Circular Economy in the Building sector:

Challenges and Opportunities for a Sustainable Building Culture

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11 December 2017,
Trondheim, Norway

NTNU
Norwegian University of Science and Technology

ZEB
The Research Centre on Zero Emission Buildings

Economy

Definition:

- "the process or **system by which goods and services are produced, sold, and bought** in a country or region"

Merriam Webster

«Circular» Economy

*"…**reuse** what you can, **recycle** what cannot be reused, **repair** what is broken, **remanufacture** what cannot be repaired."*

Walter R. Stahel

*"The circular economy is system that is **restorative and regenerative** by design"…*

Ellen MacArthur Foundation

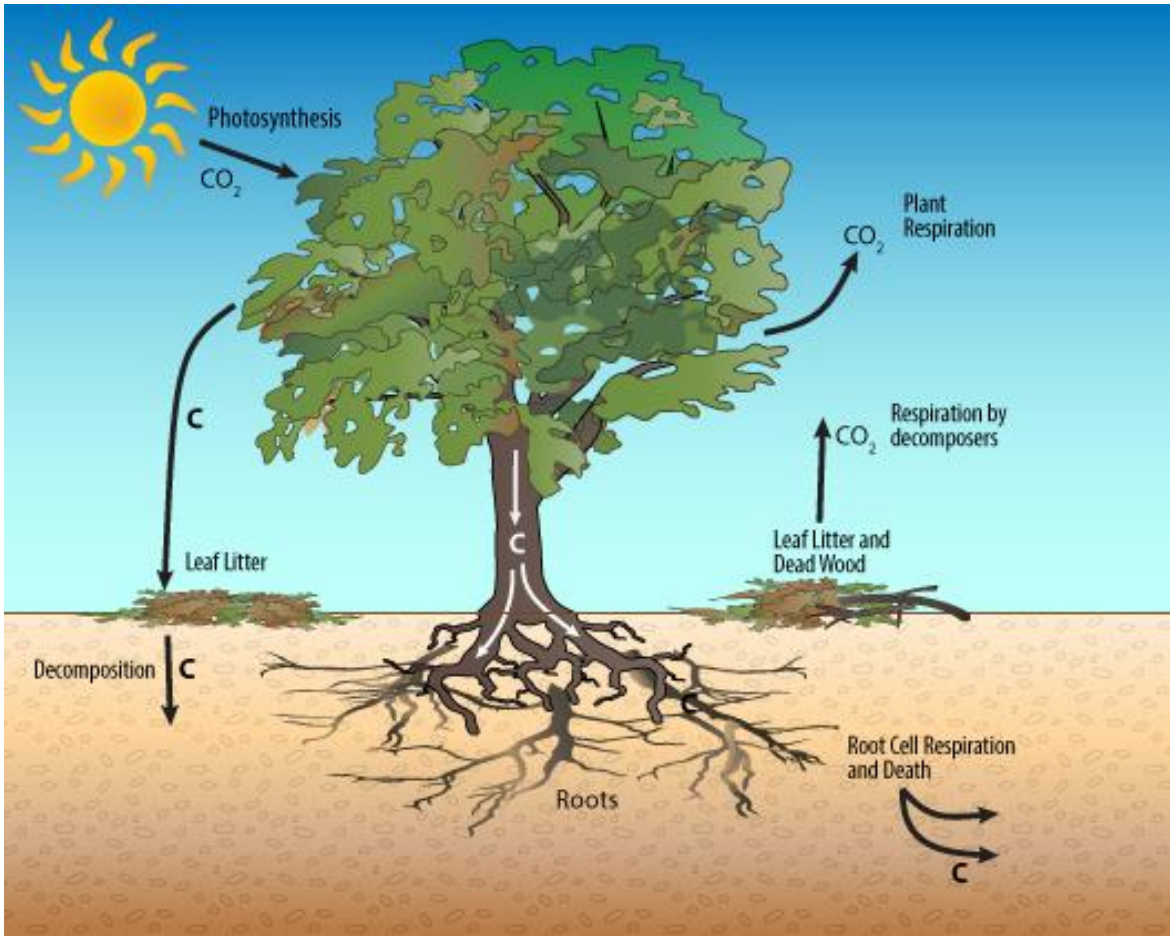
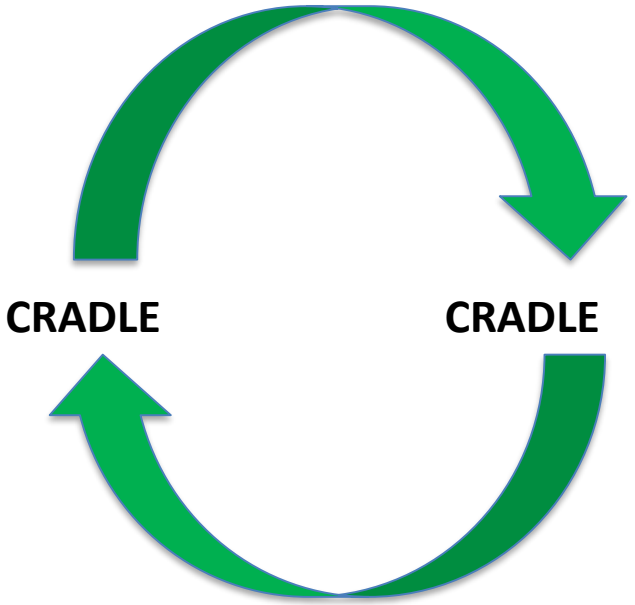


