Energy and Material Efficiency

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Global Energy/Carbon Analysis

- “Every little helps”

  Old wives’ tale widely quoted in responses to climate change

- “If we all do a little, we get a little”

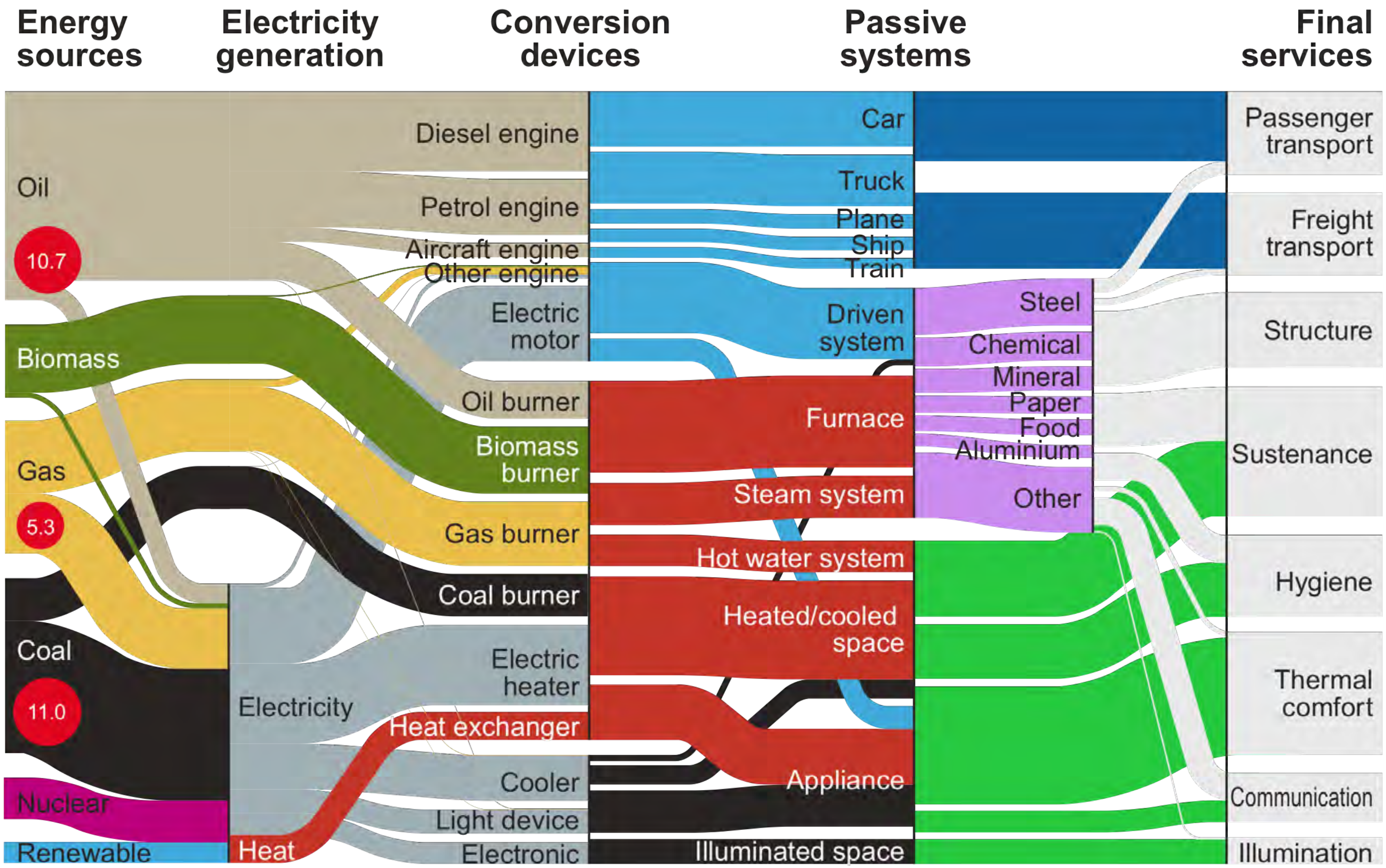
  Professor David Mackay, Chief Scientific Advisor to the Department of Energy and Climate Change

- What would make a big difference to global energy system?

  Climate science broadly accepted, but as yet little concerted action for change by governments

  Initial response to climate concern is almost all on the supply side

  Unclear where to take action – what would make a big (enough) difference



Global energy demand in 2005, total = 475 EJ

Global carbon emissions in 2005, total = 27 Gt CO_2

JM Cullen and JM Allwood
Energy Policy 38 (2010) 75–81

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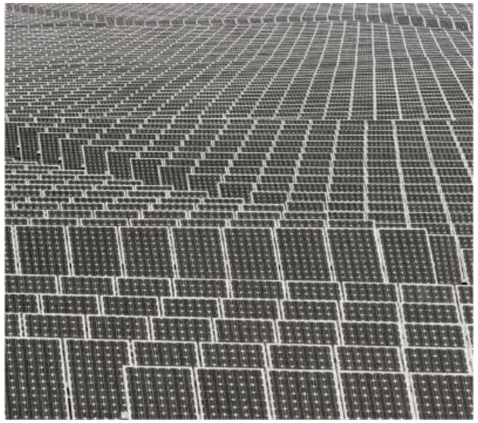
Energy supply substitution is difficult…because we don't have enough land:



Renewables are diffuse

POWER PER UNIT LAND AREA

Wind	2 W/m^2
Offshore wind	3 W/m^2
Tidal pools	3 W/m^2
Tidal stream	6 W/m^2
Solar PV panels	5 W/m^2
Plants	0.5 W/m^2
Solar chimney (Spain)	0.1 W/m^2
Concentrating solar power (desert)	15 W/m^2
Ocean thermal	5 W/m^2
Rain-water (Scotland)	0.24 W/m^2
Rain-water (England)	0.02 W/m^2

