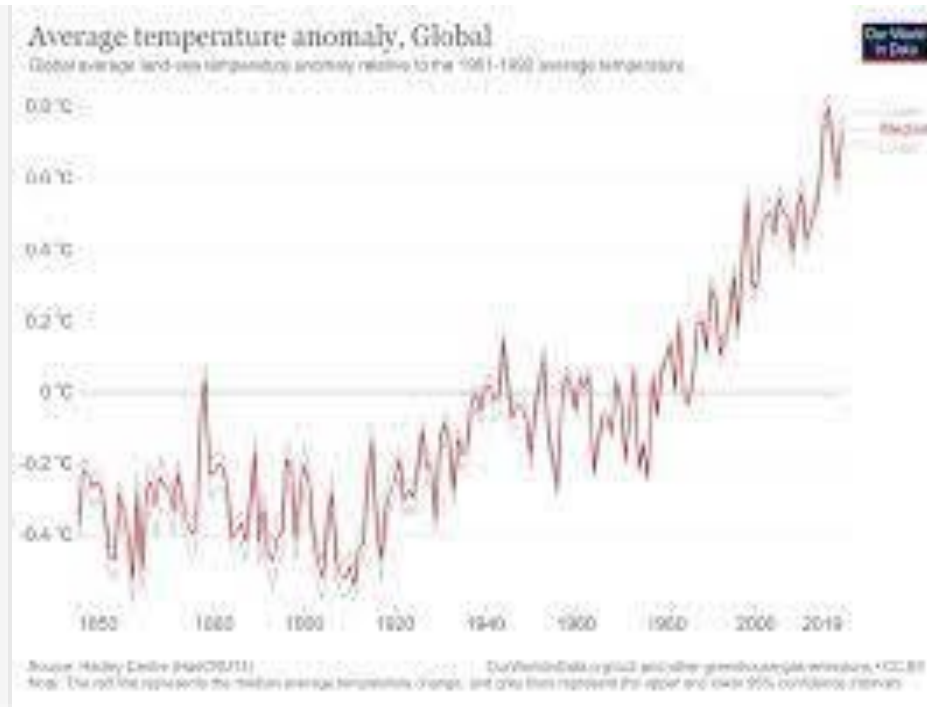
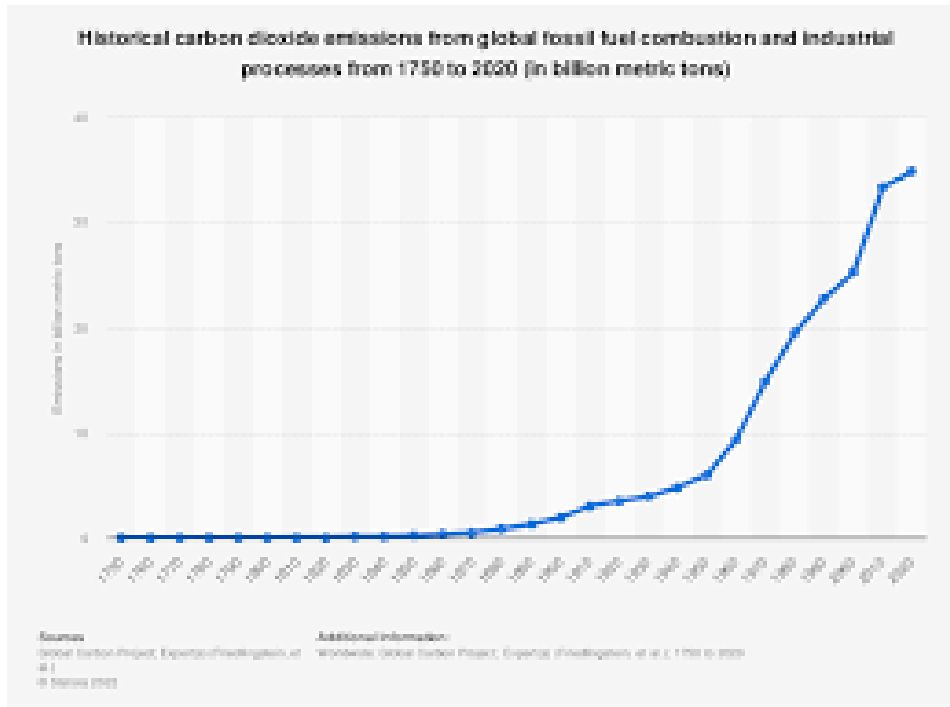


Climate change, effect management & Net Zero

Biodiversity support



It's easy to be very concerned

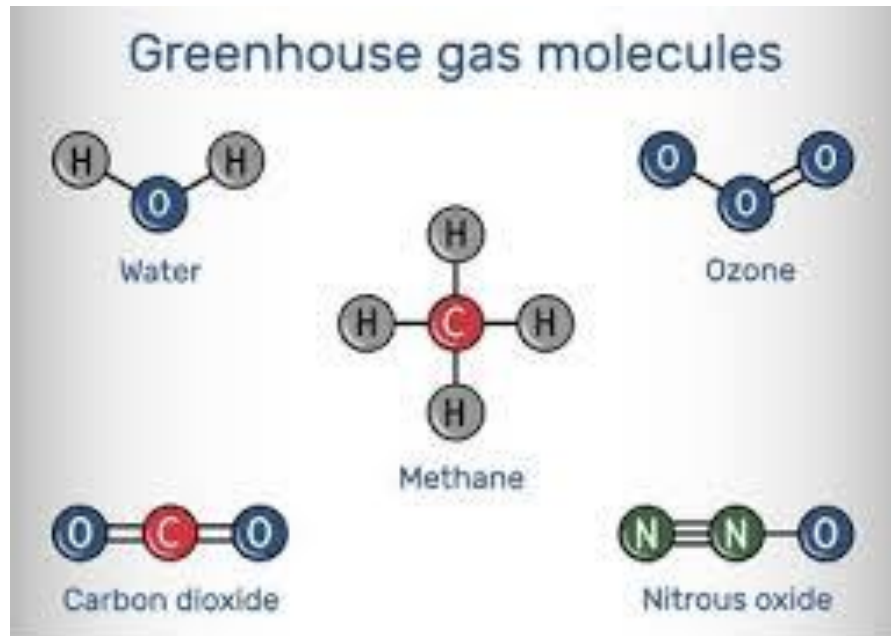


“The greenhouse effect has been detected and is changing our climate”

