NTNU

Norwegian University of
Science and Technology

Sustainable tunneling

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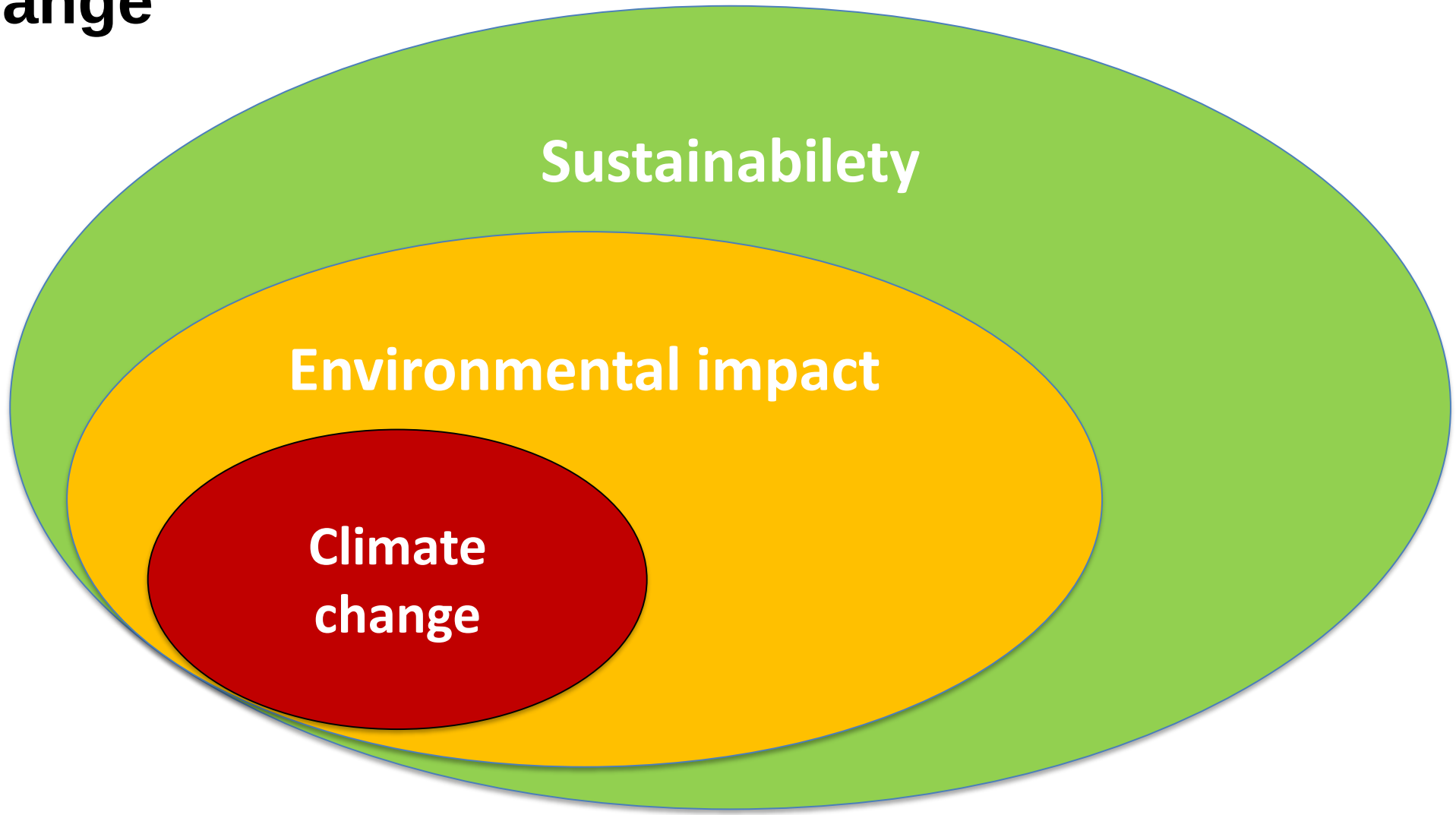
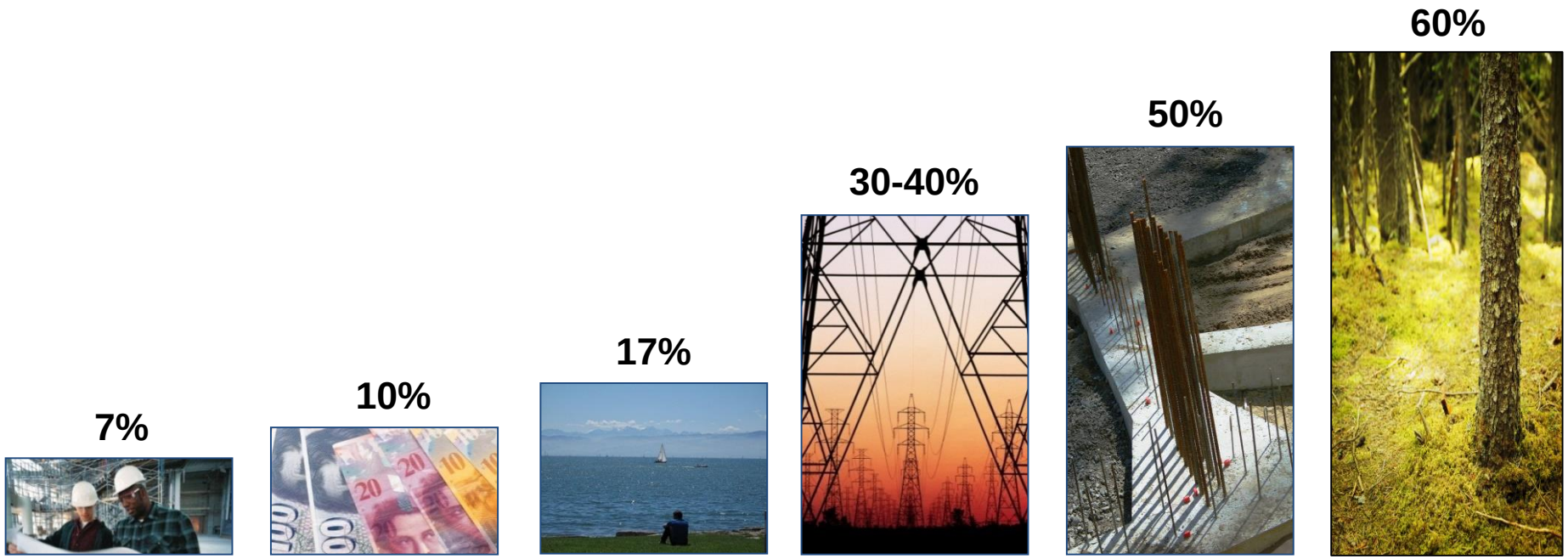
We have limited resources at our disposal