- To make a difference, renewable facilities have to be country-sized

David Mackay: "Sustainable energy without the hot air",
www.withouthotair.com

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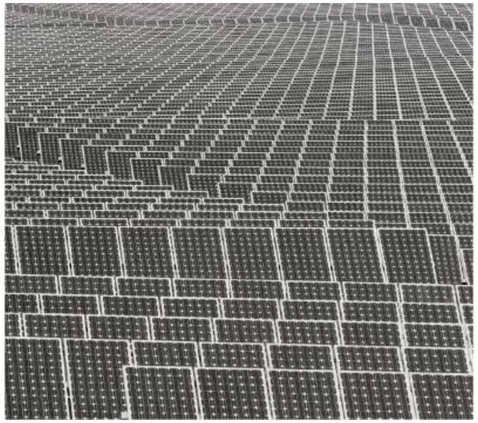
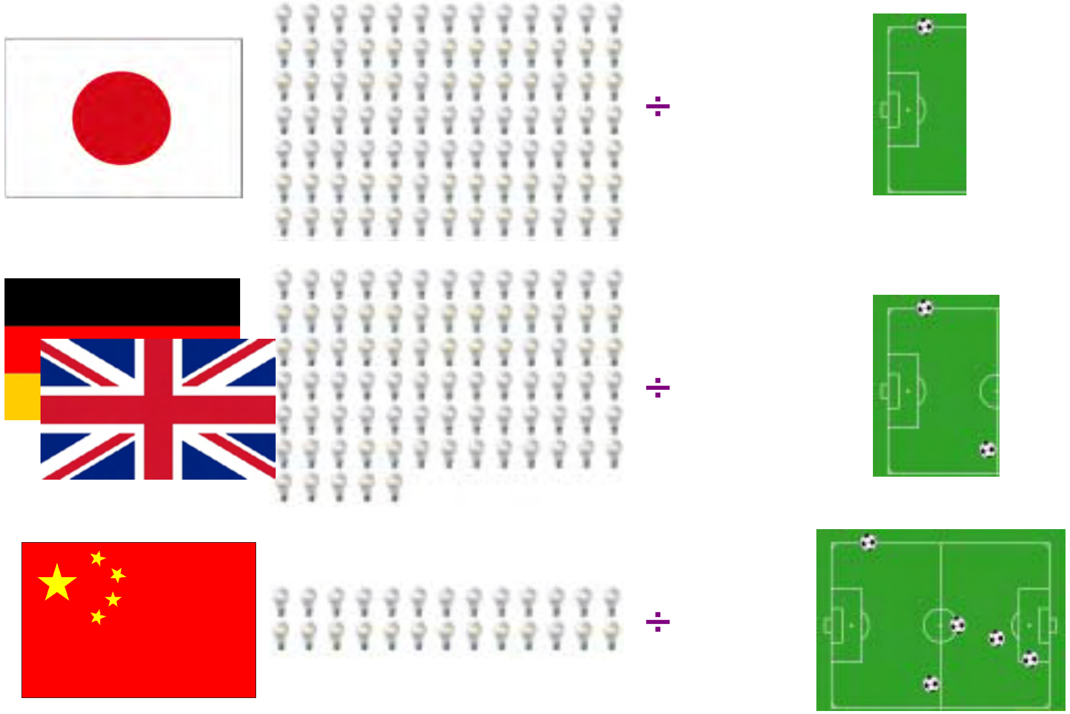
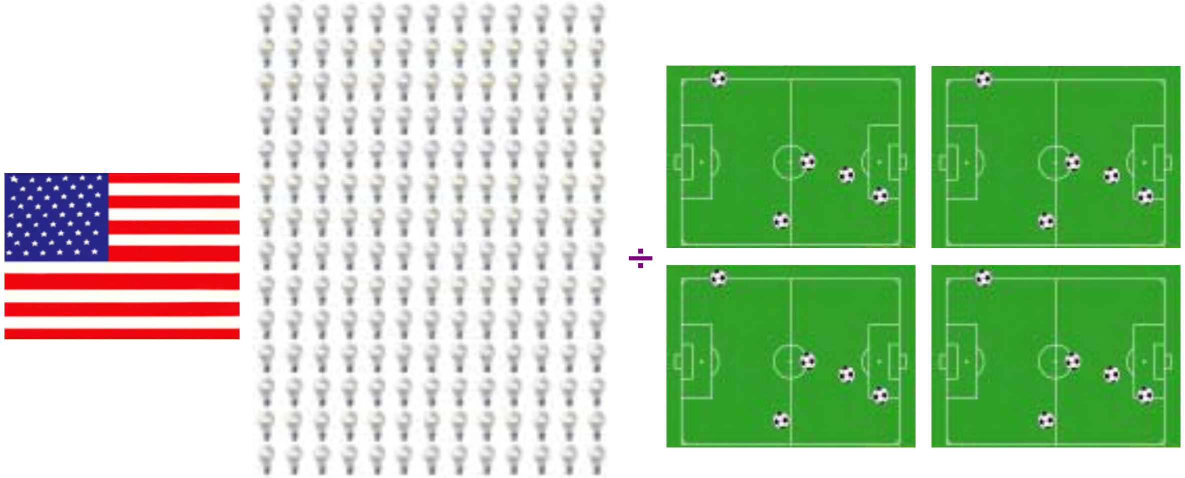




= 1.95 W/m^2

= 1.25 W/m^2

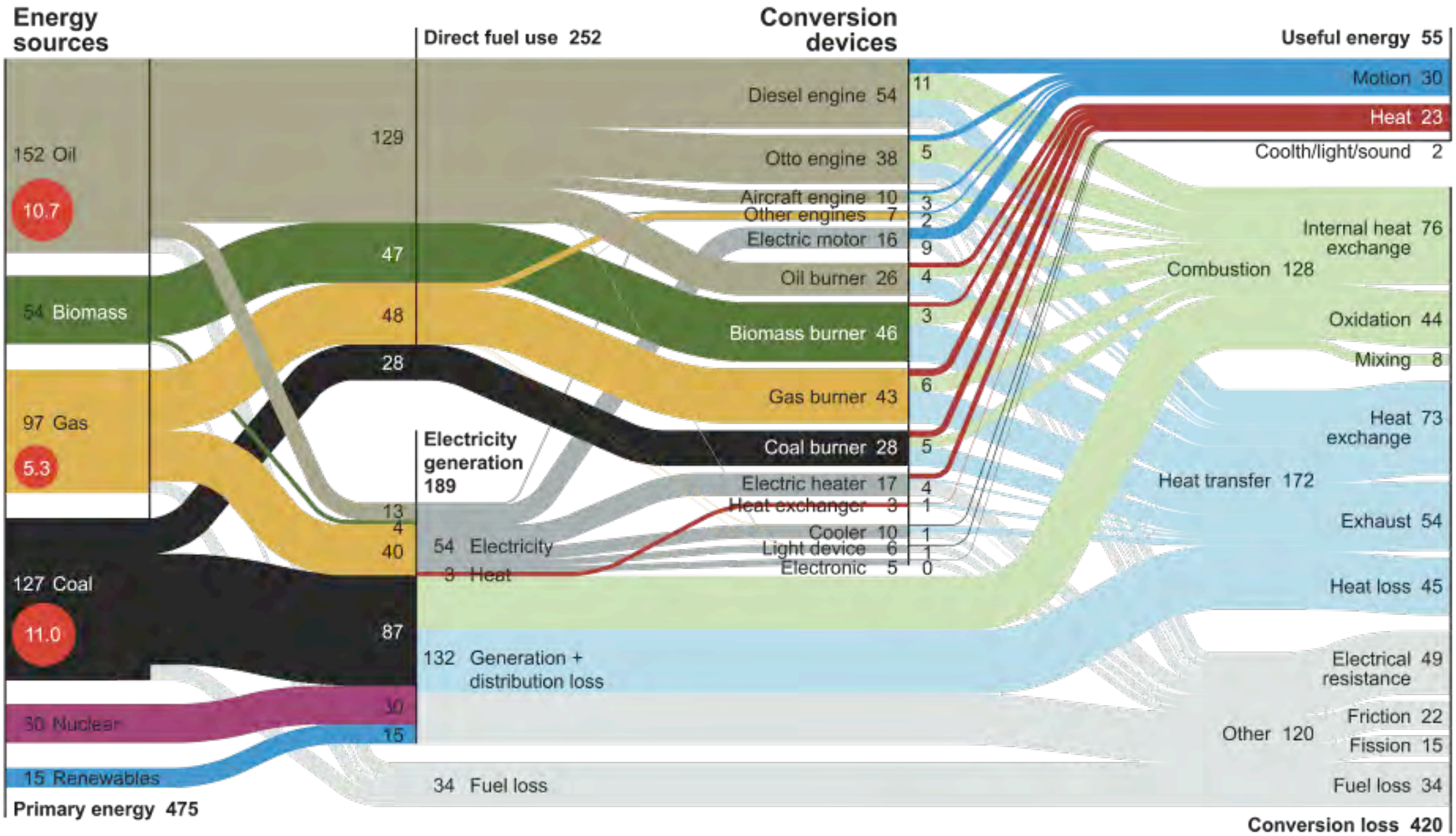
= 0.2 W/m^2



= 0.3 W/m^2

David Mackay: "Sustainable energy without the hot air", www.withouthotair.com

Theoretical efficiency limits in energy conversion devices (11%)