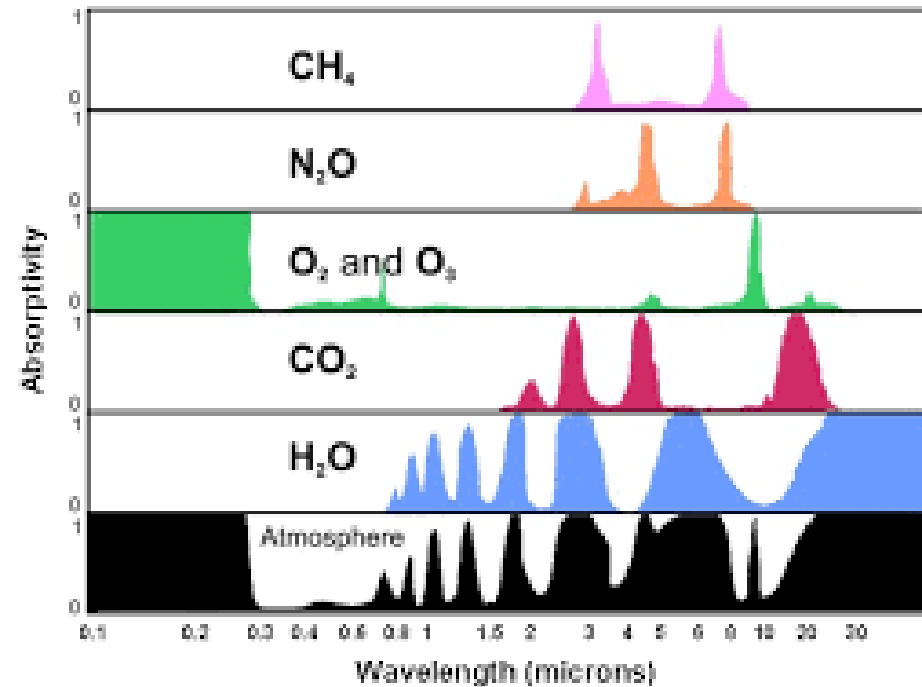
James Henson (NASA, 1988)

What is the science of the greenhouse effect ?

It's all about vibration !



shutterstock.com - 2069415935



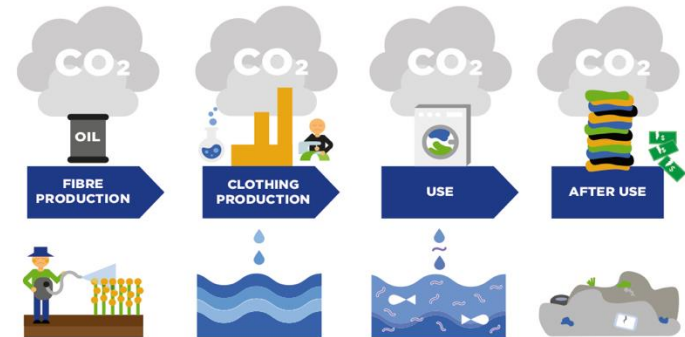
Why we are at the heart of all this.....

Fashion....

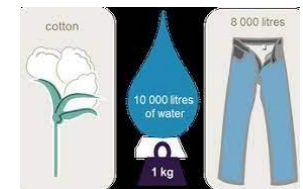


- By 2030, global apparel consumption up by 63% & will use 35% more land for fibre production

- The industry produces 8-10% of global CO₂ emissions !



- Responsible for ~20% of industrial water pollution...



- ~35% (190,000 tonnes per year) of oceanic primary microplastic pollution & vast textile waste (>92 million tonnes pa),

And another example.....

Aviation.....



- Global passenger numbers will almost double by 2037, reaching 8.2 billion annually.

- Over 37,000 new aircraft
- valued at \$5.8 trillion are required over 20 years.



- Doubling of the world's passenger fleet to more than 48,000 aircraft.

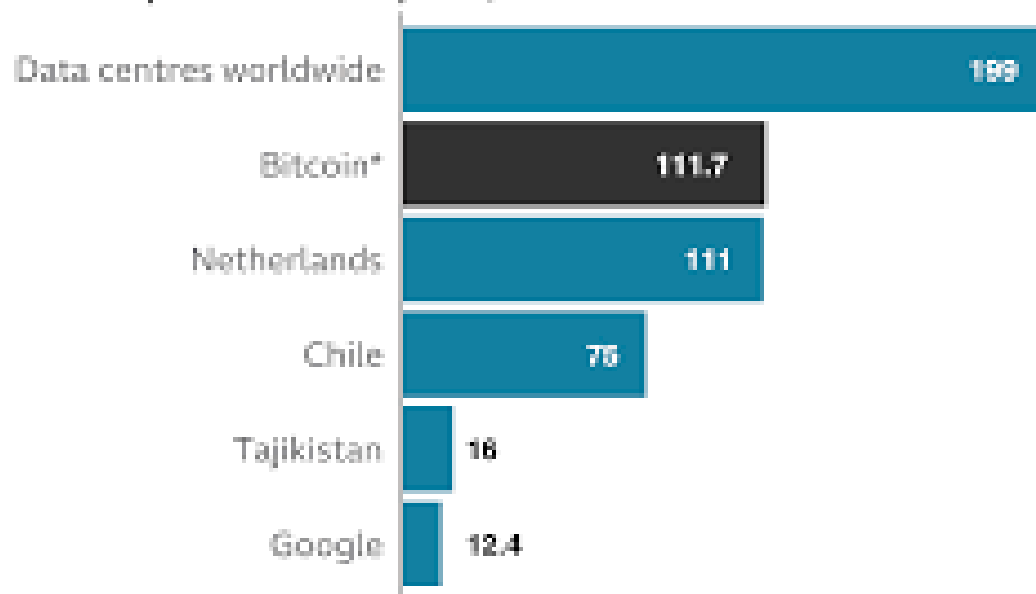
And an example of unregulated growth ?