Photo Credit: Valerie Martin, TERC

Background Circular Economy

- Earth finite system
- Life cycle thinking
- Cradle to Cradle design
- Scarce resources

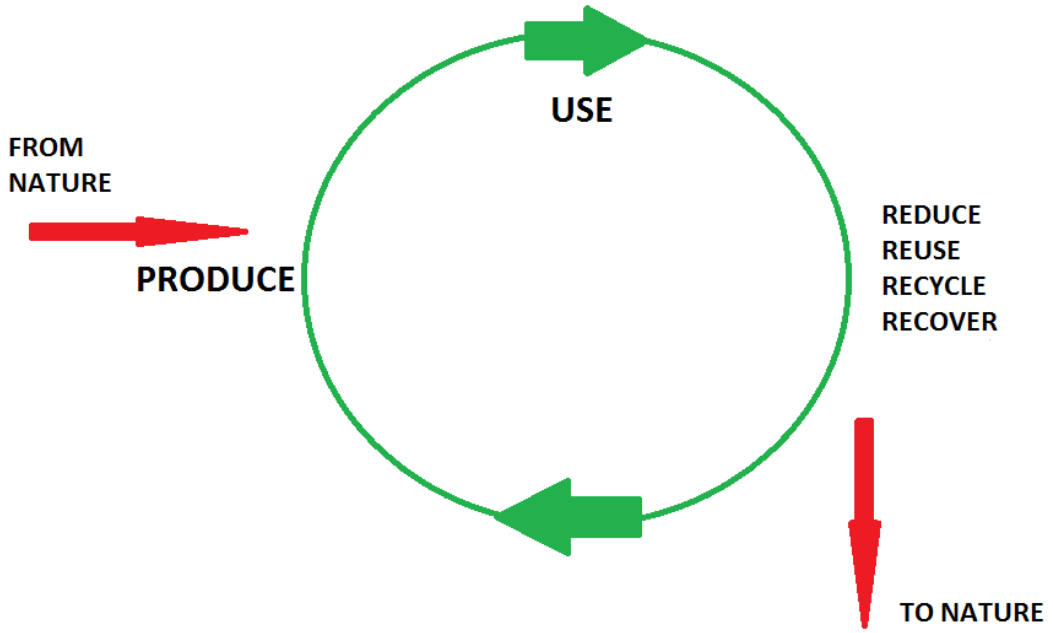


Kenneth E. Boulding, 1966: The Economics of the Coming Spaceship Earth

William McDonough and Michael Braungart (2002) Cradle to Cradle: Remaking the Way We Make Things

Definitions of a Circular Economy

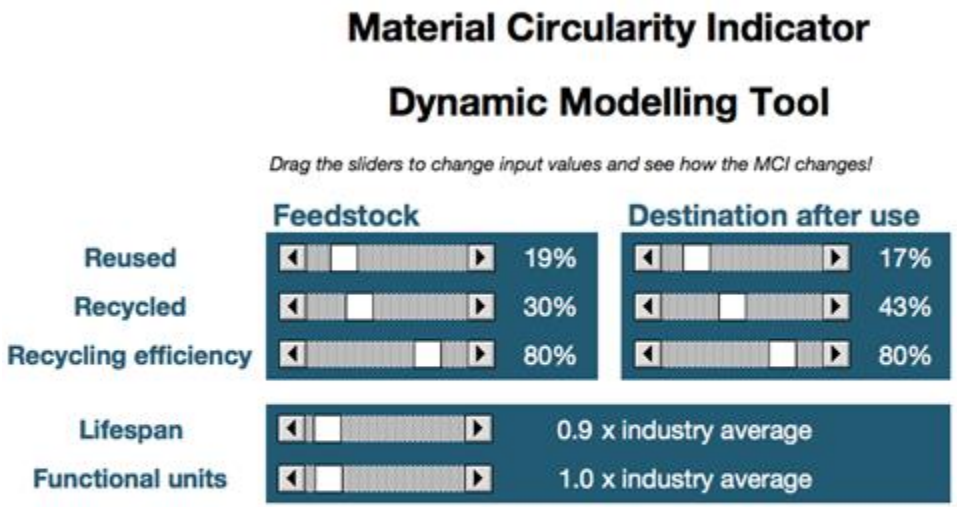
1. Reduce
2. Reuse
3. Repair
4. Refurbish
5. Repurpose
6. Rethink
7. Recycle
8. Remanufacture
9. Recover



"*Conceptualizing the circular economy: An analysis of 114 definitions*"
Julian Kirchherr et. al (2017)

«Circularity» Tools and Indicators

- Material Flow Analysis:
  - «*MFA is a systematic assessment of the flows and stocks of materials within a system defined in space and time*»
- Material flows and resource productivity
- Material Circularity Indicator



