Discussion of Key Parameters and Methods for Comparison of Energy Needs of Machine Tools

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- **R. Neugebauer**
- **M. Wabner, T. Koch, W.-G. Drossel**

Discussion of Key Parameters and Methods for Comparison of Energy Needs of Machine Tools

1. Motivation
2. Key Parameters
3. Influence Analysis
4. Conclusion

Why comparison of energy needs in production technology?

1. Machine manufacturer

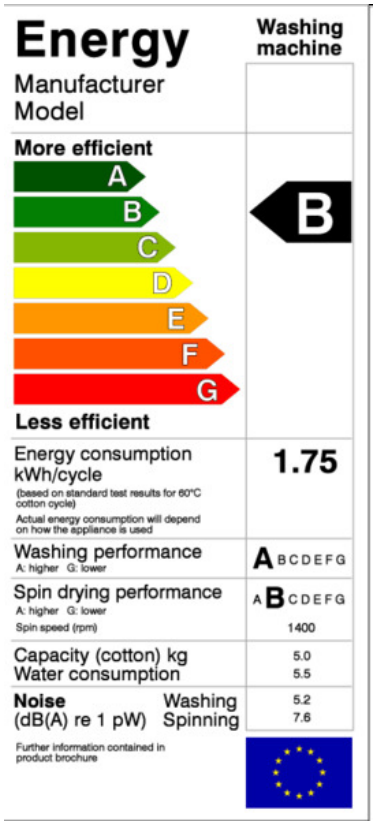
- Optimization of energy efficiency of the own products

2. Machine user

- Comparison of different manufacturer and production solutions as base for investment decision

3. Policy

- EU: Applying of eco-design framework directive on machine tools (2006/32/EC)



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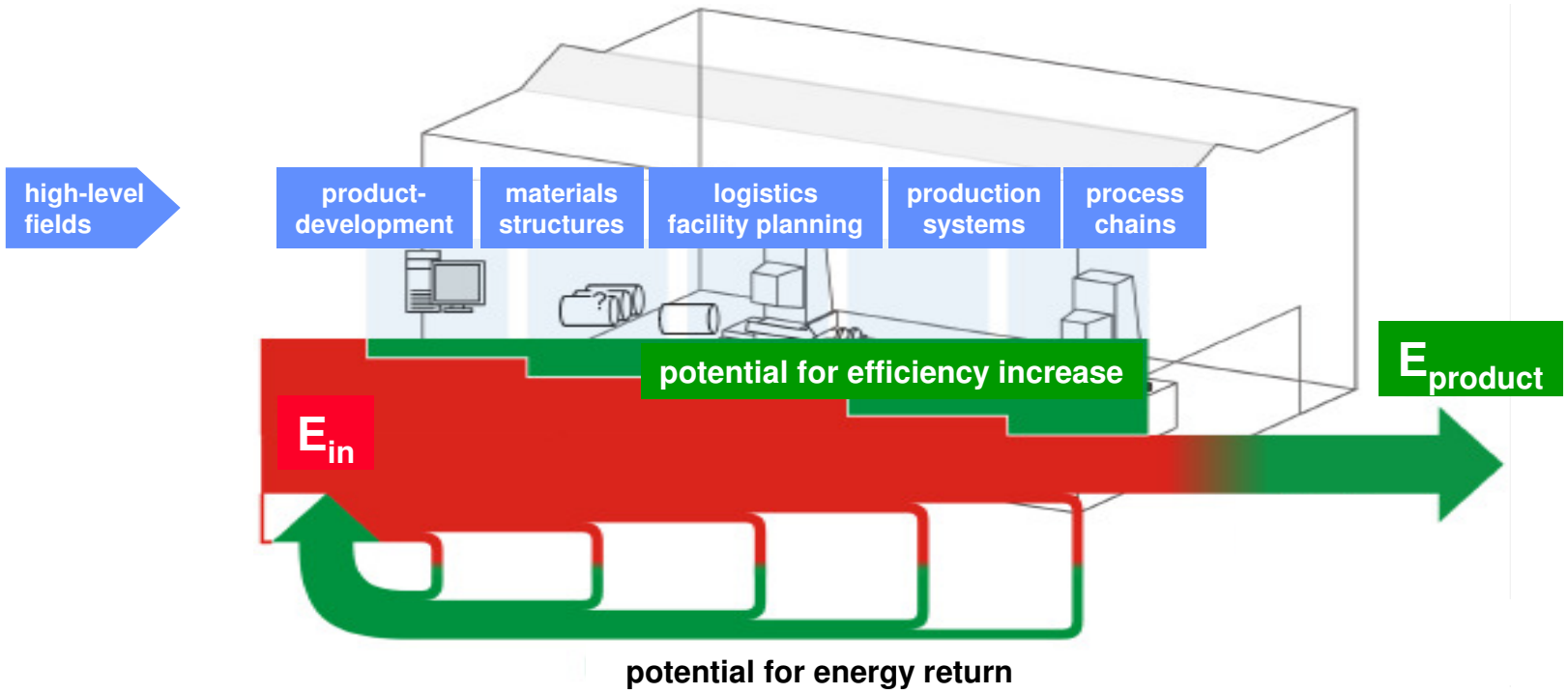
2 Key Parameters