Cryptocurrency.....

- Global energy consumption is uncontrolled and out of control.....Best guess ? Bitcoin = Netherlands

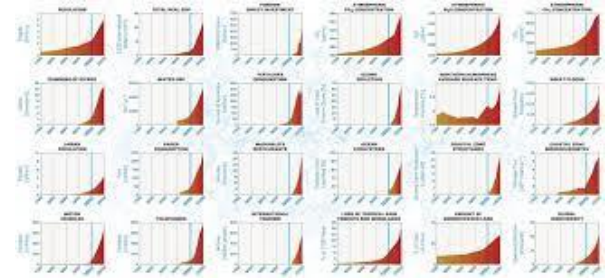
Bitcoin consumes a 'similar amount of power to the Netherlands'

Annual power consumption, in TWh



*All figures 2019 except Bitcoin, which is annualised middle estimate for bitcoin electricity consumption in January 2021

But there is more.....



The “great acceleration”

- **Global Consumption...**
- Where is it going ?
- Over the next 10 years ?

- **Even more unregulated resource usage**
- Is it happening ? How ?



Chemistry, engineering & technology are slap bang at the heart of this !!

Our fast-changing world.....

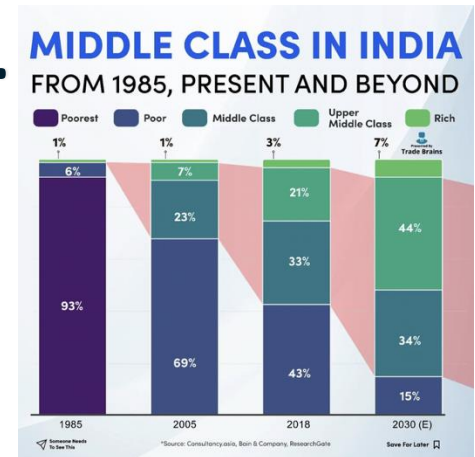
By 2030, the global middle class will reach 4.8 billion people
Over 50% of the global population



They are the “consumer class” ...
Purchasing power ?

\$42 trillion 2020

\$62 trillion 2030

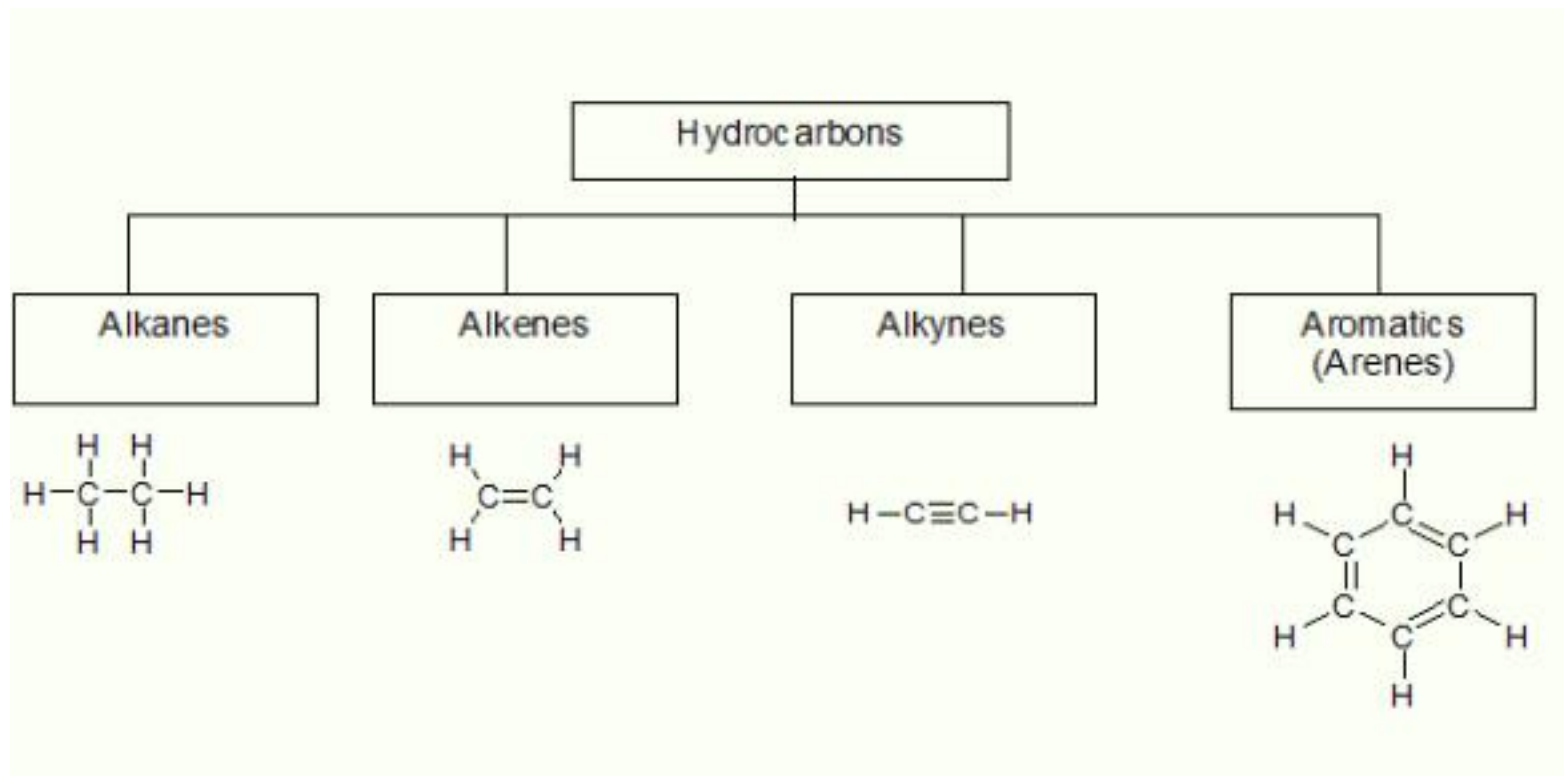


Source: Brookings Institute (2023)

Chemistry is at the heart of consumption



Where do we start.....



