Making things happen
Making things happen
Making things happen: normal engineering practice

- Hotter, faster, smaller
- Cheaper
- Increased welfare
- Supply
- Demand
- Price
- Quantity

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Good things
Off the charts
The richest 1 percent of the world’s population is so much wealthier than the poorest half that the top 1 percent column doesn’t fit on this graph.

GT2: Climate safety

Global discussions and Global emissions

- **1st Report of the IPCC**
- **2nd Report of the IPCC**
- **3rd Report of the IPCC**
- **Kyoto Protocol at COP3**
- **4th report of the IPCC wins Nobel Peace Prize**
- **5th report of the IPCC**
- **IPCC: Intergovernmental Panel on Climate Change**
- **COP: Conference of the parties**
- **United Nations Framework Convention on Climate Change**
- **UK Climate Change Act: 80% reduction by 2050**
- **UK: 100% reduction by 2050**
- **Paris Agreement at COP21**
- **4th report of the IPCC**

Gt CO$_2$/yr

We don’t mind trying to make good things happen provided that economic growth carries on as if we weren’t doing anything different.
GT1 Innovation...
GT2 Innovation…
Climate policy evaluation: are good things happening?
Rising emissions and pledges

Legally committed to zero emissions by 2035:
- Finland

Legally committed to zero emissions by 2040:
- Austria, Iceland

Legally committed to zero emissions by 2045:
- Germany, Sweden

Legally committed to zero emissions by 2050:
- EU, USA, UK, S Korea, Australia, Canada

Policy document for zero emissions by 2050:
- Most South American countries

Policy document for zero emissions by 2060:
- China

Policy document for zero emissions by 2070:
- India

Data from https://eciu.net/netzerotracker

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Rising temperature and risk

Global discussions and emissions

1st Report of the IPCC
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UK Climate Change Act: 100% reduction by 2050

Average temperature anomaly, Global
Global average land-sea temperature anomaly relative to the 1961-1990 average temperature.
"There is a 66% likelihood that the annual surface global temperature 2023 – 2027 will be more than 1.5°C above pre-industrial levels for at least one year”

(WMO, May 2023)
Rising temperature and risk

Crop yield changes 1990-2090 averaged over Global Gridded Crop Models

Source IPCC SRCCL (2019)
Rising temperature and risk: tipping points

Antarctica sea-ice far lower than usual
Daily sea-ice extent in million sq km, 1979-2023

Ocean temperatures highest on record
Daily average sea surface temperature between 60° North and 60° South, 1979-2023

Five-day rolling average of sea-ice extent
Source: National Snow and Ice Data Center (NSIDC), data to 14 Sep 2023

Source: ERA5, C3S/ECMWF

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Why isn’t it working?

Unpacking burden-shifting via aggregation & deployment rates
“I’m making good things happen!”

Hydrogen!

Hydrogen production 2021

- Hydrogen
- Trade
- Carbon offsets
- “Negative emissions technologies”
- Bio-fuels
- Synthetic fuels
- ...

Burden-shifting is endemic to climate policy at present

Source: International Energy Agency (2022)
Incumbent thinking on how to reach zero emissions
Aggregating demand for three “zero-emissions resources”
## Aggregation analysis

