system perspectives on the circular economy

Jonathan Cullen
jmc99@cam.ac.uk
an elegant solution …
that in reality is more complicated …
Closed systems outputs become inputs (Boulding, 1966)
Regenerative design processes restore energy and materials (Lyle, 1996)
Bio-mimicry innovation inspired by nature (Benyus, 1997)
Cradle to cradle design approach (Braungart, McDonough, 2002)
Performance economy selling services rather than products (Stahel, 2006)
needs a materials view ...

6 key sectors account for 70% of industry emissions.

Materials are the key link running through both the linear and circular models.
today’s linear industrial system is not that simple
why so difficult ...

4 challenges to contend with:
- in-use stocks keep growing
- materials are down-cycled
- energy is not renewable
- even steel reuse is difficult
in-use stocks keep growing ...

circular resource loops require stable stocks of materials in use
Most steel is down-cycled into lower-quality reinforcing bar. Copper and tin in the steel is an issue for using scrap to make sheet steel.

Most aluminium is down-cycled (or cascaded) from pure aluminium, to wrought aluminium (sheet metal), to cast aluminium (engine blocks and gearboxes).

Wood fibres in paper survives only 7 recycling stages. High-quality paper is down-cycled to low-quality board.

Mixed post-consumer plastic waste is difficult to recycle, and is either down-cycled into bulk plastic products, incinerated or exported to other countries.

Recycling concrete as aggregate in new concrete requires more cement than for virgin concrete.

Glass bottles mostly end up as filler material in road construction … an alternative tax-free landfill site.
energy is not renewable ...

circular resource loops require renewable energy to make sense
even reuse of steel beams is difficult …

**Small-scale local reuse**
Reuse happens when the buyer and seller can easily communicate, or are the same entity.

**Supply—demand website**
Linking demand and supply for reuse steel.
- Regular updates of quantities and timing.

**Full-scale reuse market**
Steel stockist holds certified reused steel.
- Clients/designers not part of decision-making.

**Demolition contractor**
Deconstructs building to recover steel.
- Delivers reused steel to stockist.

**Buyer**
Wants reused steel for new building.
- Shows interest in reused steel.

**Seller**
Wants to sell a property or building.
- Sees value in extracting steel from building.

**Designer**
(Engineer/architect) designs building.
- Generic design for new or reused steel.

**Fabricator**
Frames incorporate reused steel sections.

**Stockist**
Holds new and certified reused steel.

Supply chains need to be completely reconfigured.
there’s still much to do …

Today’s map

Possible future

Steel

Mining

Steelmaking

Fabrication

Nature

Assembly

Recycling

Use

Energy

1050Mt

Reuse

Steel

Mining

Steelmaking

Fabrication

Nature

Assembly

Recycling

Use

Energy

1500Mt

In-use stocks

Steel

Mining

Steelmaking

Fabrication

Nature

Assembly

Recycling

Use

Energy

1050Mt

Reuse
SUSTAINABLE MATERIALS WITH BOTH EYES OPEN

JULIAN M ALLWOOD
JONATHAN M CULLEN

Future buildings, vehicles, products and equipment – made efficiently and made with less new material

Material / energy demand reduction
Whole systems analysis
Reconfiguring supply chains
Practical efficiency limits
system perspectives on the circular economy

Jonathan Cullen  
jmc99@cam.ac.uk