The chemistry problem



- Chemicals, including petrochemicals, create 3.6% of global emissions (these are energy-related emissions from the product manufacturing (fertilizers, pharmaceuticals etc.)
- Another 5.2% greenhouse gases produced as a by-product from fossil fuel derived chemical processes (ammonia etc....)...and in production of cement (at 3%).
- There is low reuse/recycling rates & much waste eg.....
70 per cent of nitrogen input in fertiliser is not taken up by crops
Only ~10% of plastic ever created has been recycled.
- And consumption grows.....

Cleaning the world.....

Global Anionic Surfactants Market



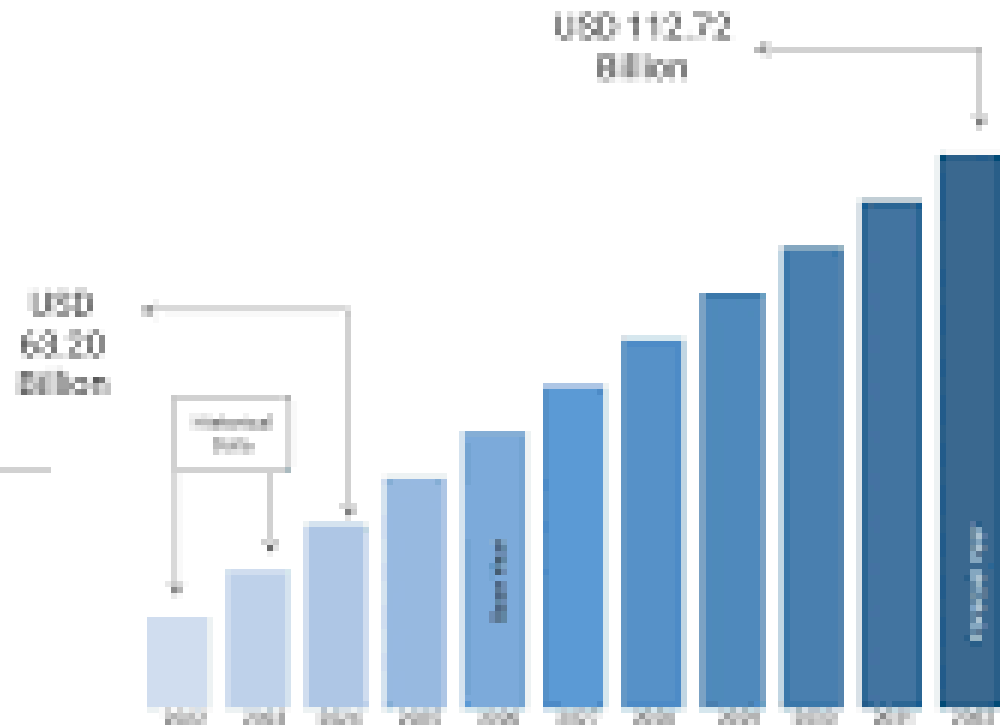
The world's future depends on what you wear.....

Global Recycled Polyester Filament Yarn Market Market Size Overview



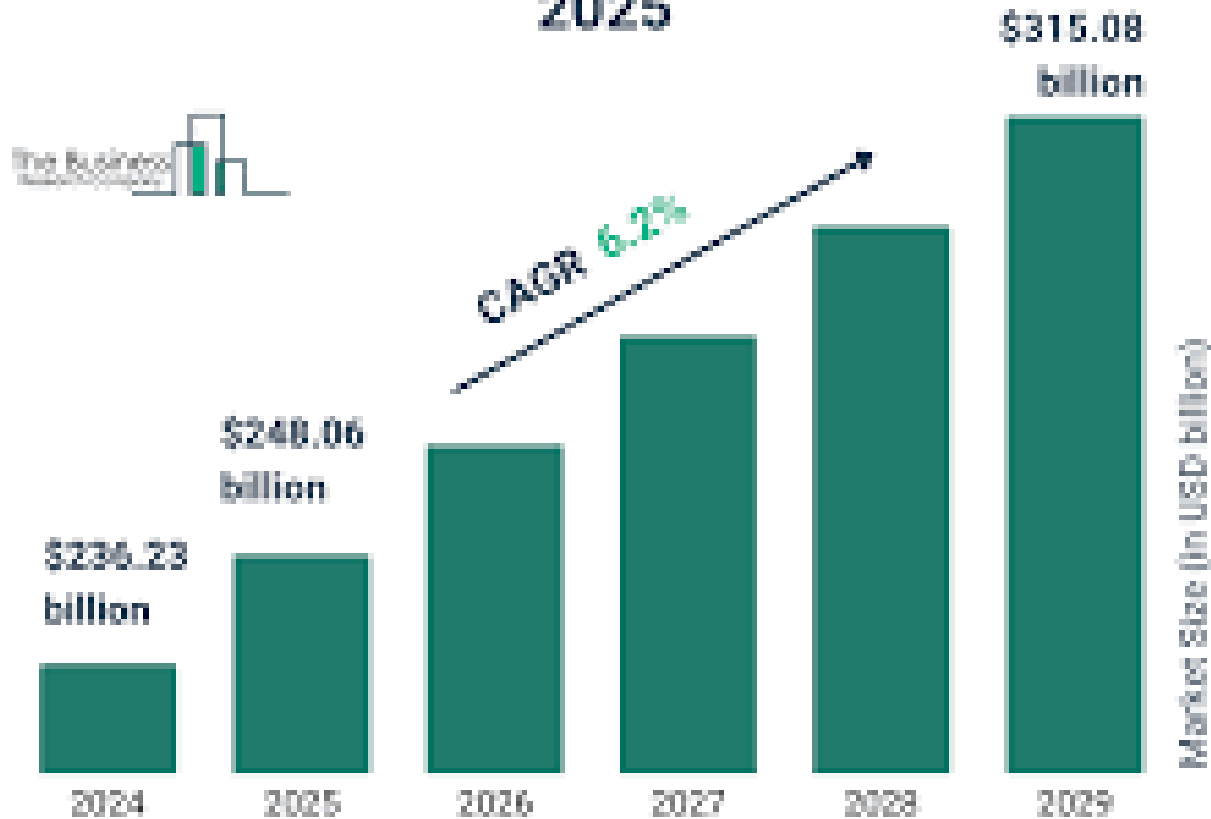
7.5%

Global market CAGR,
2024 - 2032



Shall we paint the kitchen ?

