EMPA

Materials Science & Technology

Integrating technical scaling laws into LCA

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Scaling

- A transformation that enlarges or diminishes objects
- 1. Estimation of data
  - Population size
  - Metabolic rate
  - Earthquakes
  - Financial markets
  - Production costs
  - …
- 2. Underlying mechanisms
  - Allometry
  - Euclidean relationships
  - …

Function of scaling laws

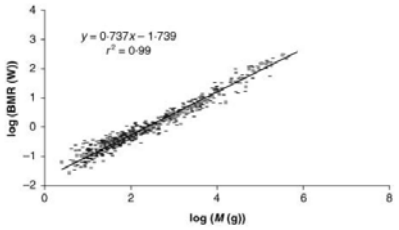
- Commonly expressed as a power law

$$y = a\, x^b$$

$$log\,(y) = b\, log\,(x) + log\,(a)$$

b: scaling factor
a: standardized constant

- Isometric $b = 1$
- Geometric $b = ⅓$
- Allometric $b = ¼$



(Savage, Gillooly et al 2004)

Scaling in LCA

- Many situations where no or incomplete data available
- Pilot plant process vs. full scale processes
- Small system vs. large system
- Many changes
  - Technological
  - Societal
  - Economical
  - Environmental
  - Legislation
  - …

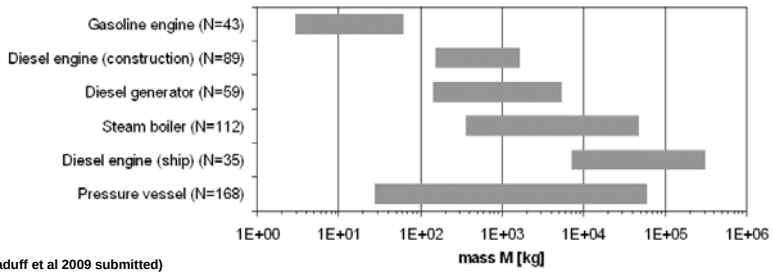
Objectives of this study

1. Goal
- Establish scaling laws for industrial equipment
- Identify underlying mechanisms
- Comparison scaling in living and non-living systems

2. Goal
- Establish scaling laws for the impacts of these equipments (production & operation)
- Determine „rule-of-thumb“ to scale LCA results
- Implement scaling laws in LCA

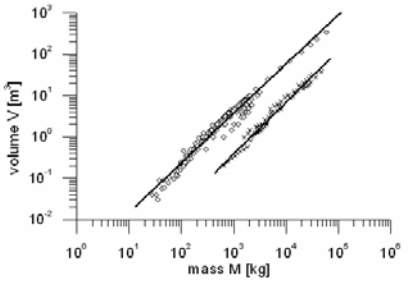
Part 1: Establishing scaling laws

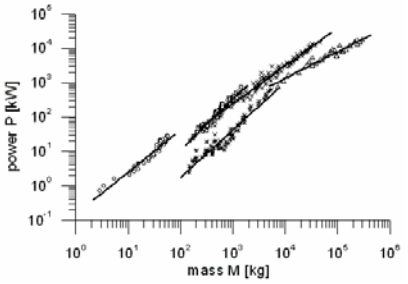
- Industrial equipment, total of 504 cases
- Variables
  - Volume: $V \propto a_v M^{b_v}$
  - Fuel use: $F_{in} \propto a_F M^{b_F}$
  - Power output: $P_{out} \propto a_p M^{b_P}$

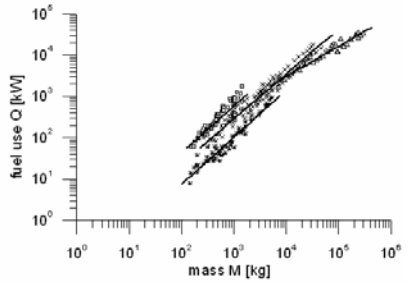


(Caduff et al 2009 submitted)

Results



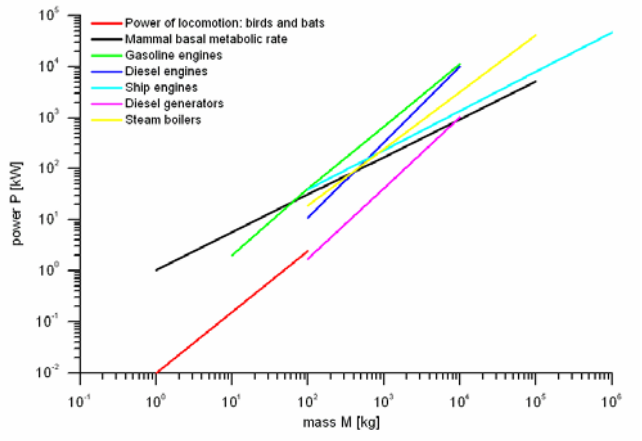




Equipment	r^2	b (95% CI)
Gasoline engine	0.94	1.27 (1.17 – 1.37)
Diesel engine	0.95	1.51 (1.44 – 1.59)
Ship engine	0.95	0.79 (0.73 – 0.86)
Diesel generator	0.94	1.43 (1.35 – 1.53)
Steam boiler	0.97	1.13 (1.09 – 1.17)