<table>
<thead>
<tr>
<th>Sector</th>
<th>2020 GHGs (MtCO2/yr)</th>
<th>Physical units</th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road vehicles</td>
<td>6,100</td>
<td>2,700 G litres petrol/diesel</td>
<td>140-320 litres biofuel per tonne biomass</td>
<td>6 litres petrol equivalent to 20kWh electric power</td>
</tr>
<tr>
<td>Train</td>
<td>200</td>
<td>40 G litres diesel</td>
<td>As above</td>
<td>As above</td>
</tr>
<tr>
<td>Shipping</td>
<td>900</td>
<td>370 G litres diesel</td>
<td>As above</td>
<td>19kWh per litre synthetic fuel</td>
</tr>
<tr>
<td>Aviation</td>
<td>2,900</td>
<td>470 G litres kerosene</td>
<td>As above</td>
<td>As above</td>
</tr>
<tr>
<td>Electricity (emitting)</td>
<td>10,000</td>
<td>17,000 TWh</td>
<td>10,000 Mt CCS</td>
<td>17,000 TWh non-emitting generation</td>
</tr>
<tr>
<td>Electricity (non-emitting)</td>
<td>9,900</td>
<td>9,900 TWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space heating</td>
<td>6,700</td>
<td>8,800 TWh gas boiler output</td>
<td>6,700 Mt CCS</td>
<td>1kWh heat pump = 3.1kWh gas boiler</td>
</tr>
<tr>
<td>Blast furnace Steel</td>
<td>3,700</td>
<td>1,400 Mt Steel</td>
<td>3,700 Mt CCS</td>
<td>3.5MWh/tonne steel via green hydrogen</td>
</tr>
<tr>
<td>Cement</td>
<td>3,100</td>
<td>4,100 Mt Cement</td>
<td>3,100 Mt CCS</td>
<td></td>
</tr>
<tr>
<td>Other industry</td>
<td>6,700</td>
<td></td>
<td>6,700 Mt CCS</td>
<td>Same total electricity as steel</td>
</tr>
<tr>
<td>Deforestation</td>
<td>1,100</td>
<td>Assumed to stop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertiliser/rice/soil/crop</td>
<td>5,300</td>
<td>Un-changed</td>
<td>Direct Air Capture</td>
<td></td>
</tr>
<tr>
<td>Ruminants</td>
<td>3,000</td>
<td>Un-changed</td>
<td>Direct Air Capture</td>
<td></td>
</tr>
<tr>
<td>Waste</td>
<td>1,600</td>
<td>Assumed to stop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct Air Capture</td>
<td></td>
<td>Applicable to all emissions</td>
<td>4MWh/t capture and store plus 1 t CCS per t DAC</td>
<td></td>
</tr>
</tbody>
</table>

Data from multiple sources: [https://ukfires.org/blog-cop26/](https://ukfires.org/blog-cop26/)

Copyright © J M Allwood 2023
Aggregation of plans discussed at COP26

Source: https://ukfires.org/blog-cop26/
Deployment rates

World non-emitting electricity generation (TWh/yr)

Source BP Statistical Review of World Energy (BP, 2021)

Source Global CCS Institute (2021)

Most plans to date have not become reality

75% of CCS today increases fossil fuel extraction

Growth~350TWh/yr/yr

Global biomass harvest

Source Zhou et al. (2018)
Deployment rates

Years after Energy Source Begins Supplying 5% of Global Demand

Sources: Smil (2014), update BP World energy statistics (2022)

Proportion electricity supply

- Lab demonstration
- Pilot studies at increasing scale
- Connection to infrastructure
- Legal and environmental permissions
- Social consent after first accident
- Financing needs

Proportion behaviour change

- Lead petrol (World)
- Asbestos (World)
- Ozone (US)
- Ozone (World)
- CCGT (UK)
- Wind (Denmark)
- Nuclear (France)

Source: Nelson & Allwood (2021)
Project examples

Nuclear Power Timeline

- Outline policy intent
- Contract partners agreed
- Safety checks and licensing
- Select, procure & planning permission
- Agree investment strategy
- Design and equipment manufacture
- Site preparation (inc. infrastructure)
- Excavation
- Construction
- Start up

Hinkley Point C (21.5 years)  
IAEA Project Management Guidelines (12 years)

Offshore Wind Power Timeline

- Outline policy intent
- Contract partners agreed
- Safety checks and licensing
- Select, procure & planning permission
- Agree investment strategy
- Design and equipment manufacture
- Site preparation (inc. infrastructure)
- Excavation
- Construction
- Start up

Hornsey Project 2 (16 years)  
Deloitte project Lifecyle (13 years)

Source: Use Less Group analysis

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Preliminary result: policy will be constrained by resources

Non-emitting electricity (TWh/yr)