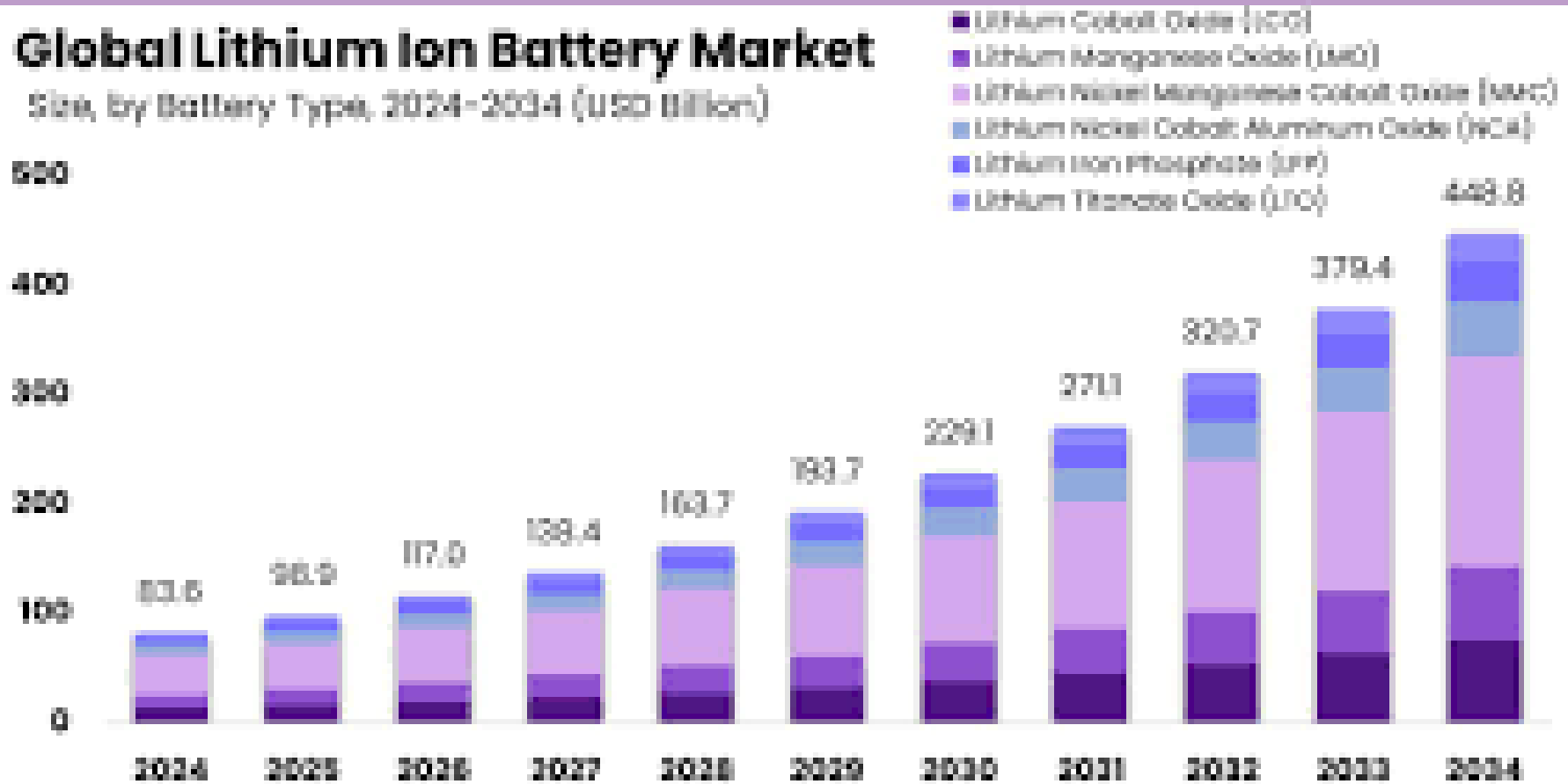
Paints And Coatings Global Market Report 2025



Or buy an electric car ?

Global Lithium Ion Battery Market

Size, by Battery Type, 2024-2034 (USD Billion)



The Market will Grow
At the CAGR of:

18.3%

The Forecasted Market
Size for 2034 in USD:

\$448.8 B

 market.us

The clue is in the name....."rare earths"