Sustainabilety, Environmental impact and Climate change



UN’s Sustainable Development Goals

Worldwide importance of the construction industry



Source: Visualisation based on data from UNEP-SBCI, IEA and EU statistical office.
H. Wallbaum/Chalmers

Where humanity's CO_2 comes from

91% 33.4 billion metric tonnes

Fossil Fuels & Cement 2010

9% 3.3 billion metric tonnes

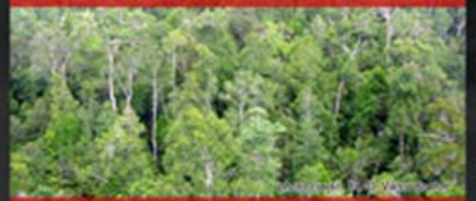
Land Use Change 2010

Where humanity's CO_2 goes

50% 18.4 billion metric tonnes

Atmosphere 2010

26% 9.5 billion metric tonnes



Land 2010

24% 8.8 billion metric tonnes

Oceans 2010

Global Carbon Project

2010 data updated from:
Le Quéré et al. 2009, Nature Geoscience
Canadell et al. 2007, PNAS

CO2Now.org

Environmental Impact, E_i

$$E_{i_{tot}} = \sum_{E_i} \left(E_{i_e} + E_{i_p} + E_{i_t} + E_{i_u} + E_{i_m} + E_{i_d} + E_{i_w} \right)$$

tot= total

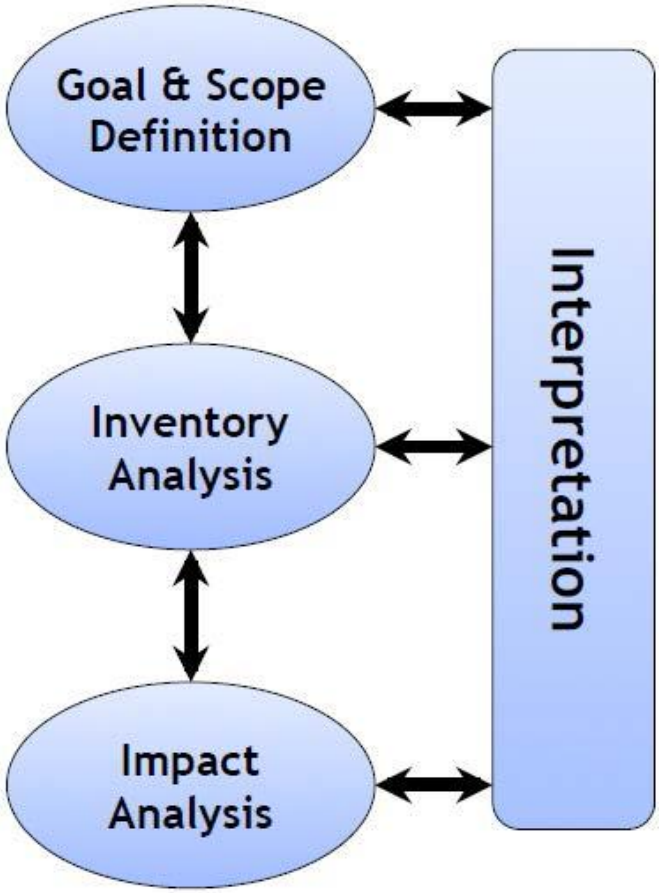
e= extraction
p= production
t= transport
u= use
m= maintenance
d= deconstruction
w= waste handling, end of life