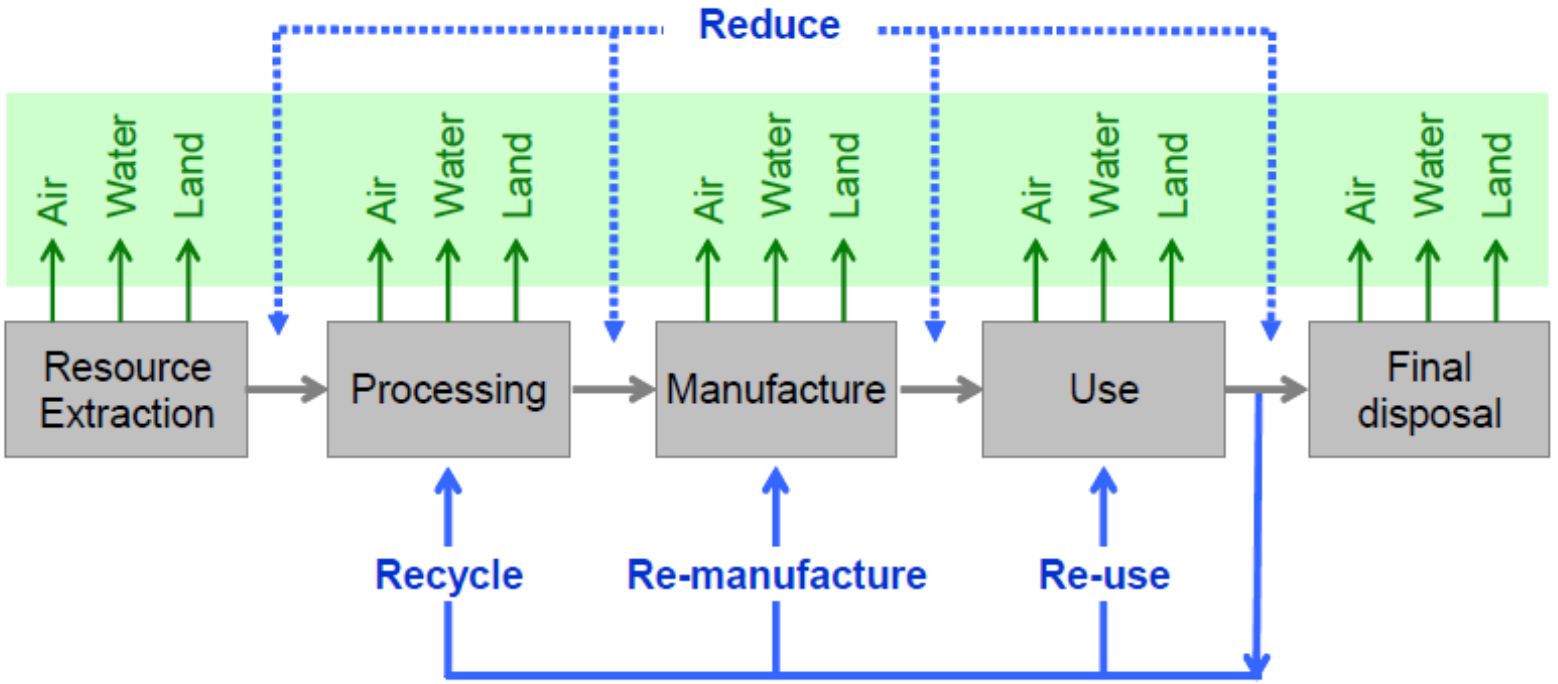
GRANTA MATERIAL INTELLIGENCE

Life

Brunner and Rechberger, 2004
OECD: Measuring material flows and resource productivity (2008) Guidelines
Granta Design and Ellen McArthur Foundation, 2015, EU research project LIFE

Circular Economy Thinking

2. Schematic representation of material flows through the commercial life-cycle



OECD: Measuring material flows and resource productivity (2008) Guidelines

Closed loop – Open loop recycling

- Open loop
  - Downgrades
  - New raw material
  - Not recycled indefinitely

- Closed loop
  - Into same type of product
  - “Eternal“ loop-indefinitely without degradation

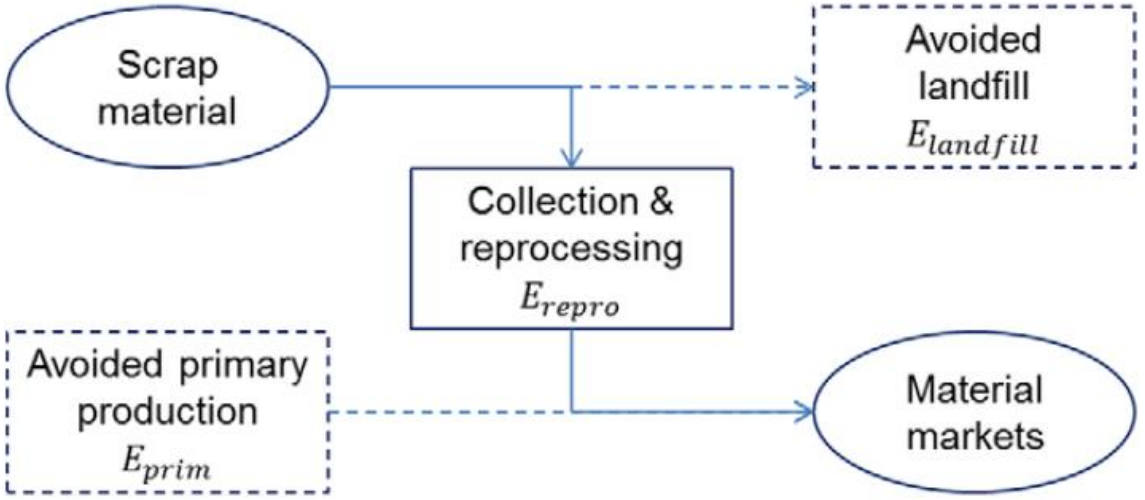


Figure 1 Environmentally successful recycling avoids primary production and landfilling of material.