Global energy demand in 2005, total = 475 EJ

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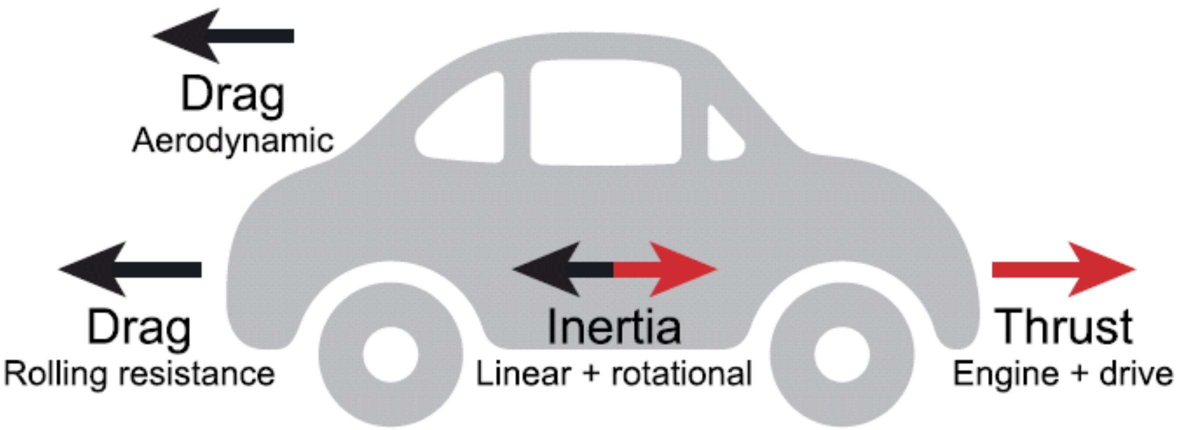
Practical efficiency limits in passive energy systems

Car example



$$F = F_M + F_A + F_I = \mu m g + \frac{1}{2}\rho \nu^2 C_D A_f + m\frac{d\nu}{dt}$$

Mechanical drag (rolling resistance)

- friction coefficient
- mass of vehicle

Aerodynamic drag

- drag coefficient
- frontal area of vehicle

Practical efficiency limits in passive energy systems

Car example

Weighted average of current cars

Practical minimum

91% potential for saving energy

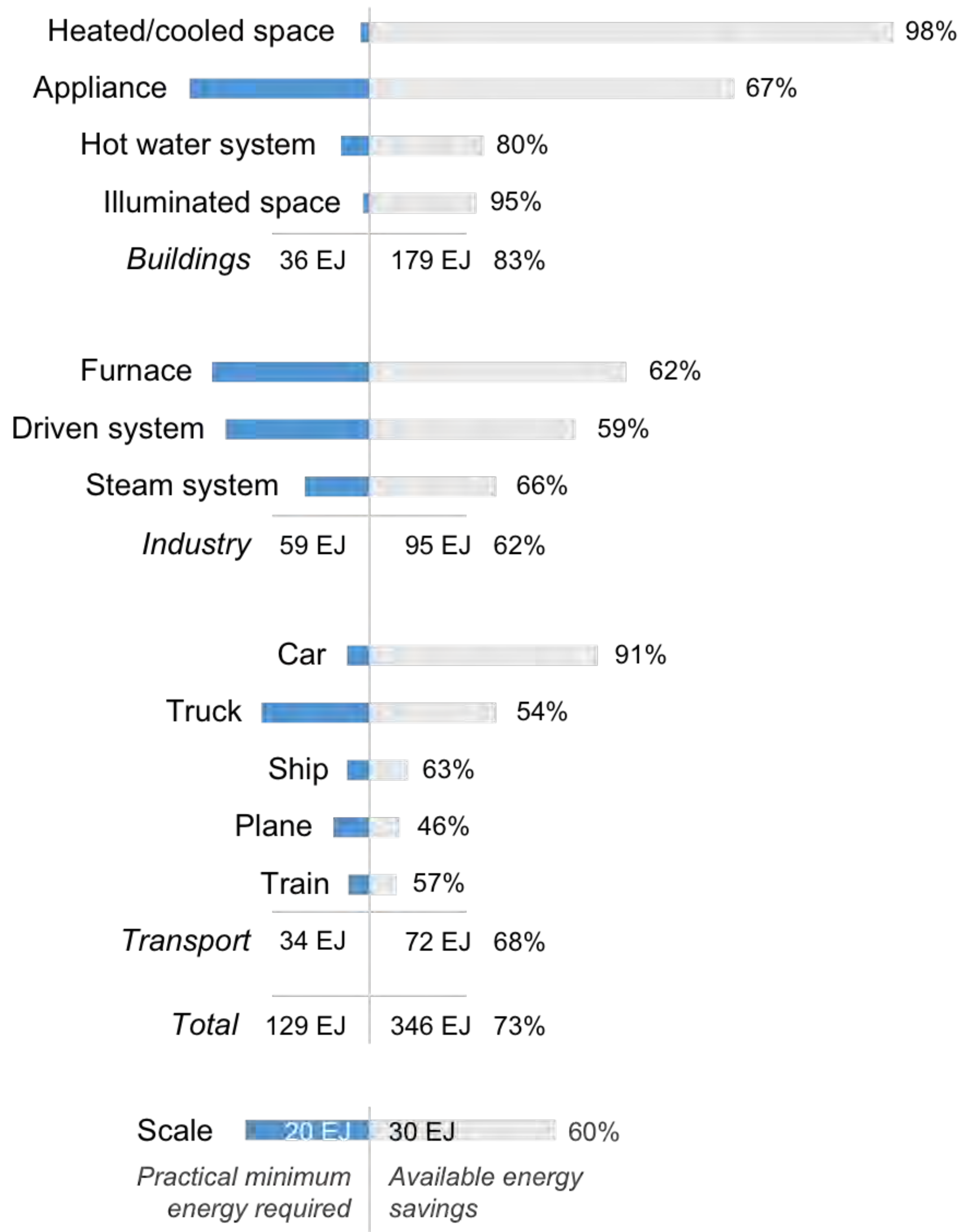
Practical savings available in cars

Design[1]	m	ν	μ	C_D	A	f_i	F_M	F_A	F_I	F
	t	m/s			m^2	%	N	N	N	N
Gasoline										
<1.4 l	1.0	19	0.015	0.40	1.9	36	147	163	130	440
1.4–2.0 l	1.2	20	0.015	0.40	2.0	28	177	201	155	533
>2.0 l	1.4	21	0.015	0.40	2.1	6	206	232	178	616
LDV[2]	2.1	17	0.015	0.50	2.2	3	309	199	223	731
Diesel										
<2.0 l	1.3	19	0.015	0.40	2.0	11	191	174	156	521
>20.0 l	1.5	19	0.015	0.40	2.1	7	221	193	174	588
LDV[2]	2.1	16	0.015	0.50	2.2	8	309	165	219	693
Current[3]	1.3	19	0.015	0.41	2.0	100	188	183	157	528
Practical	0.3	19	0.001	0.10	1.5	100	3	33	13	49