Why Life Cycle Assessment (LCA)?

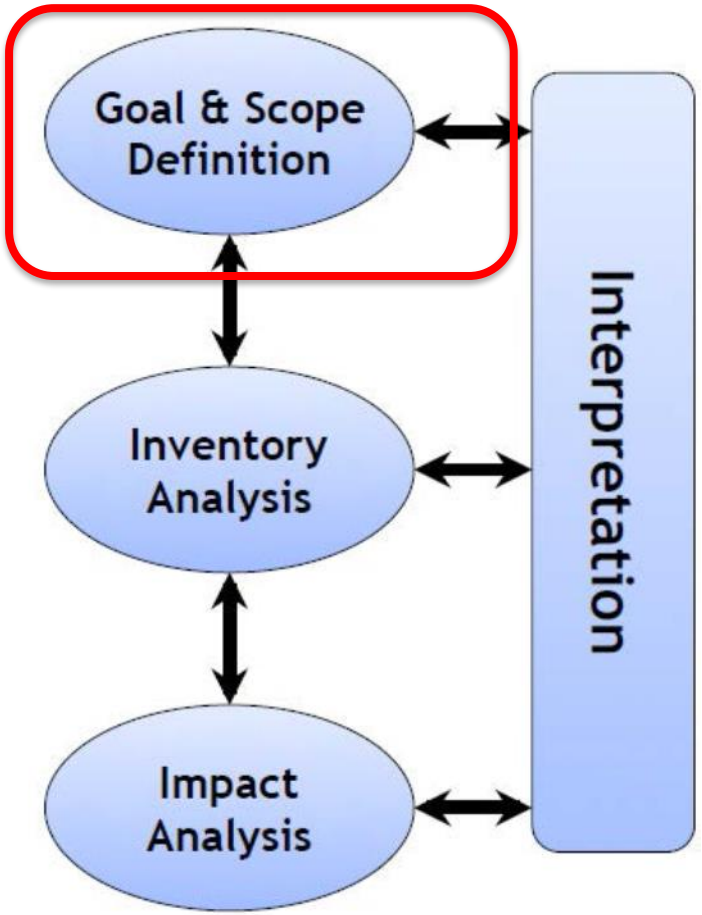
- To understand the complete lifecycle of a product or service, from;
  - Materials
  - Construction
  - Use
  - Maintenance
  - End of life

LCA Methodology: ISO 14040 Standard

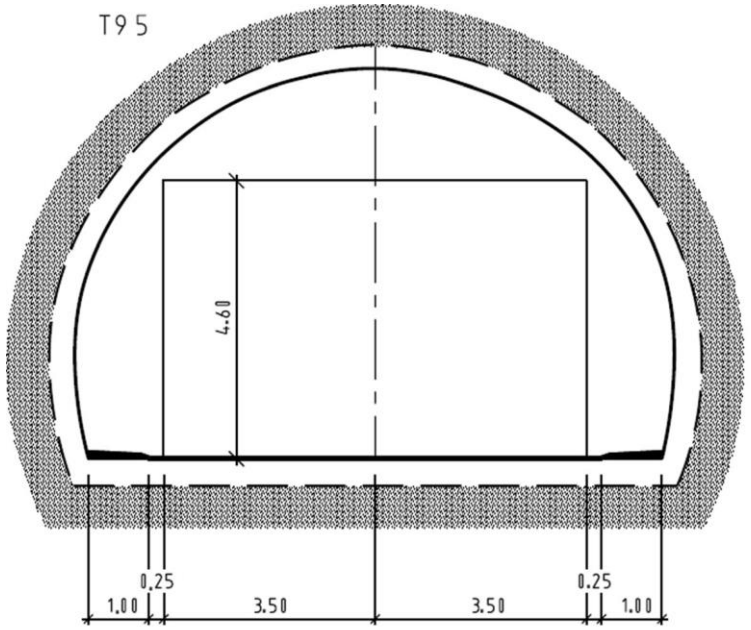
- Goal & Scope Definiton
  - Unit of analysis
  - Materials, processes, or products considered
- Inventory Analysis
  - Identify & quantify
    - Energy inflows
    - Material inflows
    - Releases
- Impact Analysis
  - Relating inventory to impact on world
- Interpretation