Penn State: College of Earth and Mineral Sciences,
Geyer, R. et al (2015) Common misconception about recycling (Journal of Industrial Ecology)

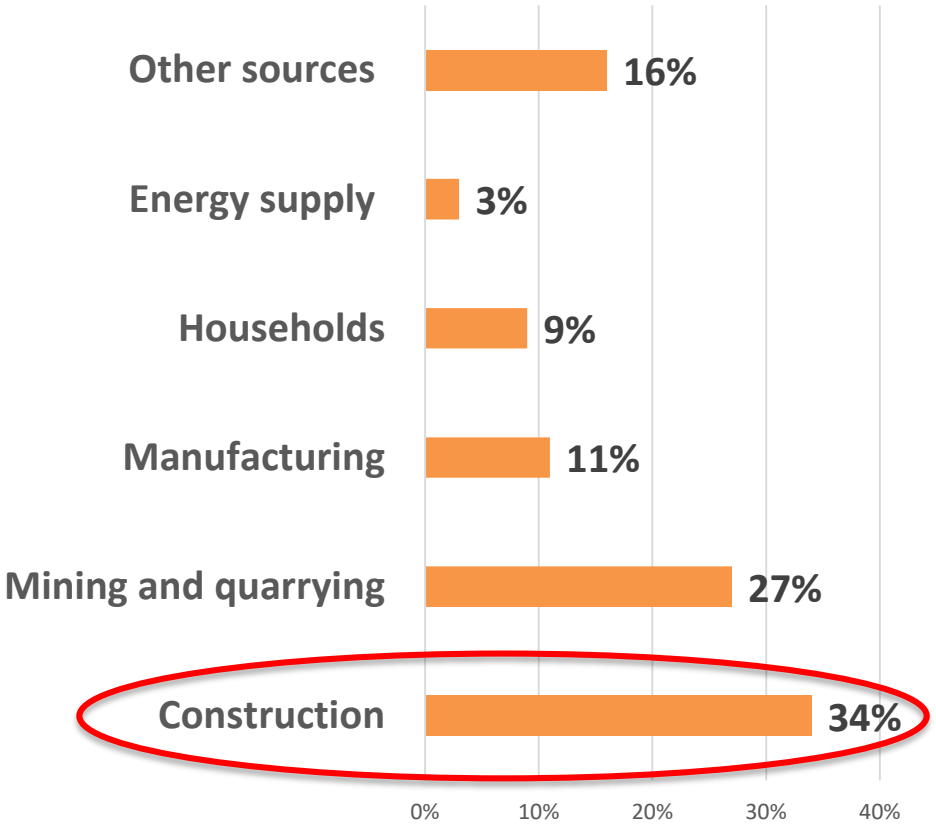
Building Sector Europe: Environmental impacts

- 40% of energy consumption
- 36% of CO_2 emissions
- 30-50% of material use

Photo: Arian Zwegers, Rundale Palace

Irati Artola et al. (2016) *"Boosting building renovation: potential value for Europe"*
Herczeg et. Al (2014) Resource efficiency in the Building Sector
https://ec.europa.eu/energy/en/eu-buildings-database

European waste by source



Materials

- Concrete
- Bricks
- Gypsum
- Wood
- Glass
- Metals
- Plastic
- Solvents…

European Environment Agency, 2017

Europe waste treatment

- 47% Landfill
- 36% Recycling
- 2% Incinerated
- 5% Energy recovery
- 10% Backfilling