(Caduff et al 2009 submitted)

Comparison Biology



(Caduff et al 2009 submitted)

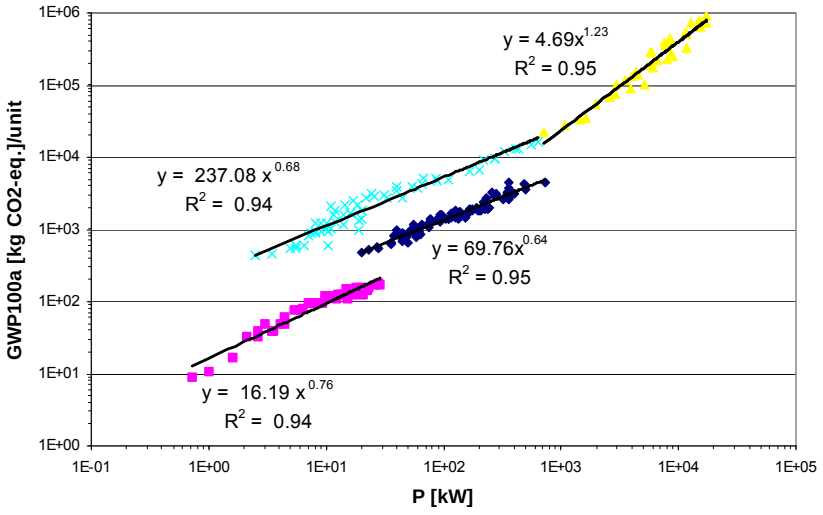
Scaling in LCA: Conclusion part 1

- Scaling of industrial equipment is not isometrically
- Material input vs. power & fuel use is not isometric, effects on LCA expected not to be isometric
- Results are comparible with active biological systems

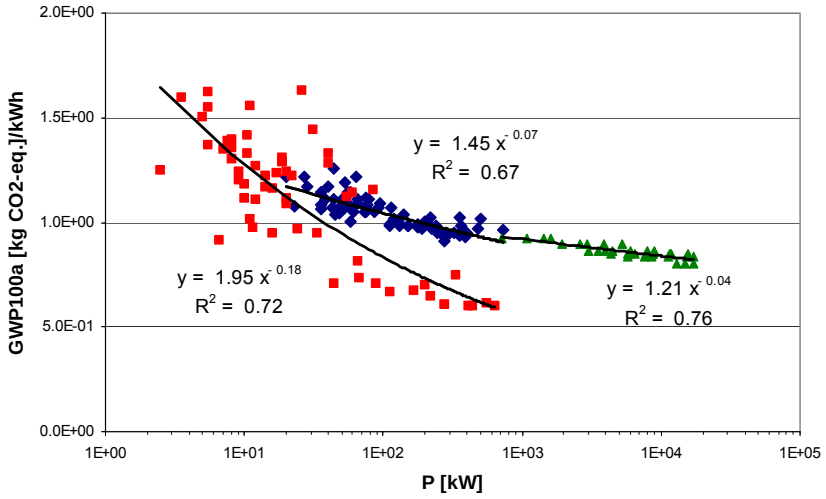
Study part 2:

- Establish inventory for each dataset
- Calculate impact of production and operation
- Plot & regression
- Determining scaling factor

Engines production – GWP / unit



Engines operation – EI99 (HA) / kWh



Scaling in LCA: Conclusion part 2

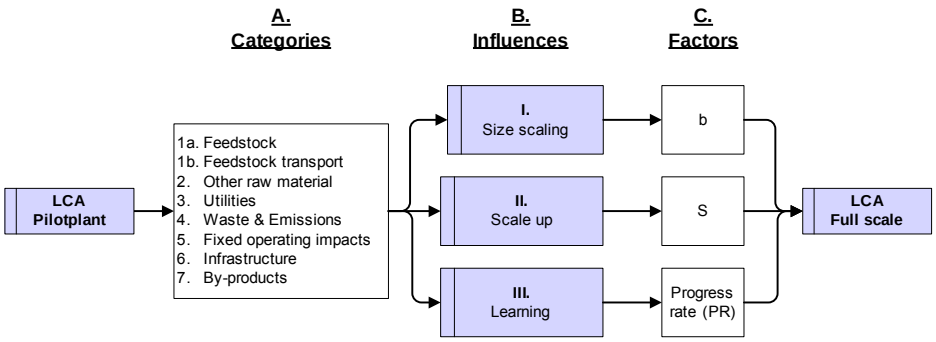
- Environmental impacts per FU do not remain constant
- First indication: „rule-of-thumb“ for infrastructure of b = 0.65
- Additional tool for prospective technology assessments

- Data intensive
- Material changes not included, still data missing
- Labour- and time intensive development work
- „pure“ size effects

Integration in LCA

- Parameterise inventory/impact using power law
  - Every single input with a factor, or
  - one scaling factor for process of material, or
  - rule-of-thumb for whole groups, e.g. plastics, infrastructure, energy, chemicals, etc.
- If no factors available → method / guideline on how to establish such factors
- Integration in e.g. ecoinvent possible, if parameterisation is possible.
- Applicable mainly for short term changes, within same technological settings
- Method can be used to also implement other influences such as learning

Outlook: Framework



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Thank you for your attention

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