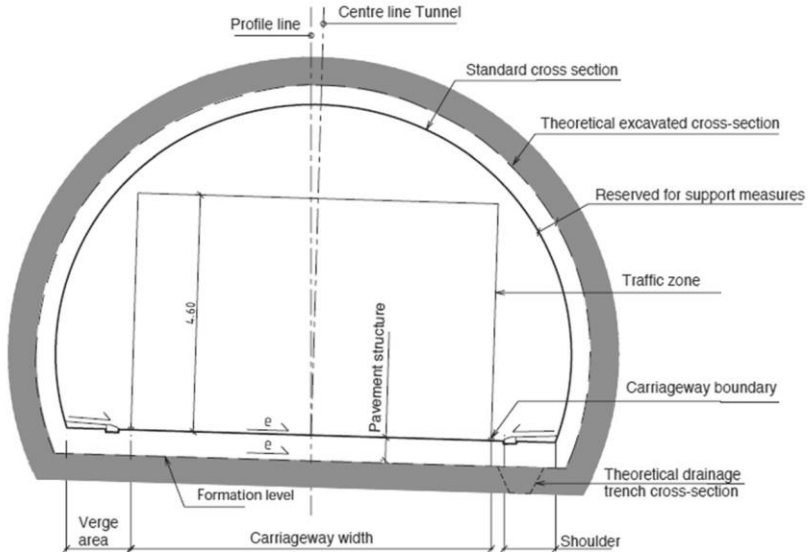


Goal and Scope

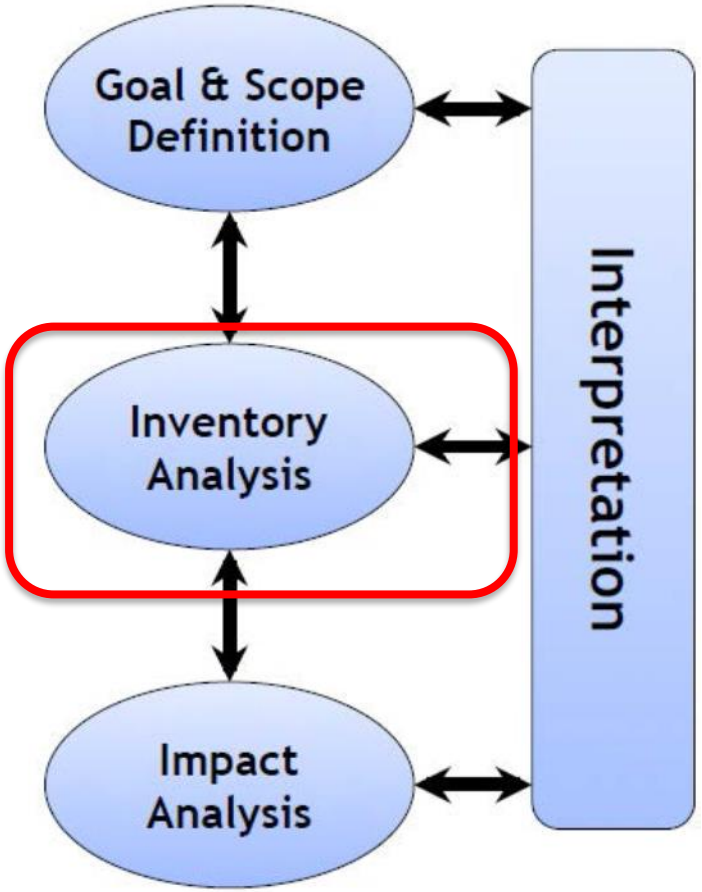


- To define what is the function
  - What is to be studied ...
- Functional unit:
  - 1 km main tunnel
  - X m^2 cross section