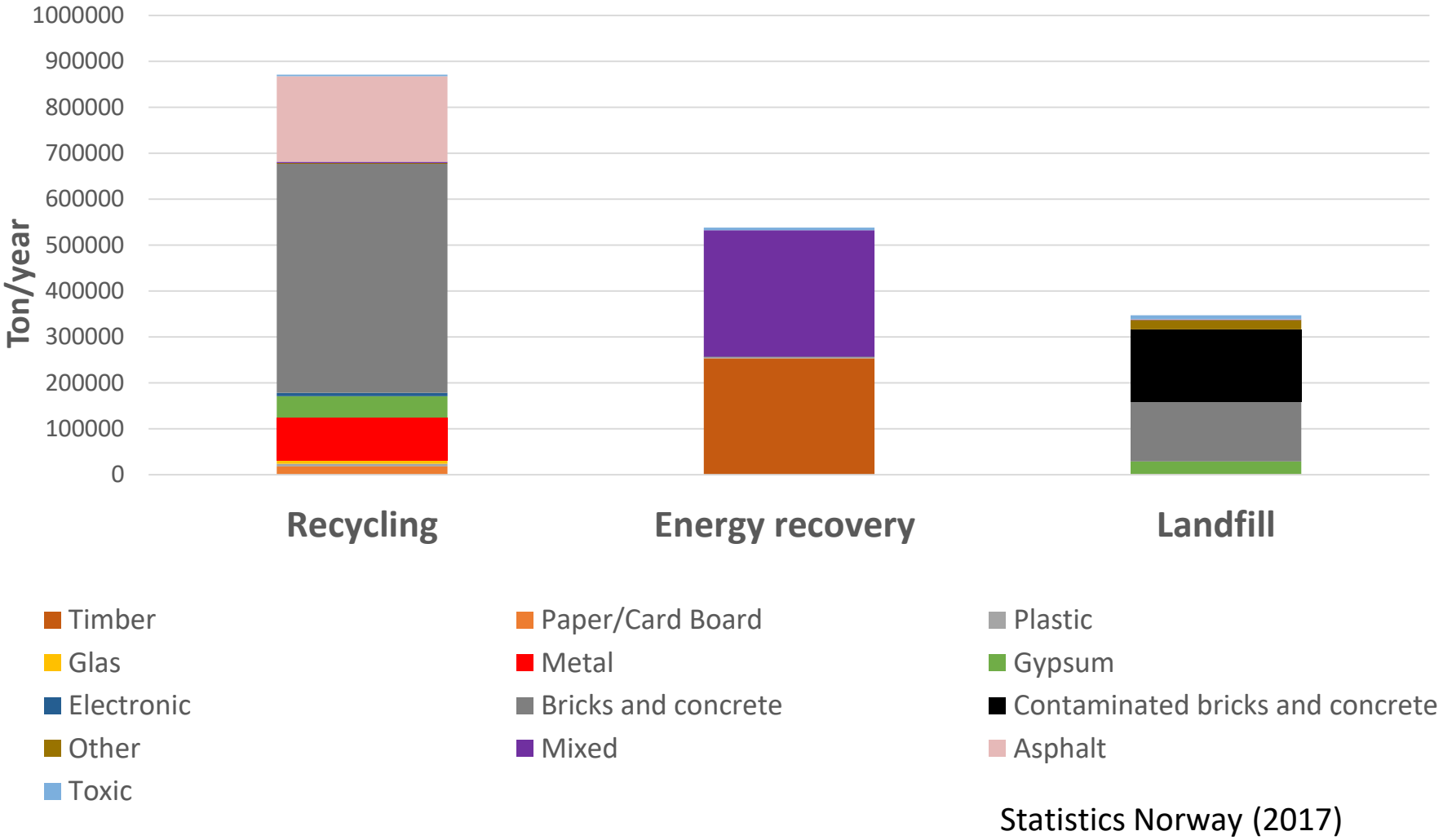
http://ec.europa.eu/eurostat/ waste statistics
Photo: Miljødirektoratet

Construction waste status: Case of Netherland

- >95% is recycled
- Foundation material
- 3-4% of new construction materials: Reused sources

Circularity in the Dutch construction sector (2015)
National Institute for Public Health and the Environment and the Ministry of Infrastructure and the Enviroment

Construction waste status: Case of Norway



Statistics Norway (2017)

Circularity in the Building Sector

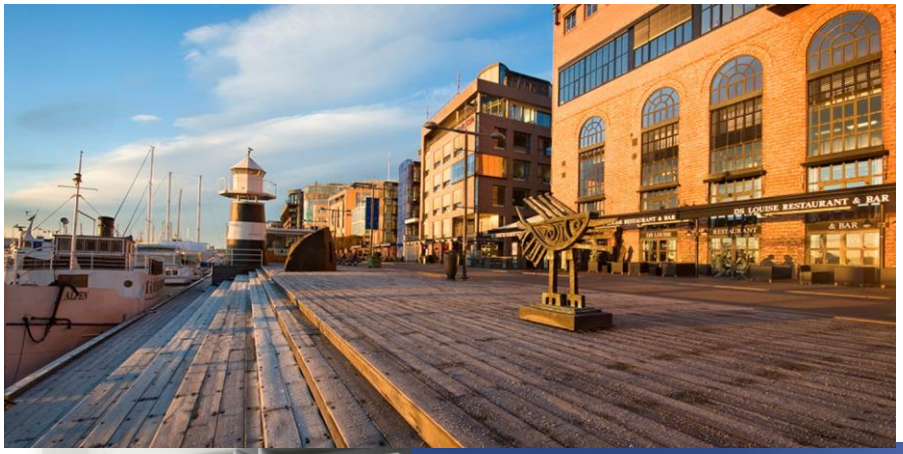
- Reduce demand
- Replace
- Circular design
- Building Services

- *Renewable energy*
- *Sustainable water*

Photos from Enova, Capsule Inn, Japan

Reduce demand new buildings: Opportunities

Creativity- Connections – Technology



- New «sharing» businesses
- Repair/Maintain business
- Innovative redesign
- Effective resource use

Photos: IKEA, w.VisitOslo.no

Reduce demand for new buildings: Challenges

- Disturbs local markets
- Old buildings - not big or fancy enough
- Culture
- Changing demands
- Not designed for reuse/flexibility
- Slow rate of energy renovations/high costs