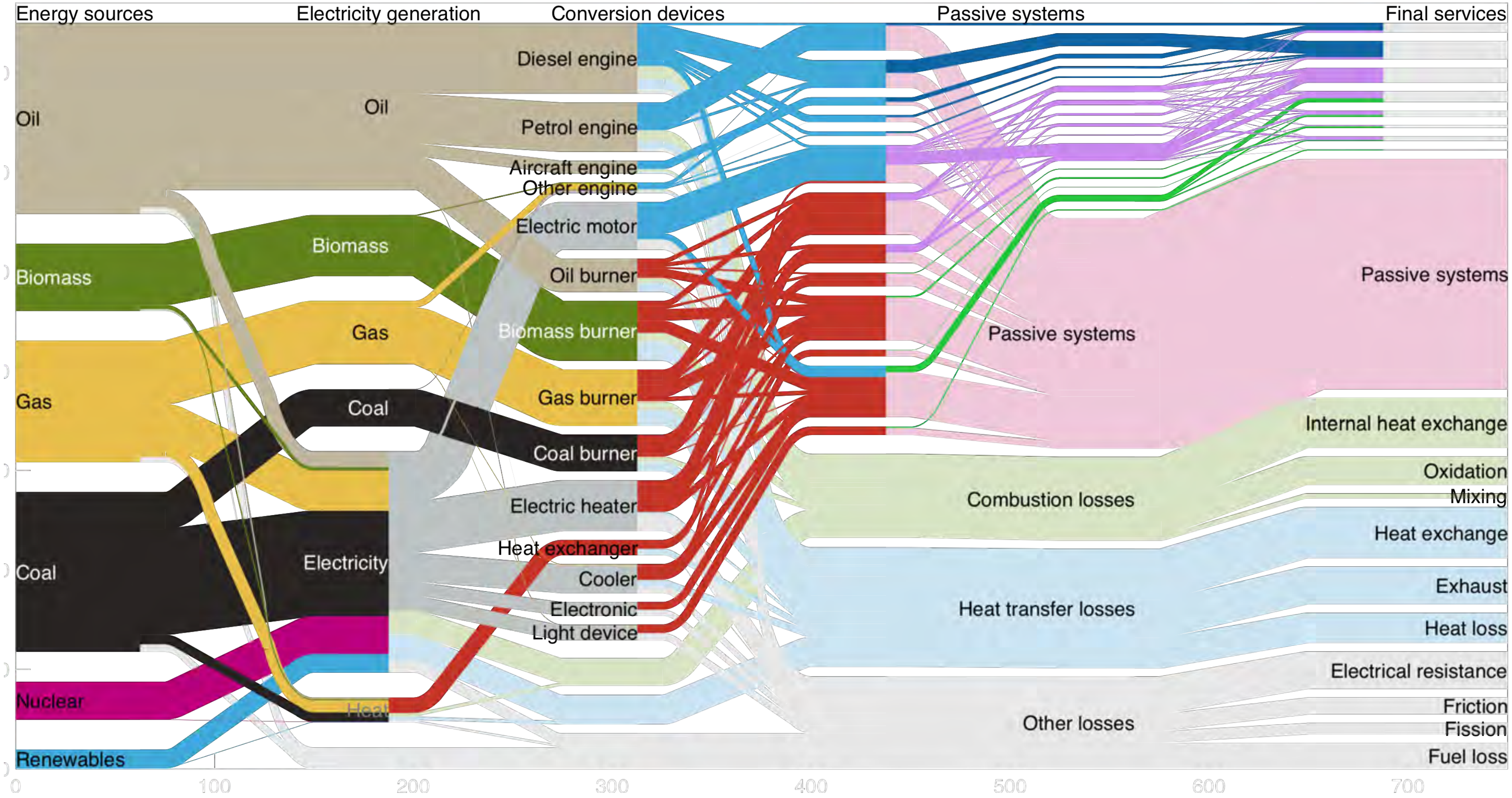
Practical energy savings available **91%**

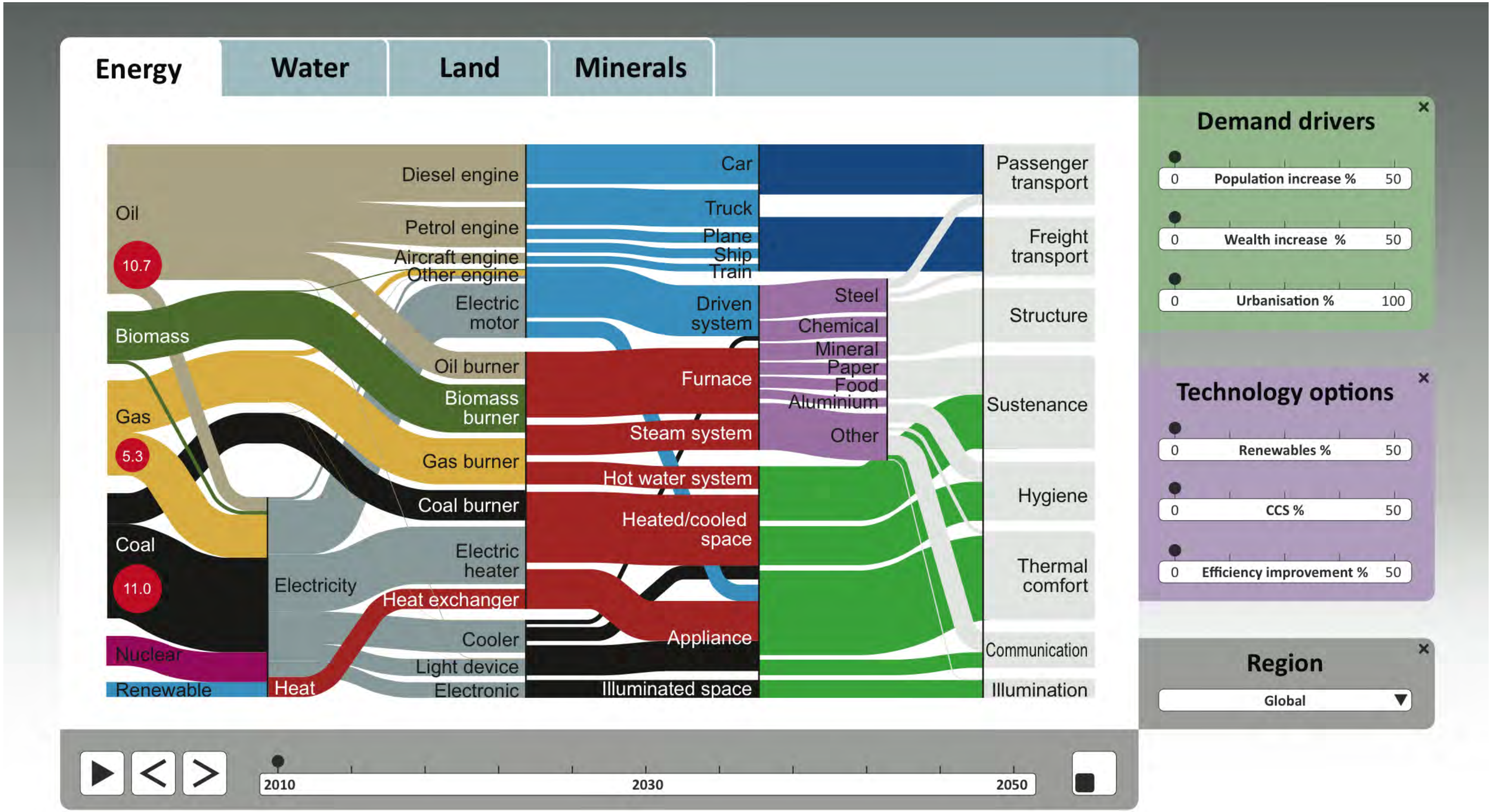
Notes: [1] by fuel type and engine size in litres, [2] LDV = light duty vehicle, [3] weighted average, by the distribution of total distance travelled (f_i). m = mass, ν = average velocity, μ = friction coefficient, C_D = drag coefficient, A_f = frontal area, F = force, with subscripts $_M$ mechanical, $_A$ aerodynamic and $_I$ inertia

Practical losses in the global energy system (73%)



Avoidable losses in the global energy system (88%)





Foreseer

future resource pathways

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Global Energy Efficiency

- What have we learnt?