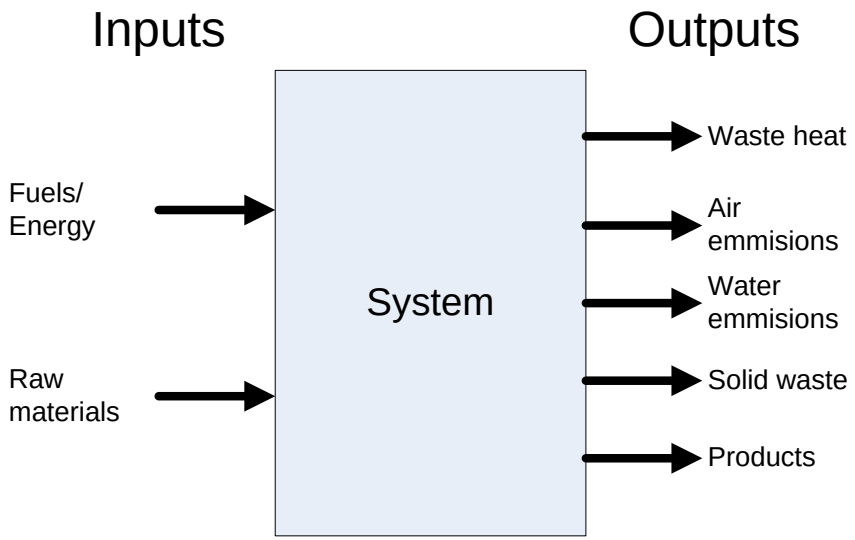




Inventory analysis



- An environmental inventory for this system is therefore simply a list of the quantities of all of the inputs which pass from the system environment, across the system boundary into the system and all of the outputs which pass from the system across the boundary and into the environment.