Photo: Sivert Mathisen Storhaug

Reuse/Recycle materials: Challenge

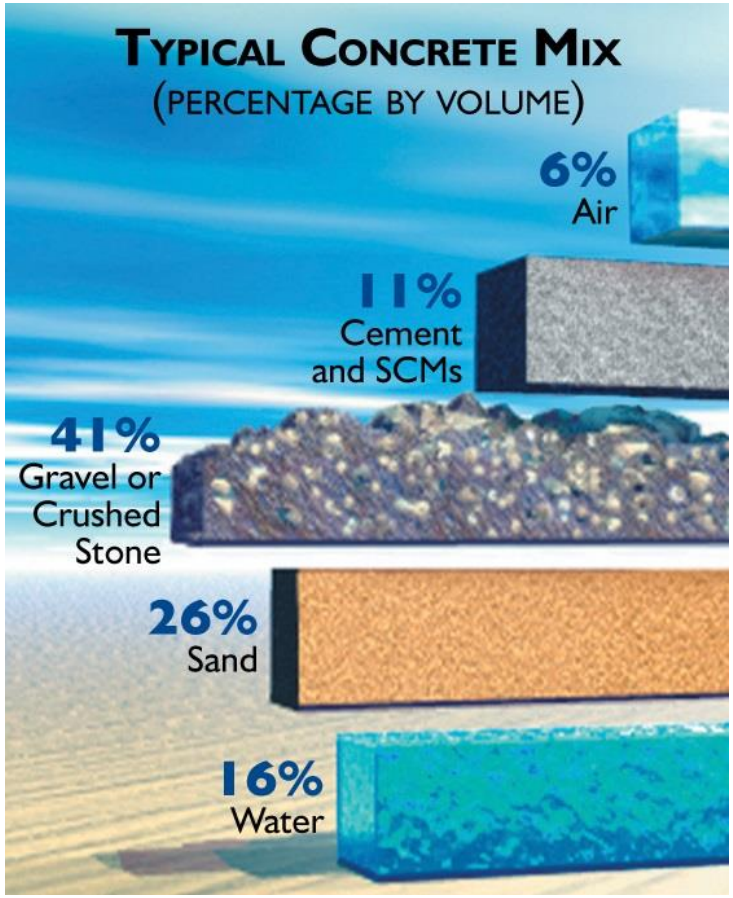
- What materials are available?
- Demand – supply?

	2015	2055
New materials	15.4 Mt (14, 1.4)	8.1 Mt (4.3, 3.8)
Waste	2.6 Mt	6.3 Mt

Heeren, N. and Hellweg, S. (2017) *«Tracking construction material over space and time: Prospective geo-referenced modeling of building stocks and construction material flows»*

- Material flow analysis
- Swiss residential building stock
- Bottom up – analysis
- Material stock and flows
- 2015-2055
- Based on national statistics
- Population growth 26%

Reuse/ Recycling materials: challenge/opportunity



Concrete:

- 89% Natural materials
- 11% Cement
  - Supplementary cementitious material (SCM)

Steel:

- Recycled into new steel products
- Scrap quality

Haupt, M (2017) Influence of Input-Scrap Quality on the Environmental Impact of Secondary Steel Production. Canada Concrete industry, www. rediscoverconcrete.co

Reduced demand for new materials: Reuse/recycle challenges

- Availability
- New materials cheap
- Technical durability
- Regulations
- Toxic/composit materials
- Recyclable?

– Irreversible processes
– Technology
– Robust structures

Circularity in the Dutch construction sector (2015) National Institute for Public Health and the Environment and the Ministry of Infrastructure and the Environment

Reduce demand new materials: Reuse/Recycle opportunities

- Valuable materials
- Ebay
- „Cool“ design
- Business:
  - Connections – Logistics
  - Prepare for reuse

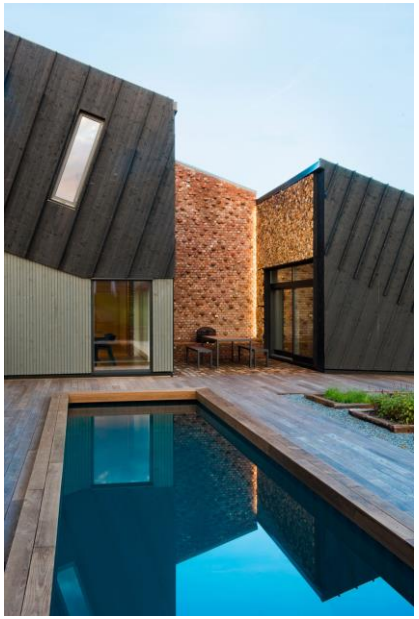
- New technologies
- «Free» raw materials
- Material development
- Material passport
- Buildings as Material Banks

BAMB
BUILDINGS AS MATERIAL BANKS

www.BAMB2020.eu

Reduce demand new materials: Reuse opportunities

- Timber
- Metals
- Bricks
- Windows
- Glass
- Doors
- Furniture



Photos: Powerhouse Kjørbo, Multikomfort (Snøhetta)
Cicero, Oddekalv (Bergens Tidene)

Reduce demand new materials: Reuse opportunities

Final Report Nordic Built Component Reuse (2016)