Key Parameters for evaluation the energy requirement of machine tools and components

Key parameter	Formula	Remark
spec. power requirement P^*	$P^* = \frac{Power_{in}}{Output}$	defined for working point or average of a cycle
spec. energy requirement W^*	$W^* = \frac{Energy_{in}}{Output}$	defined for cycle
energy effectiveness		using energy for the right things
electrical efficiency η	$\eta = \frac{Energy_{out}}{Energy_{in}}$	defined for working point (power) or cycle (energy)
energy efficiency ε	$\varepsilon = \frac{Output}{Energy_{in}}$	using less energy to provide the same level of useful work; defined for cycle;
energy productivity E	$E = \frac{Output_P}{Energy_{in}}$	$Output_P$ = production output (part, functional element, money,...); defined for cycle;
Energy Efficiency Index EEI	$EEI = \frac{\varepsilon_{reference}}{\varepsilon_{actual}}$	in percentage compared with a defined goal; set has to be defined, includes the potential

3 Influence Analysis

A: Required energy for a product



→ **Dependent relationships: Separately evaluation of machine tools?**

B: Influences on energy needs of production systems

I Process
(primary shaping, forming, cutting, joining, coating, change of material property)

DIN 8580
Σ = 155 groups

II Machine tool type
(metal machining only: forming, cutting only)

DIN 69651
Σ = 32 main groups
many sub-groups

III Machine tool configuration
(size, number of axes, automatization, power parameters,…)