  Our Sankey Diagram is the first breakdown of global energy transformation by technology (rather than economic sector) – so gives a nice basis for considering technical options

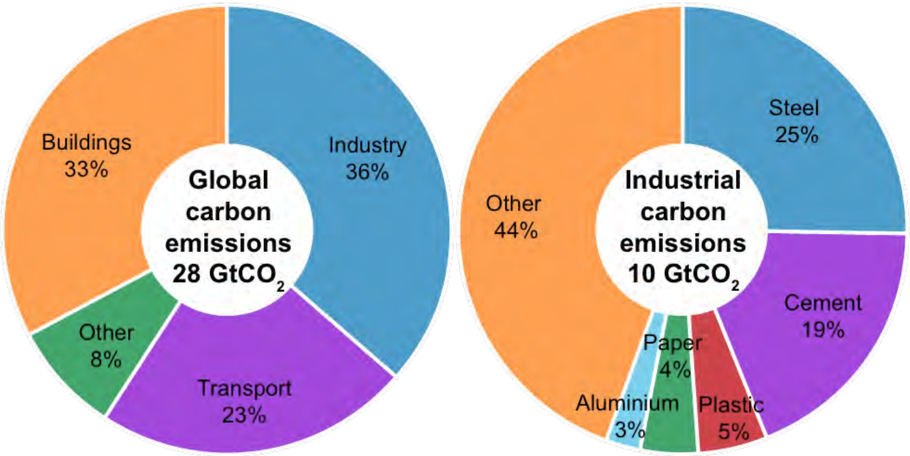
  It's very unlikely that a low carbon future will be created on the supply-side

  Tremendous demand side efficiency options exist in buildings and transport (lightweight road-vehicles and passive buildings)

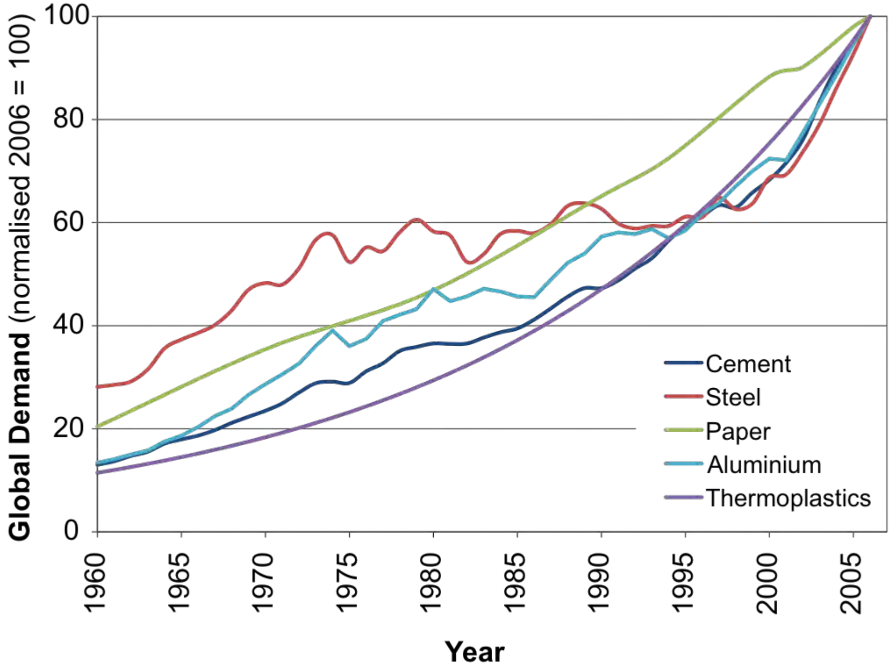
  But what about industry…..?

Energy and emissions in industry

Emissions dominated by 5 materials…



…and demand likely to double by 2050



- What would make a big enough difference?

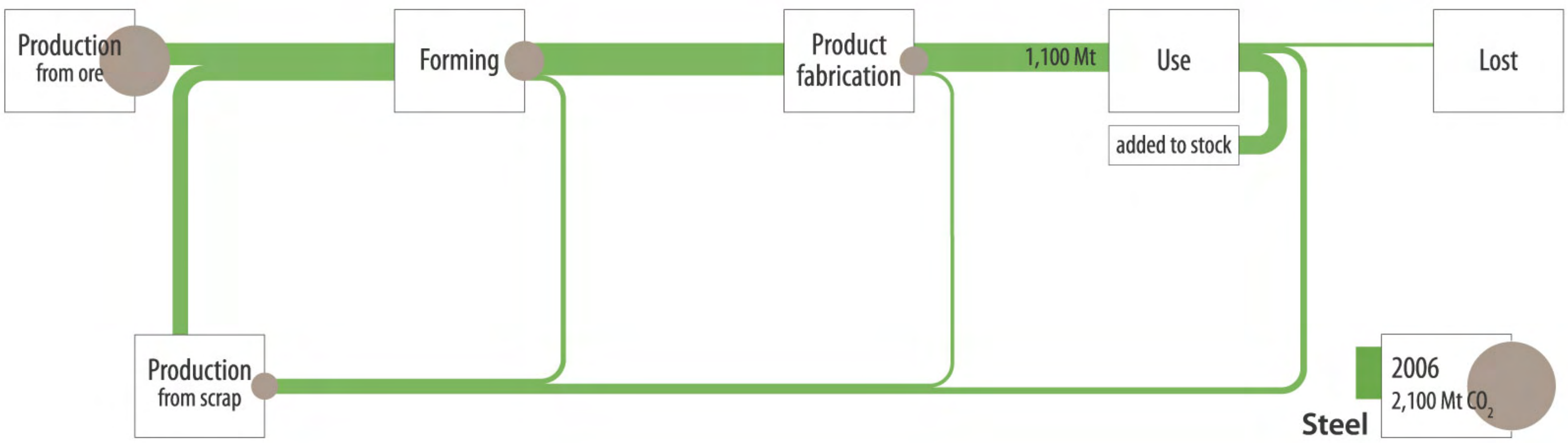
  Product based analysis (LCA, EU policy) cannot answer this question

  Total Material Requirements analysis is not specific enough

  Instead, we can take a top-down global view for these five materials….