Gjenbyg As
AsplanViak
Hjelnes Consult
Malmø T.H

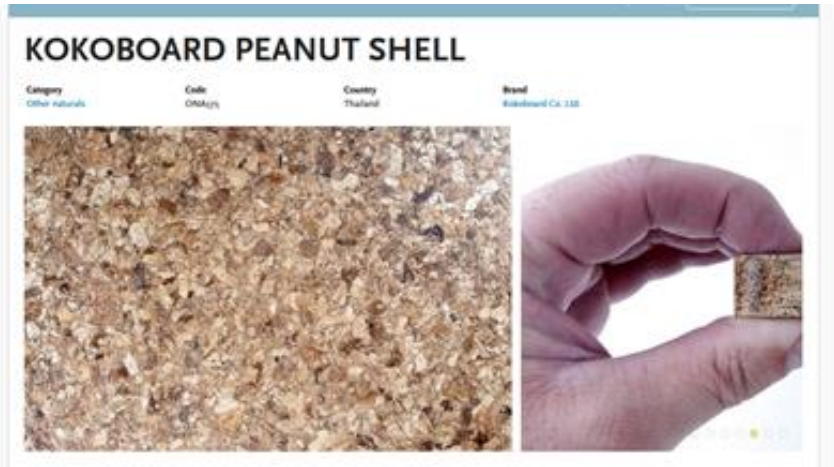
- Figure 39-41 / Details of the Spiro Facade system prototype. Left: sourced ventilation ducts.

- Figure 42 / Prototype of Spiro Facade

Reduce demand new materials: Recycle challenges and opportunities

Photo: David Tsay

Renewable material opportunities/challenges



Jones and Brischke (2017)

Photos from Hunton and Treteknisk

Building services

- Sell light?
- Sell heat?
- Sell clean air?

Challenge

- Rapid development
- Short service lifetimes
- Fragile

Opportunities

- Design for replacement/reconstructions
- Sell „Service“

„Circular“ design: Challenges and Opportunities

- Adaptivity
- Deconstruction
  - Push-fit connections
- Reuse/recycling
- „Clean“
- Durability
- Health

Opportunities

- Product development
- Flexibility/mobility

Challenges

- Long service lifetimes
- Many stakeholders
- Different criterias

Photo: www.lego.dk
https://www.buildingcentre.co.uk

Circular “Modules”?