Σ → ↑↑

IV Part, tool, process parameter

Σ → ∞

→ **Classification necessary, but even possible?**

I Process und II Machine tool

Example: Influence of considered system boarders on energy needs in production

Cutting only

- long process chain
- lower utilization of material

→ **Energy need of machine ↓**

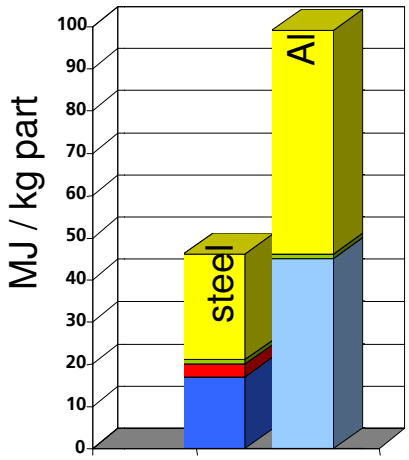
→ **Overall energy need of product ↑**

Forming and Cutting

- shorter process chain
- better utilization of material

→ **Energy need of machine ↑**

→ **Overall energy need of product ↓**



I sawing
II forging

I turning
II milling
III burring
IV scraping

I hardening

I strength blasting
II grinding

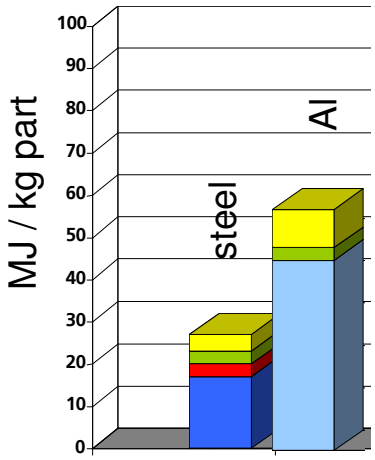
process chain

I sawing
II forging

I turning
II milling
III burring
IV ---------

I hardening

I ----------
II grinding



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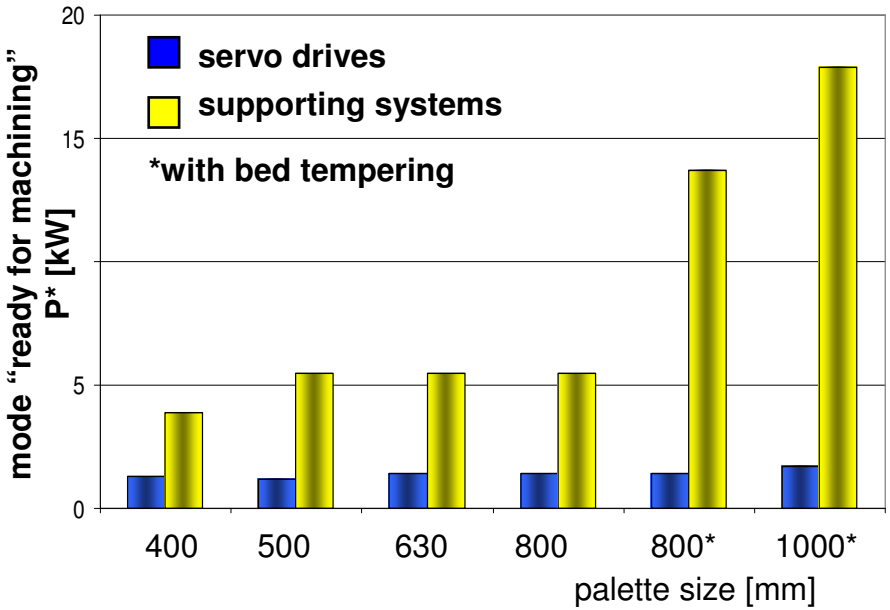
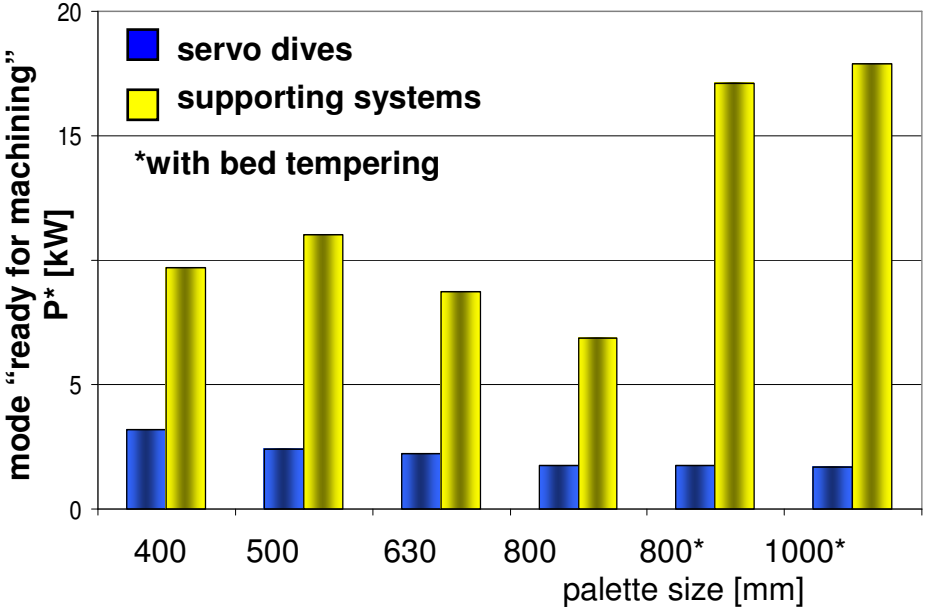
III Machine tool configuration