The scope of required change in industry

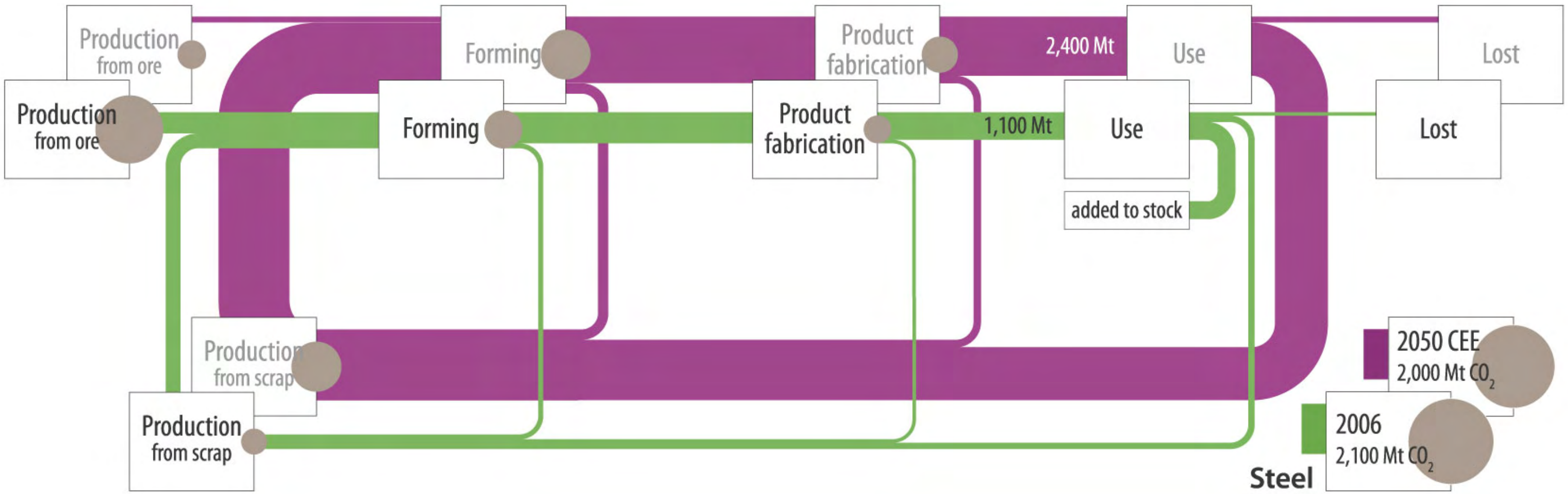
Current situation



Data from Yale "Stocks and Flows" project scaled by IISI global demand data.

The scope of required change in industry

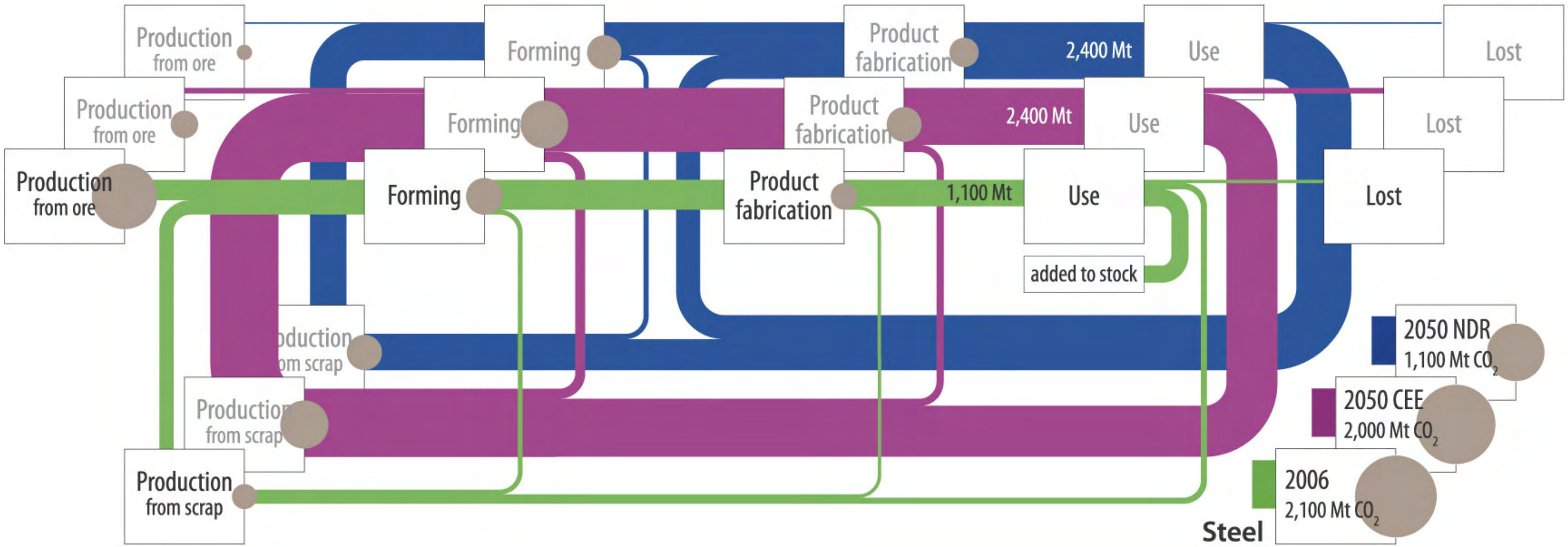
Doubling of demand with perfect implementation of all known gains in efficiency (40% cut in primary emissions due to technology gains plus 20% de-carbonisation of all energy



Data from Yale “Stocks and Flows” project scaled by IISI global demand data.

The scope of required change in industry

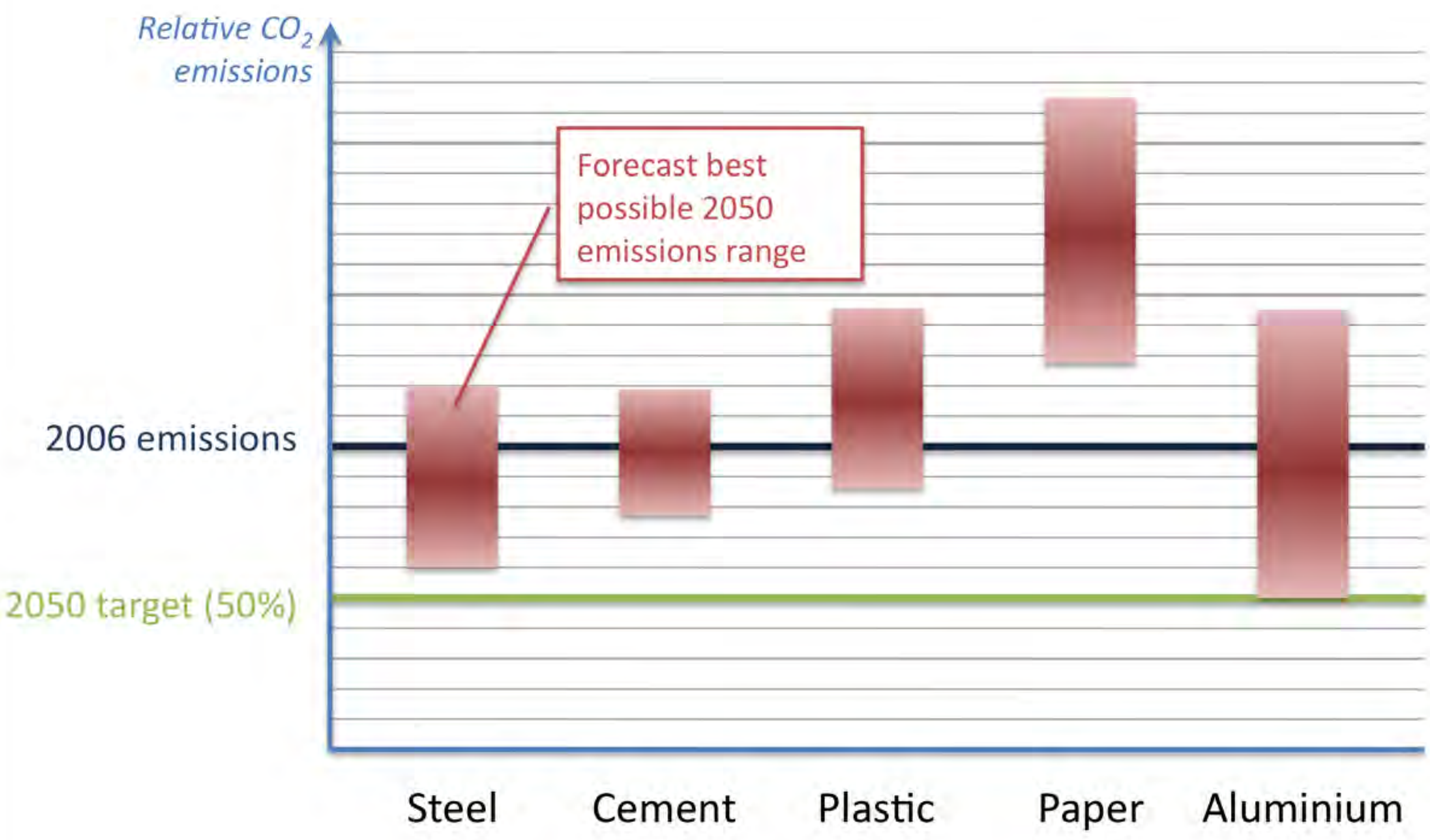
Doubling of demand with forecasted gains in efficiency, and non-destructive recycling