- Inventory analysis make no value judgments about the relative significance of the different inputs and outputs; instead the analysis aims to provide the quantitative data upon which judgments can subsequently be made



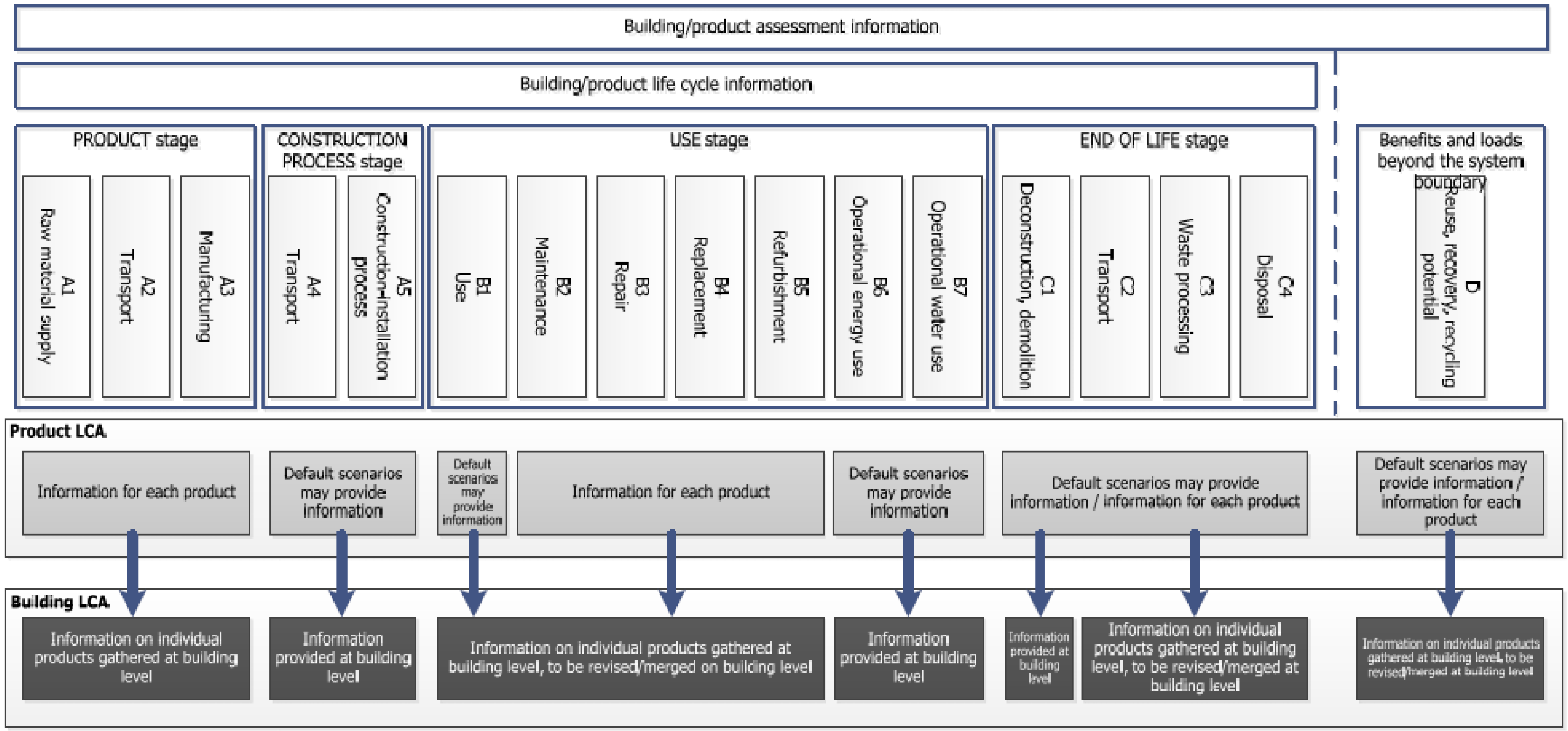
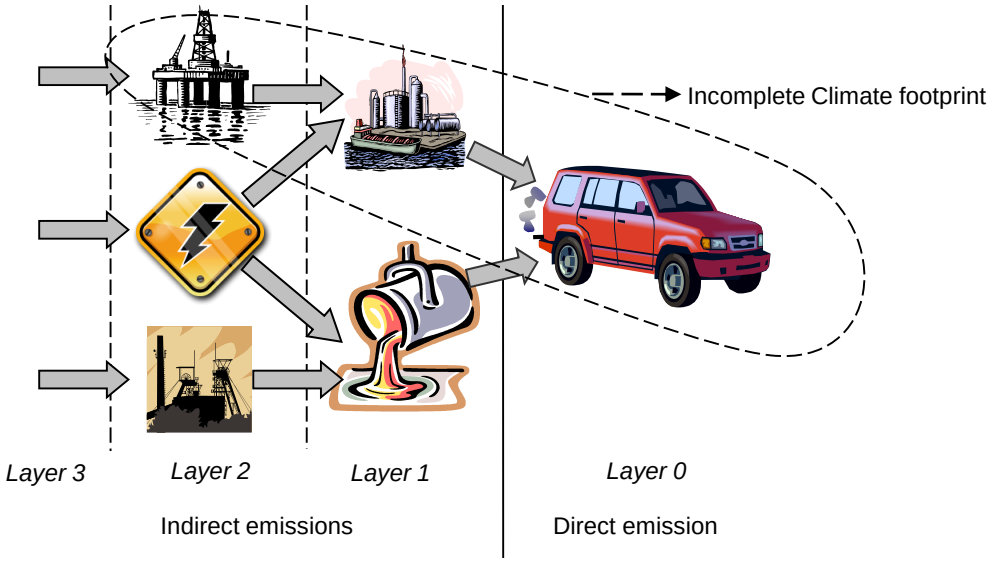