Example: sizes of a type series of a 5-axes machining center

Power requirement, absolute



Power requirement, divided by palette size

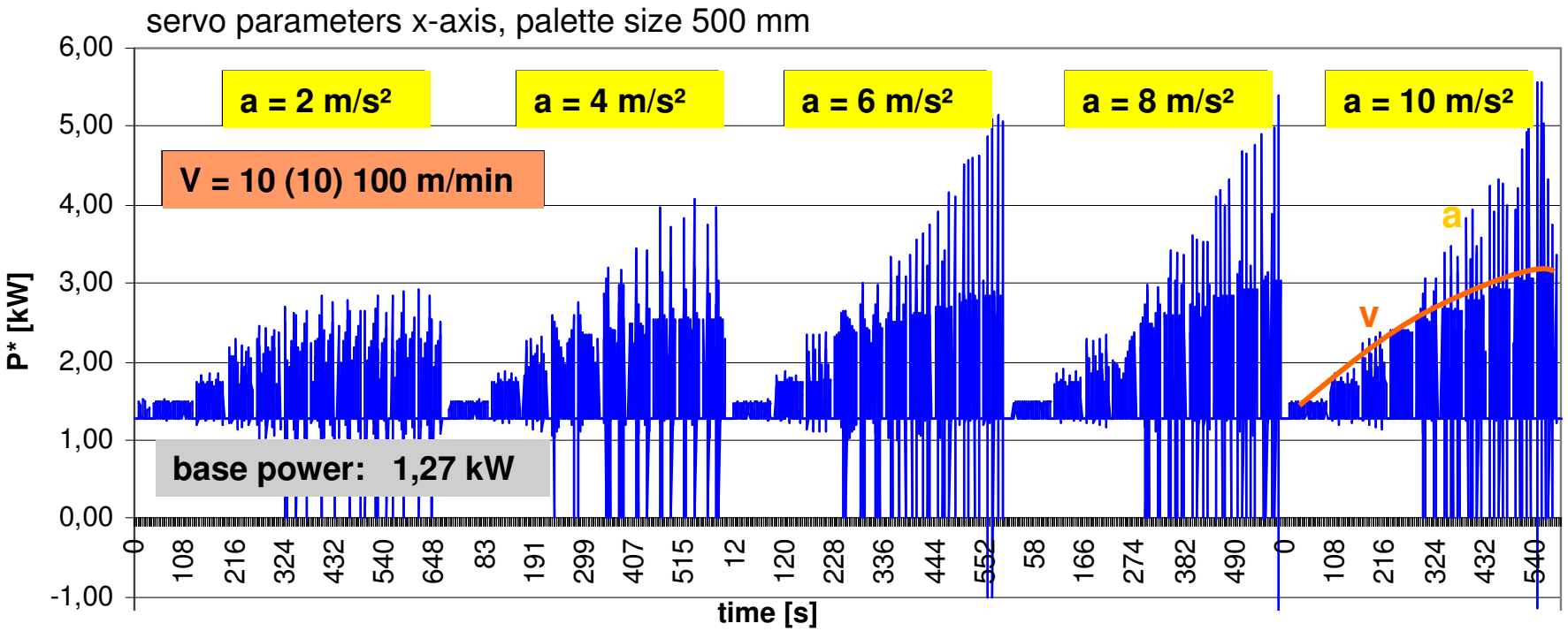


→ size specific power requirement is sinking with growing machine tool size

→ energy needs for additional options (bed tempering for higher accuracy) clarifies necessity of consideration performance parameters during energy needs evaluation