Energy Efficiency will not have enough impact in Industry. However there are additional options within **Material Efficiency**.

Data from Yale "Stocks and Flows" project scaled by IISI global demand data.

How far can energy efficiency go within existing industry?



- Even with the strongest possible assumptions, we cannot hit carbon emissions targets by energy/process efficiency within the existing system

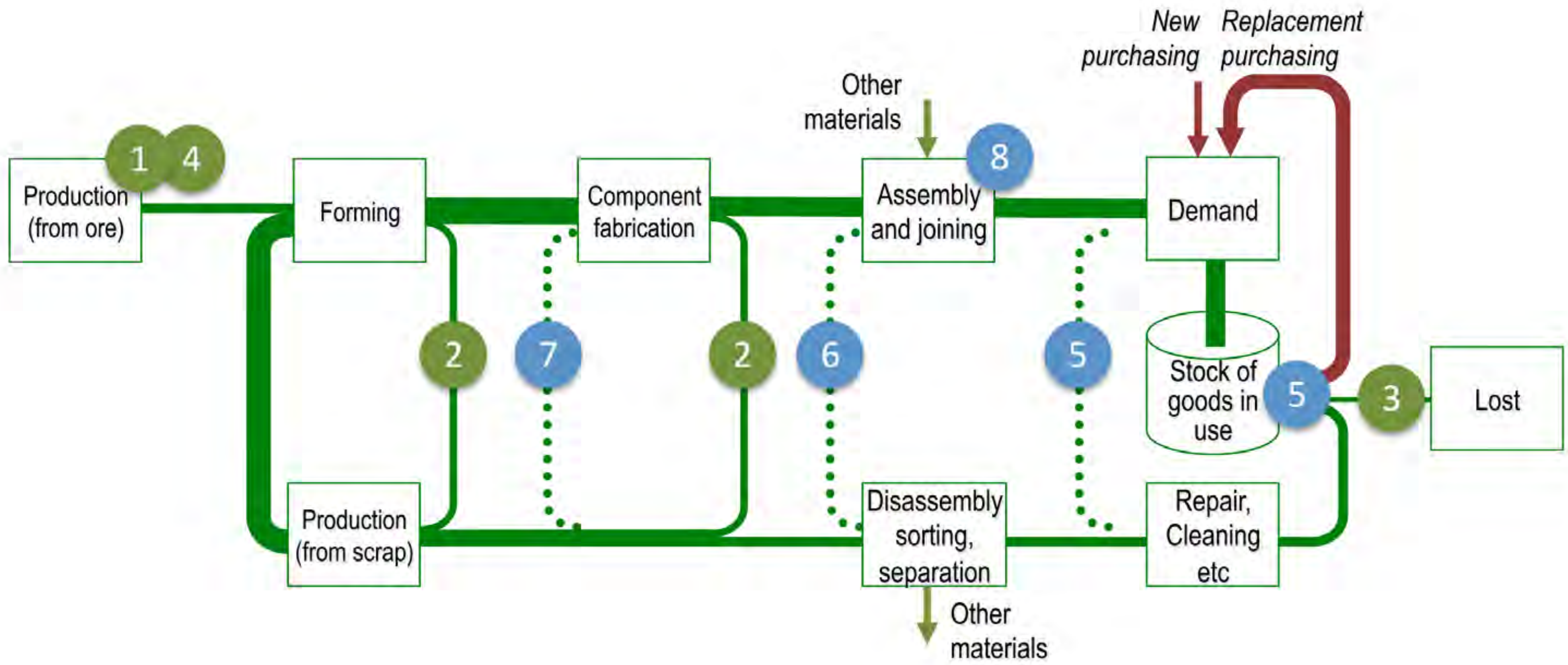
Options to halve emissions while demand doubles?

Energy and Carbon Efficiency strategies:

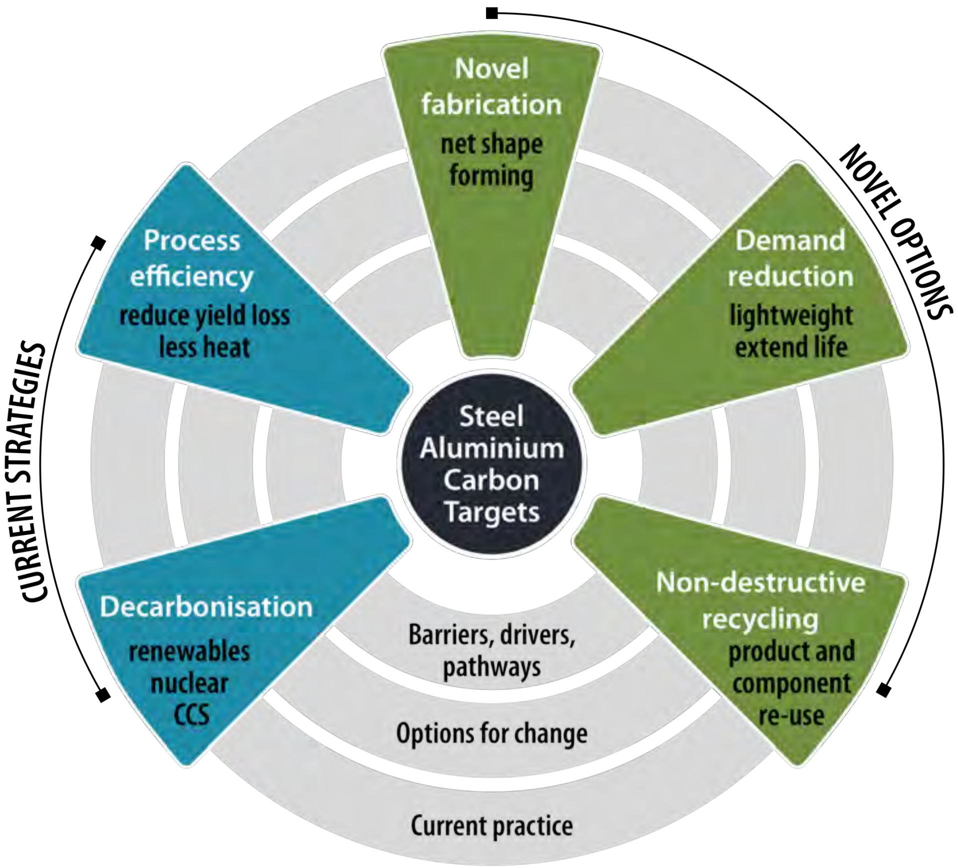
1. Energy efficiency
2. Yield improvement
3. More recycling
4. Carbon Capture – process or energy

Material Efficiency strategies:

5. Longer life, more use, repair and re-use
6. Product upgrade
7. Component re-use
8. Less metal, same service



WellMet2050 themes and partners



www.wellmet2050.com

Theme 1: Reuse without melting

- Which applications?
- Costs, emission saving?
- System requirements
- Certification?
- Design?
- Cleaning, machining, re-forming, joining…
- Incentives?