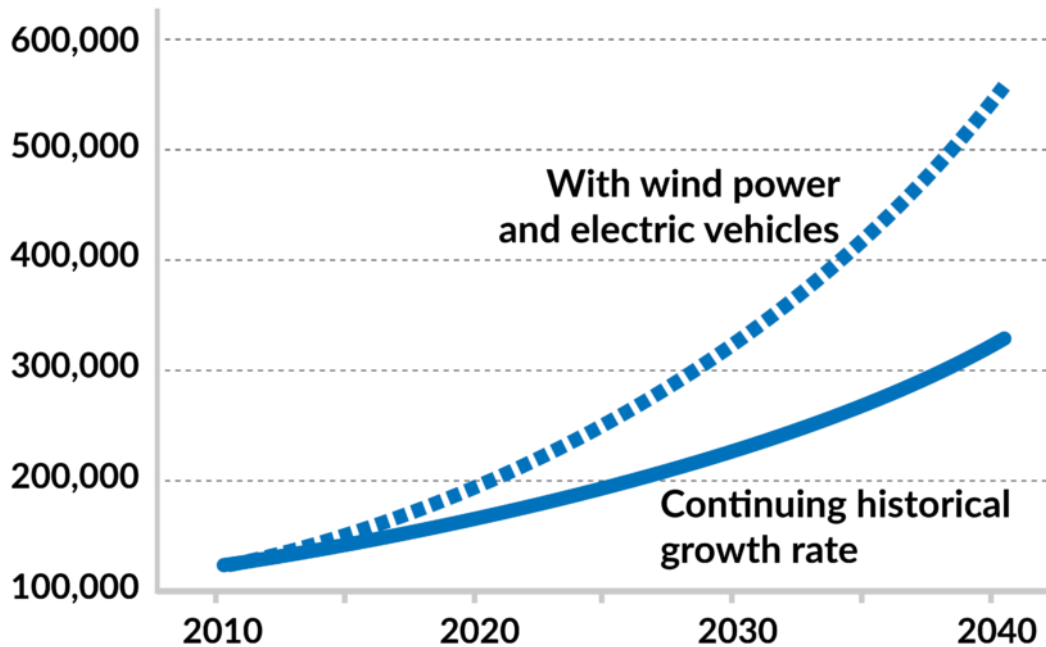
Rare earth elements

- Light
- Sc** Scandium
- La** Lanthanum
- Ce** Cérium
- Pr** Praseodymium
- Nd** Neodymium
- Pm** Promethium

- Medium
- Sm** Samarium
- Eu** Europium
- Gd** Gadolinium

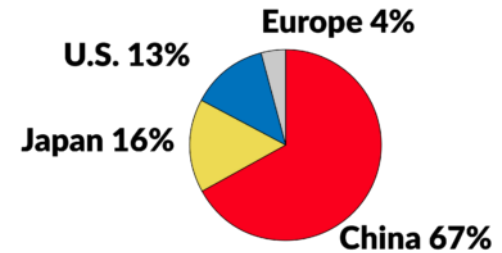
- Heavy
- Tb** Terbium
- Dy** Dysprosium
- Ho** Holmium
- Er** Erbium
- Tm** Thulium
- Yb** Ytterbium
- Lu** Lutetium
- Y** Yttrium

Projections of demand (tons)

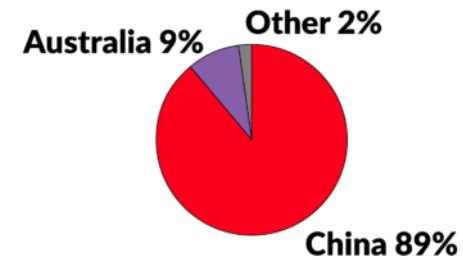


The Paris climate agreement vows to keep global warming below 2 degrees Celsius (or 3.6 Fahrenheit). That will take a lot of electric vehicles and wind turbines, which means much higher demand for rare earths.

Cosumption 2016 155,000 tons



Production 2016 175,000 tons



So, what are chemists doing about this?

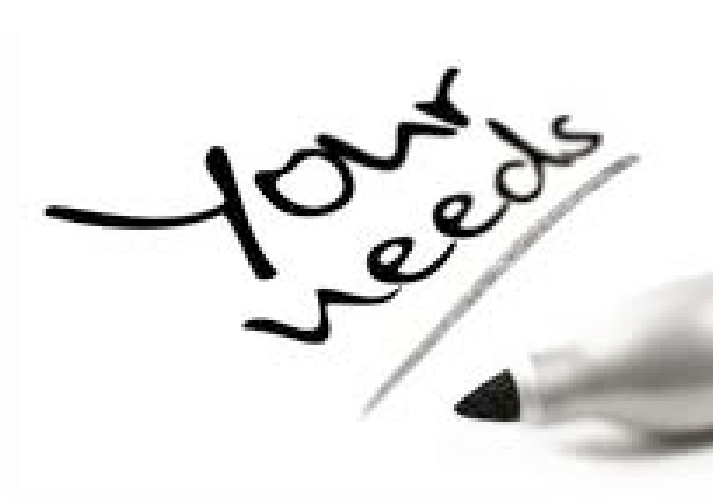
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An innovation definition.....

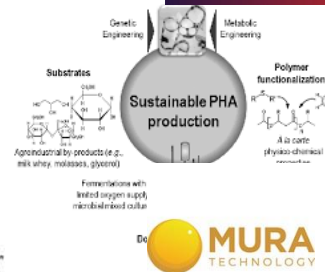
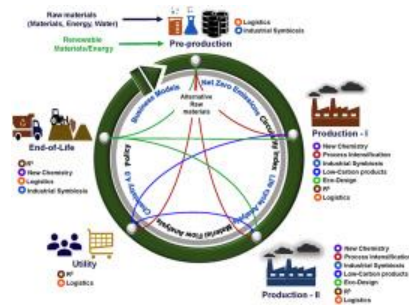
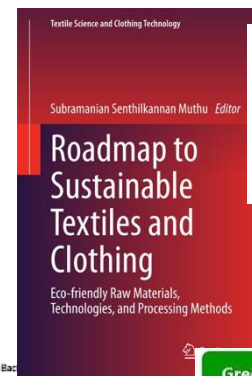
“Matching what’s possible with what’s needed to create economic value or social good..... or both.....”

Without depleting the planet’s resources.....



So, the challenge of “what’s needed” is clear But there are plenty of levers to pull in terms of “what’s possible”

- Technology
- Circularity.....a must.



Green Chemistry Pocket Guide

The 12 Principles of Green Chemistry

Provides a framework for learning about green chemistry and designing or improving materials, products, processes and systems.