Figure 2: Relation between product LCA and building LCA along the life cycle modules. Figure based on EN 15804and EN 15978

Direct and indirect emissions



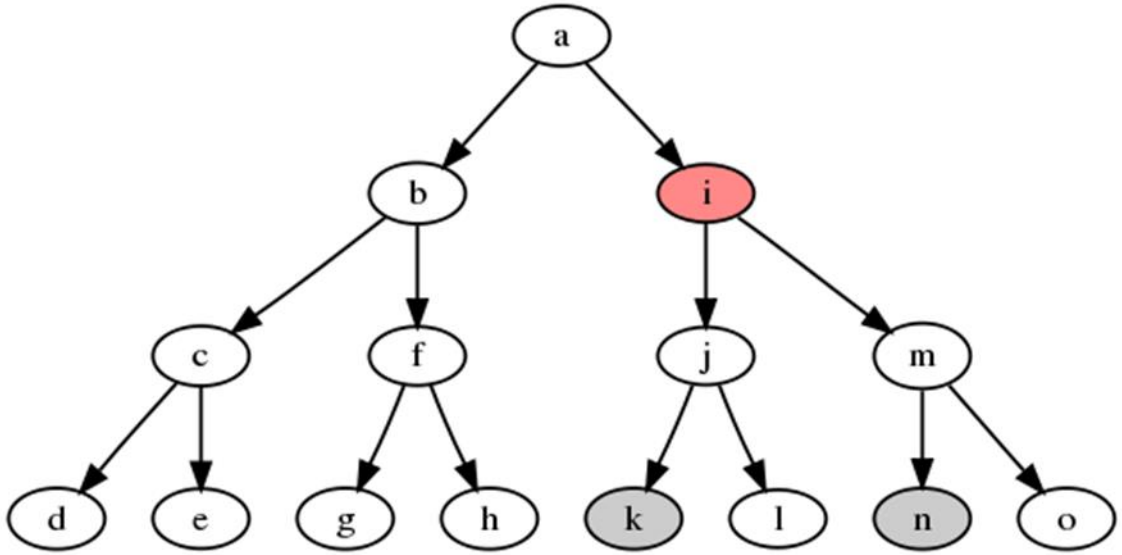


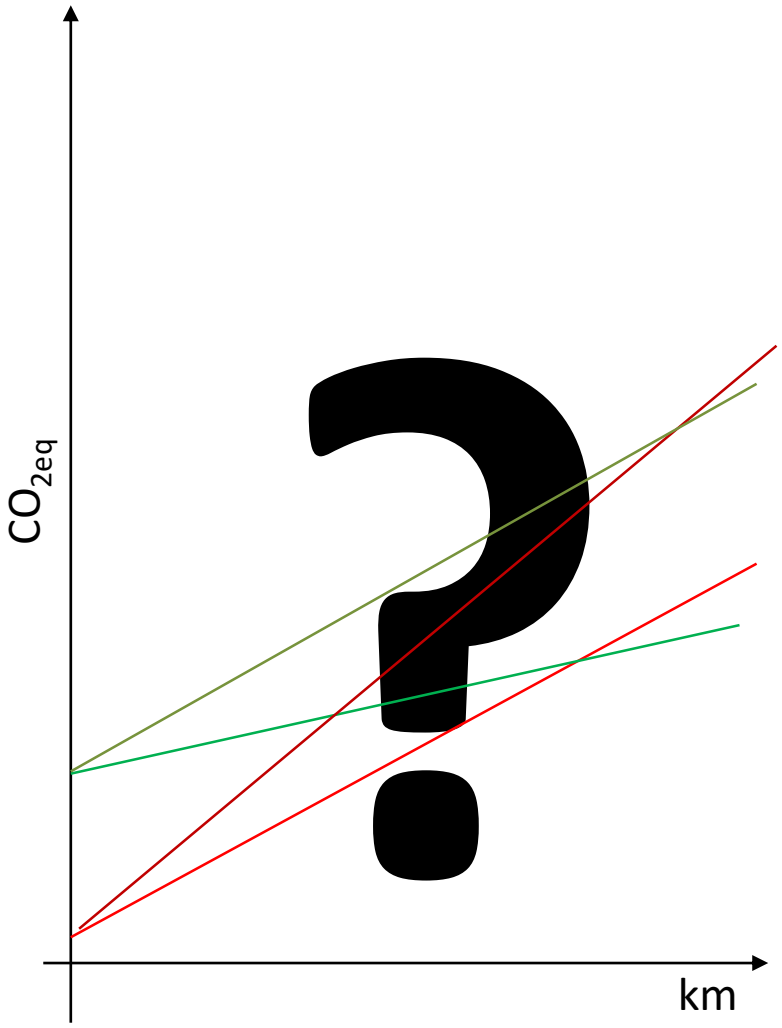
Figure C. Solli, MISA AS

D&B vs TMB method ...

	D&B	TBM
Machinery	x	X
Transport to site	x	X
Site preparation	x	X
Explosives (blasting)	X	?
Ventillation	X	x
Excavation, rubble removal	x	x
Transport from site	x	x
Rock support	?	?
Tunnel equipment	x	x
Rail or road	x	x
Etc ...	x	x