- CCS today: 40 Mt/yr
- CCS in 2050: 100-160 Mt/yr

COP26 Policy Space

- Maximum biomass
- No extra biomass, minimum direct air capture
- Maximum direct air capture

Non-emitting generation in 2050: 20,000-30,000 TWh/yr
Non-emitting generation today: 9,900 TWh/yr

Source: https://ukfires.org/blog-cop26/

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Resource-constrained climate policy

The big picture in the UK:

- By 2050 we will have ~ 2.5x as much emissions-free electricity as today
- We will have no significant carbon storage, surplus biomass, hydrogen or negative emissions technologies
- We have to electrify everything possible, close anything else, and use ~60% as much electricity as we’d otherwise like
- For householders only 4 actions matter - stop using:
  - fossil boilers,
  - fossil cars,
  - fossil planes,
  - ruminants.

[Link to Absolute Zero]

https://ukfires.org/absolute-zero/
“We’ll just have to go a bit faster then…”

… and we’re gonna test the new e-carbon storage tech right under your school

No problems! And if you need to cut teachers to pay for it, go ahead
Academic responsibility

Average tonnes CO$_{2e}$ per person per year

Source: https://ourworldindata.org/grapher/per-capita-ghg-emissions
(The page at this link then gives all the primary data sources)
Does restraint mean misery?
Using fossil boilers at home
Driving fossil cars & vans
Eating beef, lamb and dairy
Construcing new buildings
Making large equipment
Using fossil boilers at work
Fossil trucks
Constructing roads etc.
Agriculture, forestry and other land use
Fugitive emissions
Other
At home
At work
Stop
Stop
Electrify & half power
Electrify & half power
Use electrically-recycled materials only
Quite complex....
“Restraint sounds a bit tricky”
Eighty eight pianists

The flying animals
Welfare = 

- Imagination
- Fascination
- Diversity of activity
- Endeavour
- Appreciation
- A “balanced life”
- Fulfilment
- Wonder
- Virtue
- ...

... which allows restraint
Engineering reality
Facing up to the supply-demand gap

Target Economic Growth

Zero-emissions resource demand

Zero-emissions resource supply

Resource Efficiency

Output

Time

Now 2050

Excitement in Resource Efficiency innovation

Avoid

Reduce

Re-use

Recycle
Drawing green circles doesn’t help

Resource inputs ➔ Lots of lovely economic growth ➔ "Bydgroecycling"

Avoid
Reduce
Re-use
Recycle

It’s time to radically rethink fashion

Clothes are designed to last longer: they are never used and are never recycled. Do not release toxins or pollution.

Circular is the new black
To date, copper contamination has not been a problem because it can be absorbed in rebar.

It will become a global problem ~2040-50.

There is a technology opportunity for innovation in removing copper from recycled steel or coping with it.
Sustainable metals: science and systems

Scientific discussion meeting
Part of the Royal Society scientific programme
Organised by Professor Julian M Allwood FREng and Professor Dierk Raabe.
5 – 6 February 2024

The Royal Society
6 – 9 Carlton House Terrace, London, SW1Y 5AG
Find out more at royalsociety.org/events/for-scientists
Re-use

Current “Circular”: recycling “Circular”: repair/re-use

Energy

Labour

Avoid
Reduce
Re-use
Recycle

79.4 GJ

-60%

31.4 GJ

-92.3%

2.3 GJ

Source Keh (2021)
Avoid

- Longer life
- More intense use
- Material substitution
- Product substitution

Reconfiguring existing facility and intelligent design gave 66% saving in embodied carbon, 40% cost saving.
Reduce – examples of research into practice
Innovation opportunities

Materials & Manufacturing

Business growth in a transformative journey to zero emissions

Construction Sector Innovation within Absolute Zero

Business growth in a transformative journey to zero emissions

Entrepreneurs not Emissions

New business opportunities to fill the gap in UK emissions policy

www.ukfires.org
Specification scrap: construction

Utilisation ratio
0.75 - 1.0
0.5 - 0.75
0.25 - 0.5
0 - 0.25

7.5m

Source Moynihan & Allwood (2014)

Source Dunant et al. (2018b)
Scrap in car-production

Source: Horton and Allwood (2017)
Folding-Shearing

1. Fold

2. Shear

Source: Allwood et al. (2019), Cleaver et al. (2022)
Folding-shearing compared to deep-drawing

Drawing with blankholder
BHF = 15 kN

Drawing with blankholder
BHF = 50 kN

Folding-shearing
BHF = 15 kN

Max thinning = 15%

Max thinning = 10%
Folding-Shearing
DeepForm Ltd.