1. Prevent waste
2. Atom Economy
3. Less Hazardous Synthesis
4. Design Benign Chemicals
5. Benign Solvents & Auxiliaries
6. Design for Energy Efficiency
7. Use of Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis (vs. Stoichiometric)
10. Design for Degradation
11. Real-Time Analysis for Pollution Prevention
12. Inherently Benign Chemistry for Accident Prevention

www.acs.org/greenchemistry

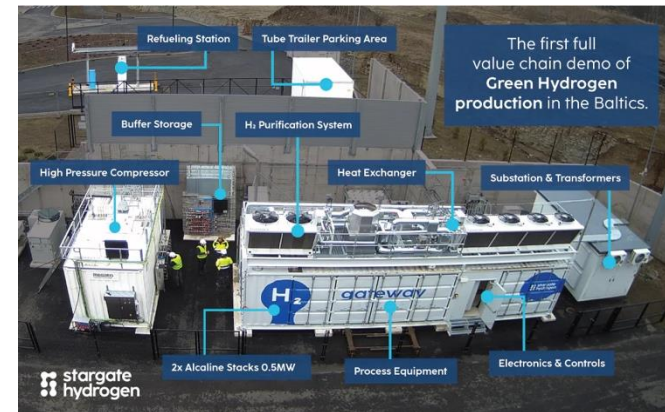
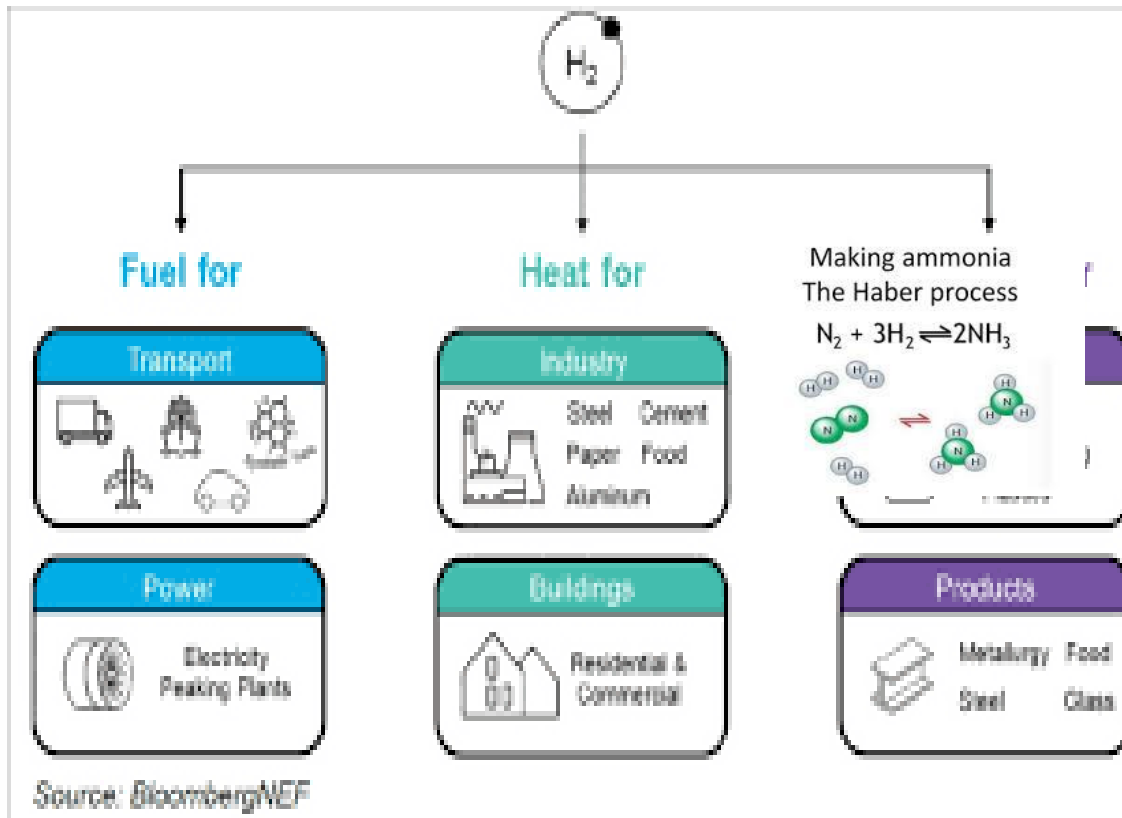
ACS Chemistry for life® ACS Green Chemistry Institute

- Proper systems thinking & partnership for action
- Incentivised investment.

Sustainable Aviation wishes to thank the following organisations for leading the work in producing this Road-Map:

“S&P Global Commodity Insights analysis suggests a \$25 trillion cumulative funding gap between forecast spending and the investment needed to achieve net-zero by 2050.”

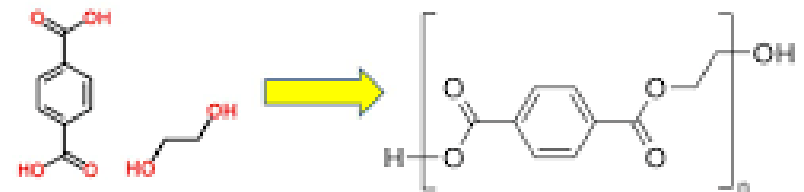
Technology Directions... H2 and NH3



Technology Directions...plastic replacements



Polyethylene terephthalate or PET polymer



Ester polymer

Used widely in food, water bottles
etc.