Themes 2-4

Theme 2: Using less metal to provide the same service



Theme 3: Using metal goods more intensely and for longer

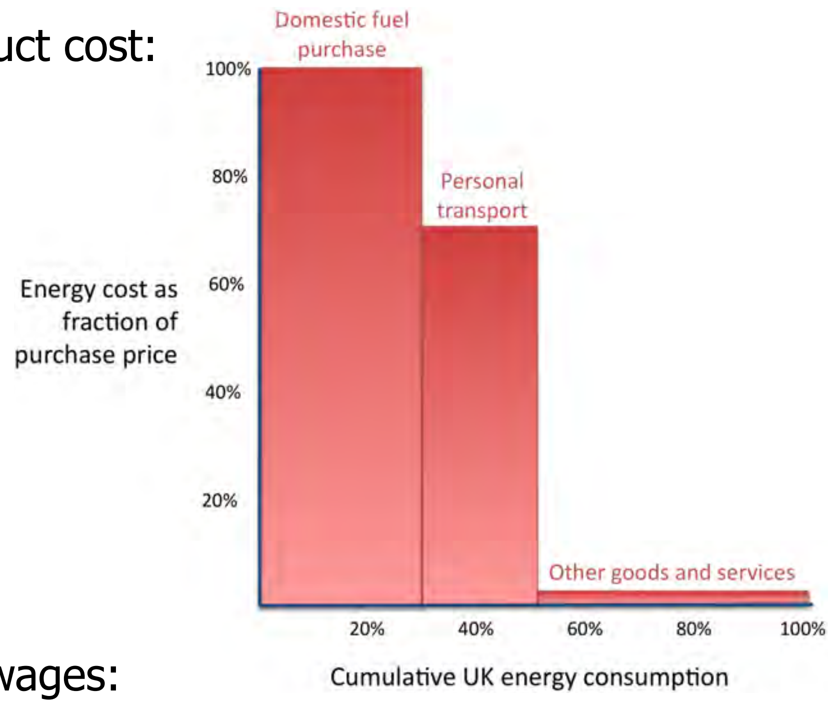


Theme 4: Supply chain compression/ radical processes

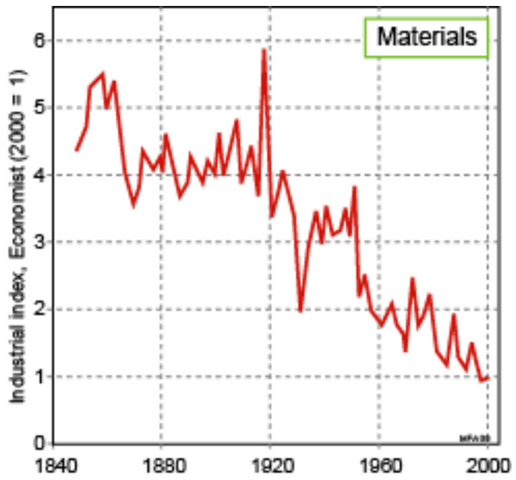


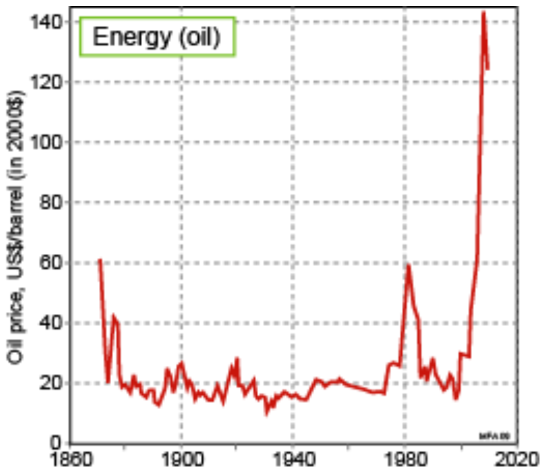
Barriers to material efficiency: economic

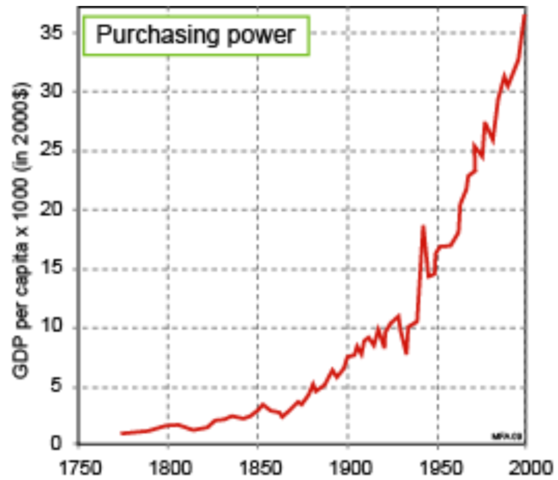
Energy cost is a small part of product cost:



Material prices are low relative to wages:







Barriers to material efficiency: social

"Materialism":

End of Physical life	Product breaks
End of Functional life	Product no longer needed
End of Technical life	Product now obsolete
End of Economical life	Same function can be had cheaper
End of Legal life	Use of product illegal
Loss of Desirability	Product unattractive - taste, fashion, etc.

The "Rebound effect":

The "value-action" gap:

Enablers of material efficiency: business opportunities

New revenue streams	Primary materials producers to create ‘second-hand’ business, like used-cars
Leasehold transactions	Rolls Royce (power by the hour) and Xerox (reconditioned modular copiers)
Brand benefits	Major retail chains in UK and US chasing brand advantage of “green leadership”
Vertical integration	Supporting revenue models that do not require increased material production
Embedded energy	As use-phase efficiency increases (light vehicles, passive buildings) embedded energy will be more visible
Learning from developing countries	India already practices material efficiency.

Enablers of material efficiency: policy

Energy price is unlikely to be influential, so policy options include:

- Taxes and charges (Packaging tax, landfill taxes, fuel price escalator)
- Subsidies and Incentives (House insulation)
- Carbon pricing
- Preferential purchasing (Government, corporate procurement)
- Changed patterns of ownership (End of life directives, deposit-return, leasehold)
- Certification and standards (Building codes, appliance efficiency standards)
- Voluntary programmes and information

Summary

- "If we want to make a big difference, we need to make a big change"
  - There is no magic supply of low carbon energy
  - Energy efficiency in transport and buildings has enormous scope
  - In industry, energy efficiency has limited further potential
- Material Efficiency
  - Is the last option before demand constraint
  - Has great technical potential - particularly in re-use of large parts
  - Is currently 'inconvenient' - but we have no choice but to make it happen
- What do we need to do now?
  - We have enough analysis.
  - We need to create big scale demonstrators that others can copy

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