- 75% reduction in trimming **scrap**
- **Environmental benefit**: 30% reduction in embodied emissions per part
- **Cost savings**: 20% reduction in piece cost
Global GHG emissions 
52 GtCO₂e Energy/process emissions, 78% 
Buildings, 31% 
Other, 8% 
Transport, 22% 
Industry, 35% 
Deforestation/deforestation/agriculture/decay, 22% 

Other GtCO₂e

Industrial GHG emissions 
14 GtCO₂e

• Concrete = cement + water + sand + aggregate;
• Cement = clinker + gypsum + supplementary materials
• Portland clinker emissions = emissions from heating + process emissions
<table>
<thead>
<tr>
<th>Technology</th>
<th>Heat</th>
<th>Chemical Emissions</th>
<th>Market fraction potential</th>
<th>Maximum abatement</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCMs</td>
<td>●</td>
<td>●</td>
<td>80%</td>
<td>45%</td>
<td>Low</td>
</tr>
<tr>
<td>Grinding</td>
<td>●</td>
<td>●</td>
<td>100%</td>
<td>20%</td>
<td>Low</td>
</tr>
<tr>
<td>Alternative fuels</td>
<td>●</td>
<td></td>
<td>80%</td>
<td>20%</td>
<td>Low</td>
</tr>
<tr>
<td>CDW raw meal</td>
<td>●</td>
<td></td>
<td>5%</td>
<td>10%</td>
<td>Low</td>
</tr>
<tr>
<td>LEILAC</td>
<td>●</td>
<td></td>
<td>100%</td>
<td>60%</td>
<td>Moderate</td>
</tr>
<tr>
<td>CCS lime production</td>
<td>●</td>
<td></td>
<td>100%</td>
<td>55%</td>
<td>Moderate</td>
</tr>
<tr>
<td>Carbon cycling</td>
<td>●</td>
<td></td>
<td>20%</td>
<td>10%</td>
<td>Moderate</td>
</tr>
<tr>
<td>Calcium silicates</td>
<td>●</td>
<td></td>
<td>Low</td>
<td>60%</td>
<td>??</td>
</tr>
<tr>
<td>Electrolytic production of CH</td>
<td>●</td>
<td></td>
<td>Low</td>
<td>50%</td>
<td>Extremely high</td>
</tr>
<tr>
<td>Solar ovens</td>
<td>●</td>
<td></td>
<td>Low</td>
<td>40%</td>
<td>High</td>
</tr>
</tbody>
</table>
Recovered Cement Paste → Heat in EAF → Rapid cooling → Portland cement

28-day strength

- Fine ground and well-sulphated
  - Commercial OPC
  - Commercial LC³
- Coarse ground and under-sulphated
  - Commercial OPC
  - Commercial LC³
- 100% CEC
  - CEC LC³

Commercial grades: 32.5, 42.5, 52.5

Source: Dunant et al. (under review)
Cambridge Electric Cement Ltd.
Conclusion
Conclusion: the role of engineers in climate mitigation

• Deployment at scale and speed is everything
• We desperately need credible engineering analysis to call out burden-shifting
• Re-focus on demand to ease impossible requirements on supply – untapped innovation potential
• New technologies can’t solve the problem in time – so we must be part of a societal dialogue.
Access and references

• A pdf of the slides used in this talk can be downloaded from:

  www.uselessgroup.org/about-us/blog

• There is a full set of references at the end of the slide-pack
References used in the talk:


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