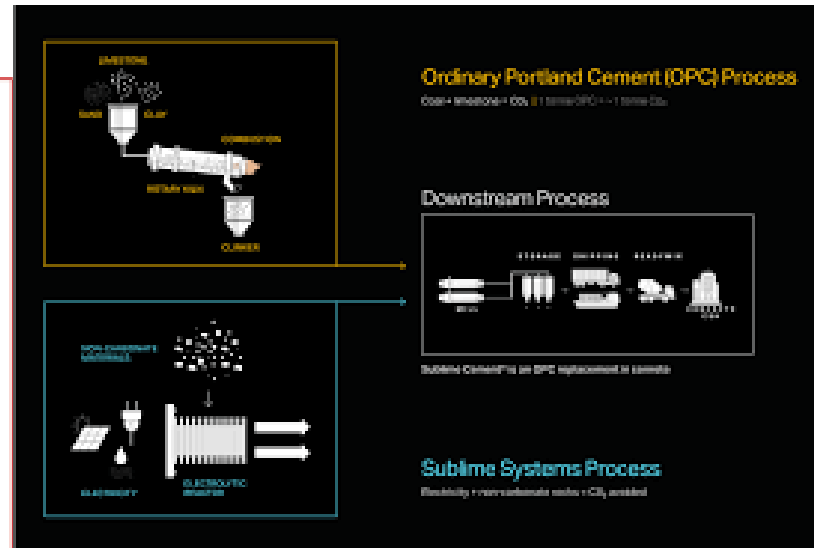
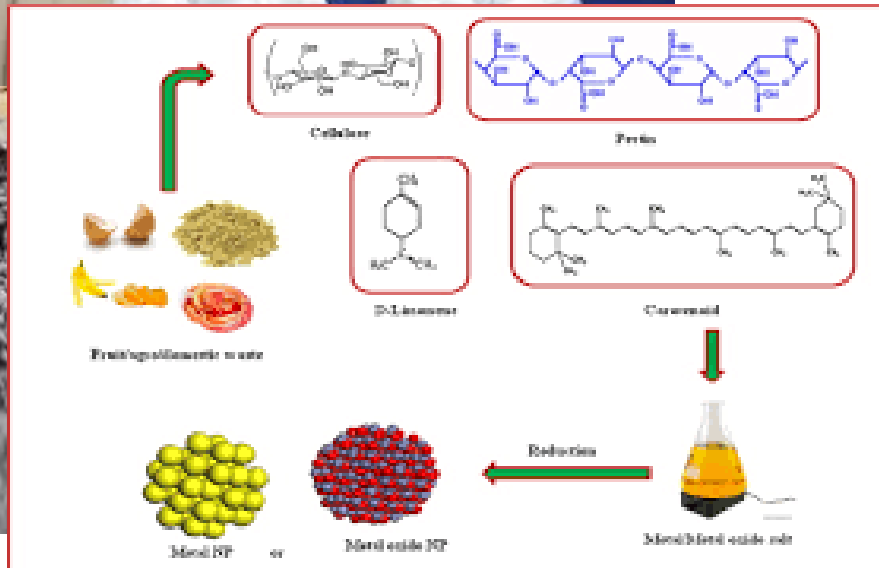
Technology Directions...asphalt/cement low carbon alternatives.....



IMPERIAL

The wonderful world of low-carbon concrete

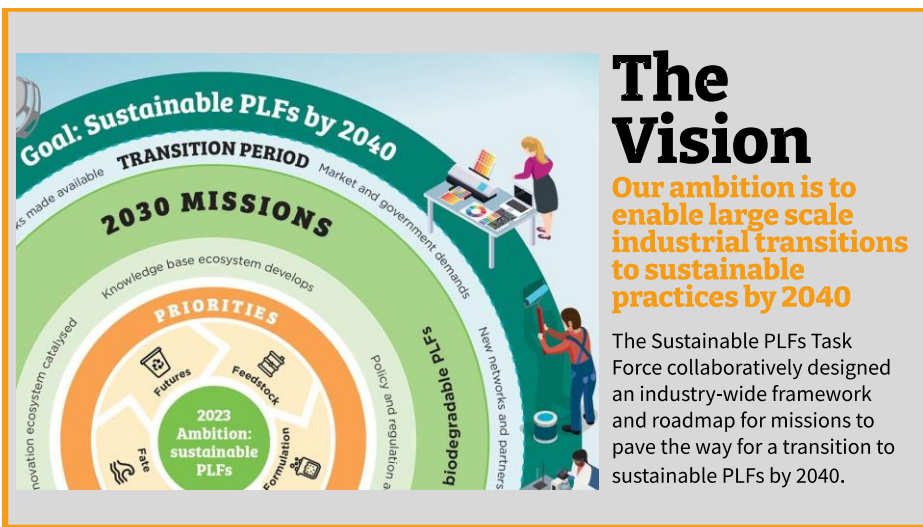
Professor Hong Wong,
Department of Civil and Environmental Engineering



Lessons from the Royal Society of Chemistry industry task force

Our 2040 roadmap for sustainable PLFs

A roadmap for sustainable PLFs



The Vision

Our ambition is to enable large scale industrial transitions to sustainable practices by 2040

The Sustainable PLFs Task Force collaboratively designed an industry-wide framework and roadmap for missions to pave the way for a transition to sustainable PLFs by 2040.

Missions To 2030

Missions are measurable, ambitious and time-bound targets that aim to tackle complex challenges such as climate change, by taking a purpose-oriented, market-shaping approach. A missions framework aims to catalyse a whole collaborative innovation ecosystem. The Task force set the following missions:

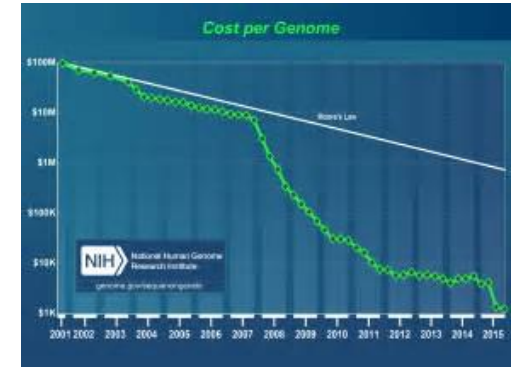
Develop and scale Biodegradable PLFs by 2030
 This mission focuses on enabling the biodegradability of PLFs across industry categories and products.

Advance the Circular Economy Infrastructure for PLFs by 2030
 This mission aims to catalyse circularity for PLFs. Innovation could target formulation efficacy; reduce non-essential usage of polymers; design for durability and end-of-life; and adoption of new business models.



Good news, we nearly always get predictions of the pace of innovative change wrong....

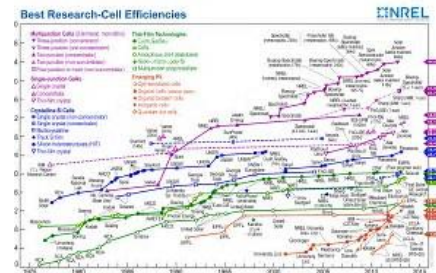
Genome sequencing



ECG hardware (reduced from \$15K to \$1K in five years)

Drones (a \$17 toy drone today uses a gyro costing around \$100K ten years ago)

Solar power efficiency



People and regulatory pressure.....



Finally, finally, it's never easy.....

“It is far better to dare mighty things, to win glorious triumphs, even though checkered by failure... than to be one of those poor spirits who neither enjoy nor suffer much, because they live in a gray twilight that knows not victory nor defeat.”

Theodore Roosevelt (1858-1919)



Thank you !

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