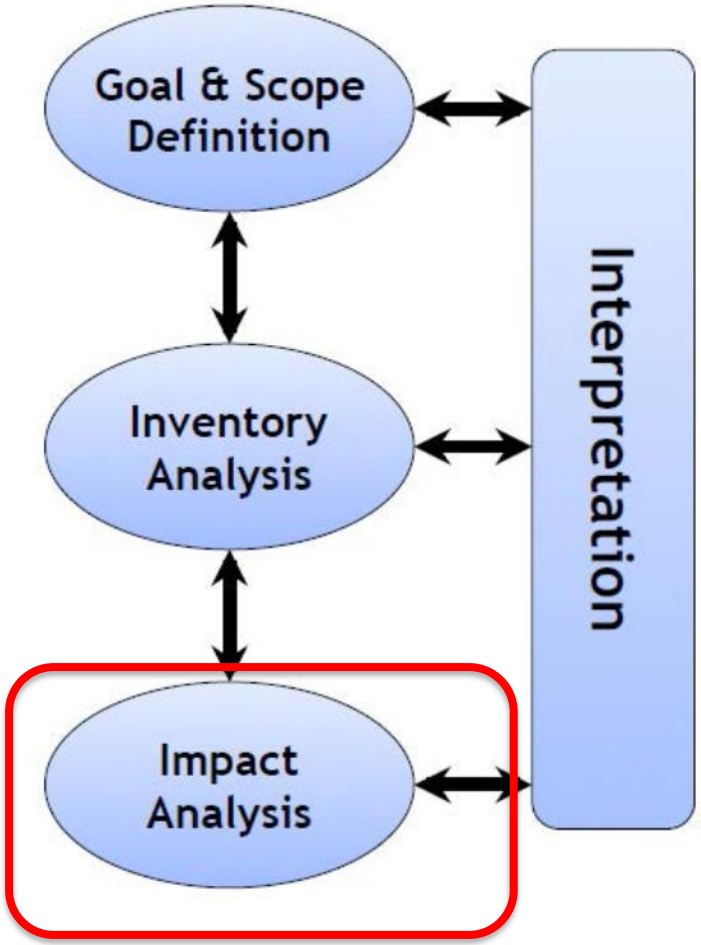
TBM

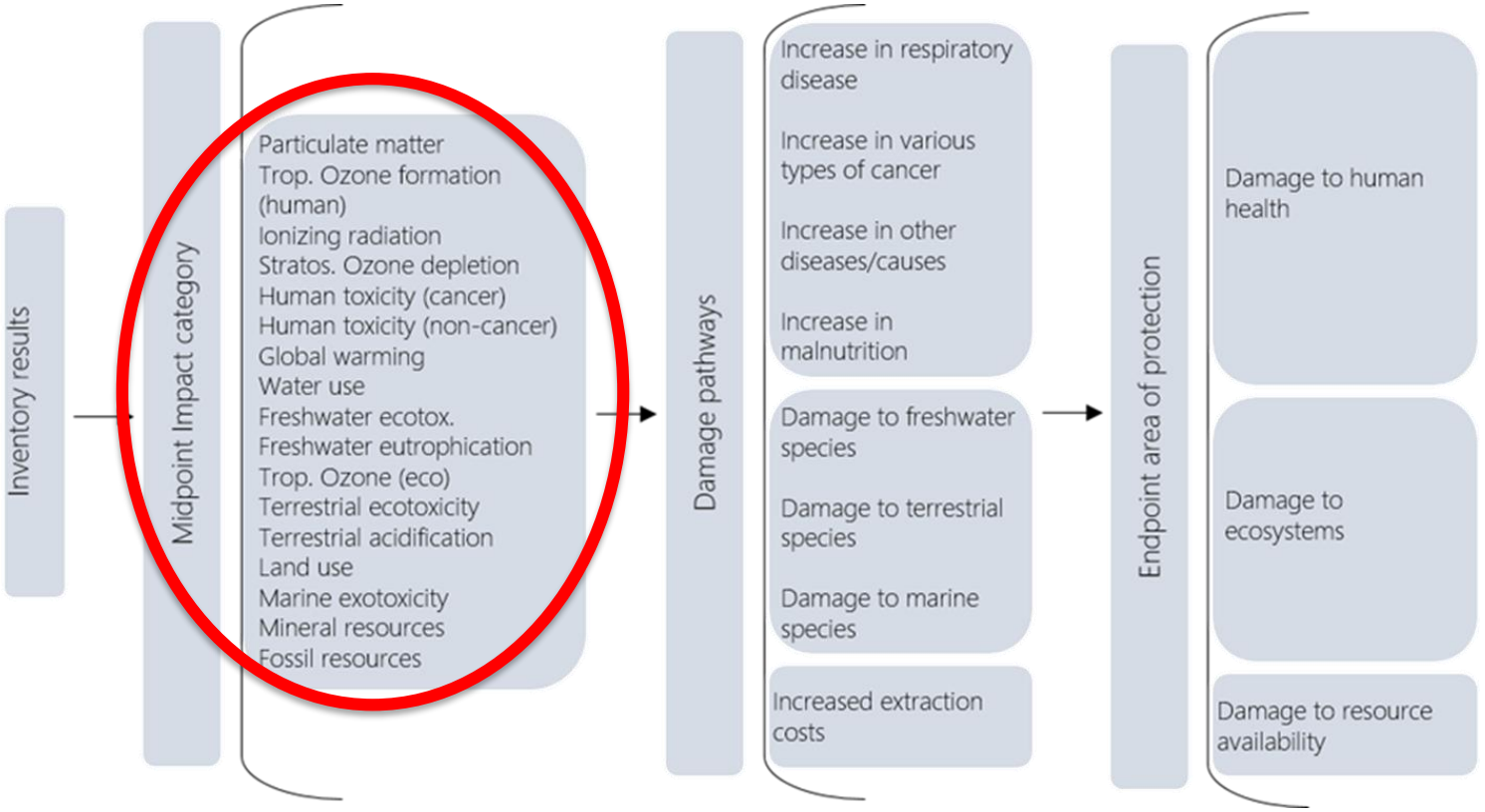
- Tunnel equipment
- Rock support
- TMB Excavation
  - Boring
    - TBM
      - Machinery
      - Steel
      - Etc ...
    - Steel
    - Electricety
  - Auxillary systems
  - Rock removal
- Site preparation



- We know that TMB has a higher «start up» cost, both monetary and environmental ...
- We know that rock support has a high cost ... both monetary and environmental ...
- We are currently working on the TBM method
- We belive that D&B is best on short tunnels, and TBM is better on long tunnels,
  - we are working on the range for different rock classes

Life Cycle Assessment






Thank you very much for the attention
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