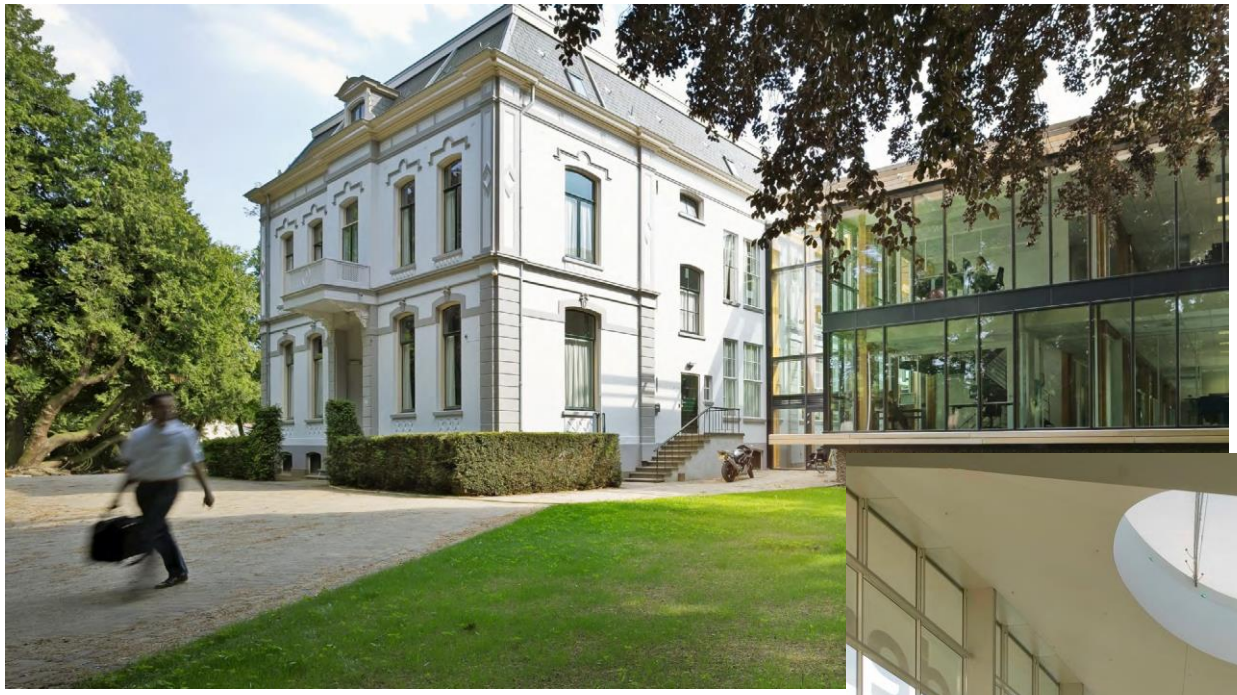
Photo: Moelven ByggModul AS

Circular Design

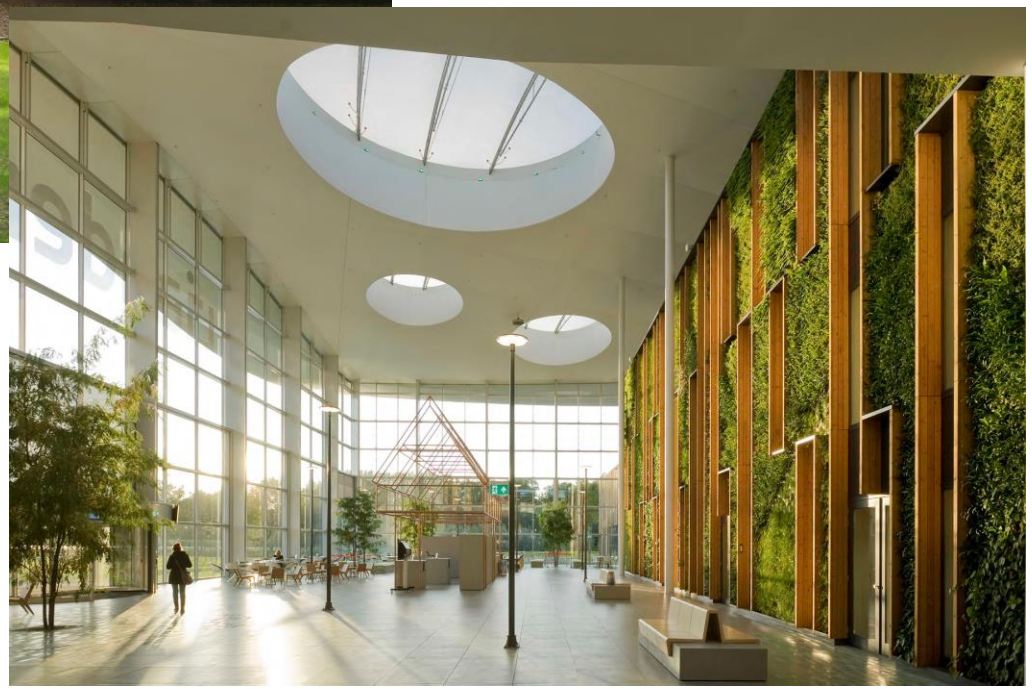
“

Arup engineers, Circular House London
Photo: Ben Blossom,

Cases: Netherland



Brummen Town Hall
Designed for
Reconstruction



Leander Head Office
80% of original raw materials reused
Re-constructible

Circularity in the Built Environment: Case studies a compilation of case studies from the ce100 (2016) (EllenMacArthur Foundation)

Circular Economy in the Building Sector: Opportunities

Dutch plant to recover cellulose from used toilet paper in sewage

Submitted by: **The Two Sides Team** 25/07/2017

Talk about upcycling—a Dutch treatment plant is recycling discarded toilet paper from the sewage into cellulose, and the resulting product has already been used for a practical purpose.

The facility is touted as the world's first in recovering cellulose from used toilet paper, Energy & Environment Management reported June 15. The technology was developed by Dutch company CirTec BV, which demonstrated that it was feasible to extract clean cellulose from sewage and create fibrous or pelletized forms.

The plant, opened on June 29, has a capacity of about 400 kilograms/day. The cellulose will be exported to England for use as a raw material to produce biocomposite and other products, according to a CirTec press release. In one demonstration project, a bicycle path was made of asphalt processed in part with the recycled cellulose.

Read more here **www.cirtec.nl/en/cirtec-geeft-gebruikt-toiletpapier-tweede-leven/**

From challenges to opportunities

CHALLENGE
Unclear concept?
Availability
Technical uncertainty
Not scarcity driven
Changing demands
None existing markets
Irreversible/composite

Opportunity

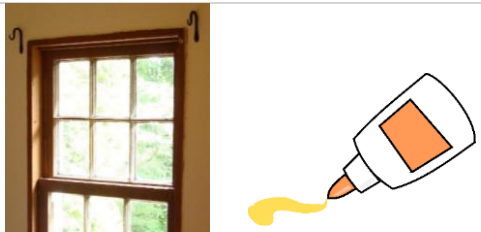
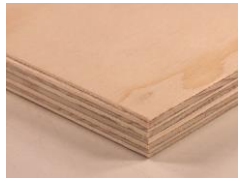
- Clarify
- Predict/material passport/new business
- Develop assessment methods
- Reduce environmental impacts
- Plan
- Create markets
- New technology/circular design

References & Further reading

- **Circularity in the Dutch construction sector (2015) National Institute for Public Health and the Environment and the Ministry of Infrastructure and the Environment**
- Circular Economy: Improving the Management of Natural Resources (Swiss Academies of Arts and Sciences) Lehman et al. (2014)
- www.EllenMacArthurFoundation.org
- www.bamb2020.eu Building as material banks.
- Circularity in the Built Environment: Case studies a compilation of case studies from the ce100 (2016) (EllenMacArthur Foundation)
- Indicator based on Material Flow Analysis/Accounting (MFA and Resource Productivity (2014) Asia Resource Circulation Policy Research Group
- Herczeg et. Al (2014) Resource efficiency in the Building Sector

Conclusion

- Circular thinking is in action
- Important tool/thinking to reduce environmental impacts/resource extraction
- Develop tool/definition further

Material use in Buildings

- High tech
- Low tech
- Chemicals
- Composit materials