III Machine tool configuration

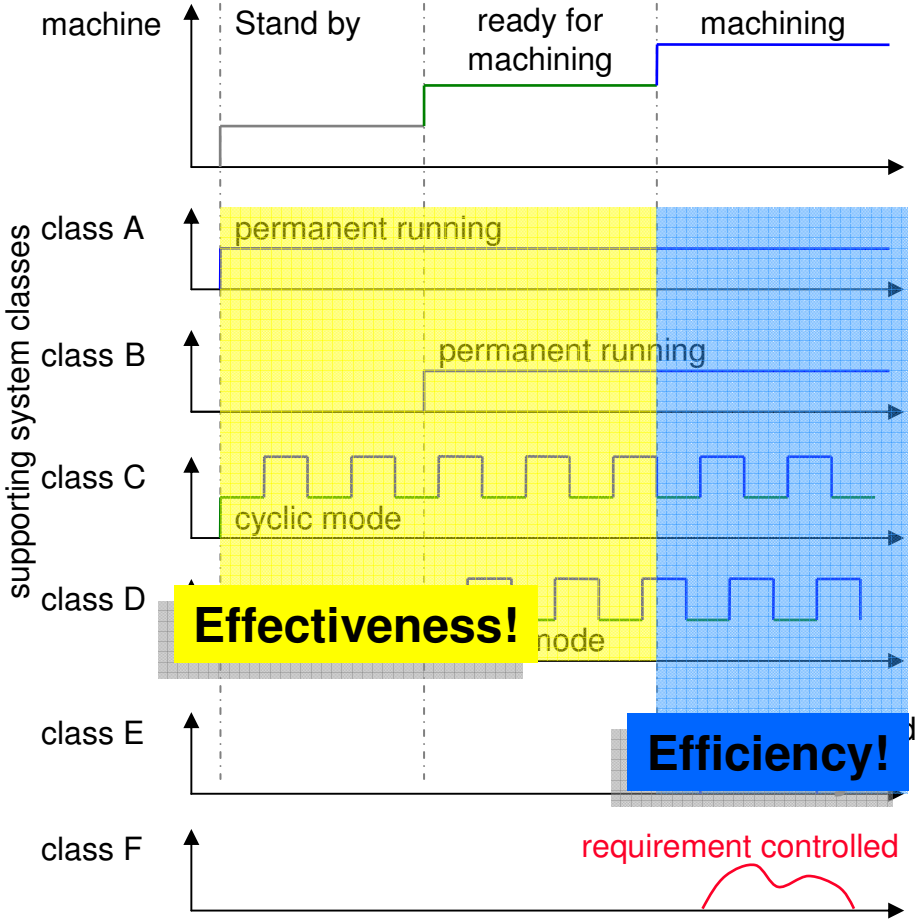
Example: dynamic parameters



→ Influence of dynamic parameters on energy need

→ Consideration of reachability and limitation of dynamic values necessary

III Machine tool configuration, Example: operating modes of supporting systems



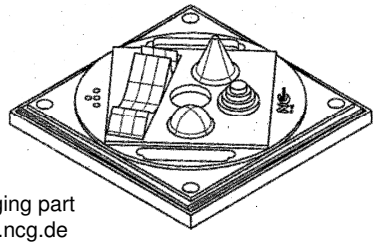
class	example	evaluation with (examp.)
A	control, fan	η, P^*
B	chip conveyor, scavenging pump	η, P^*
C	CNC cabinet heat exchanger	$P^*_{average}$ W
D	heating/cooling system of cutting fluid, hydraulic pump	$P^*_{average}$ W^*
E	high-pressure pump für cutting fluid	$W^*_{average}$
F	actual developments	$W^*_{average}$

IV Parts and processes

1. Standardized discharging part

Parts and standards:

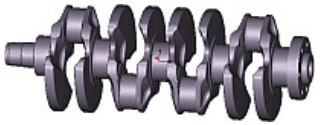
- HSC (NCG-2004)
- 5-axes simultaneous machining (NCG-2005)
- Water jet cutting (draft, NCG-2006)
- Micro machining (in preparation, NCG-2007)



HSC discharging part
Source: www.ncg.de

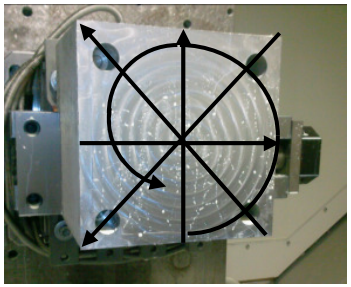
2. User-specific part

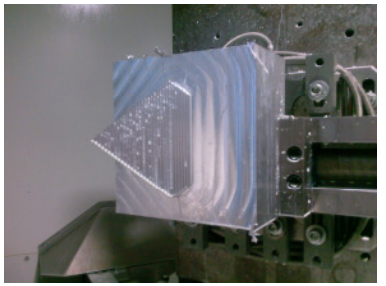
- large and middle batch sizes



3. Special test parts

- Comparison of a few classified universal machining centers possible
- Example: 3-axes machining center



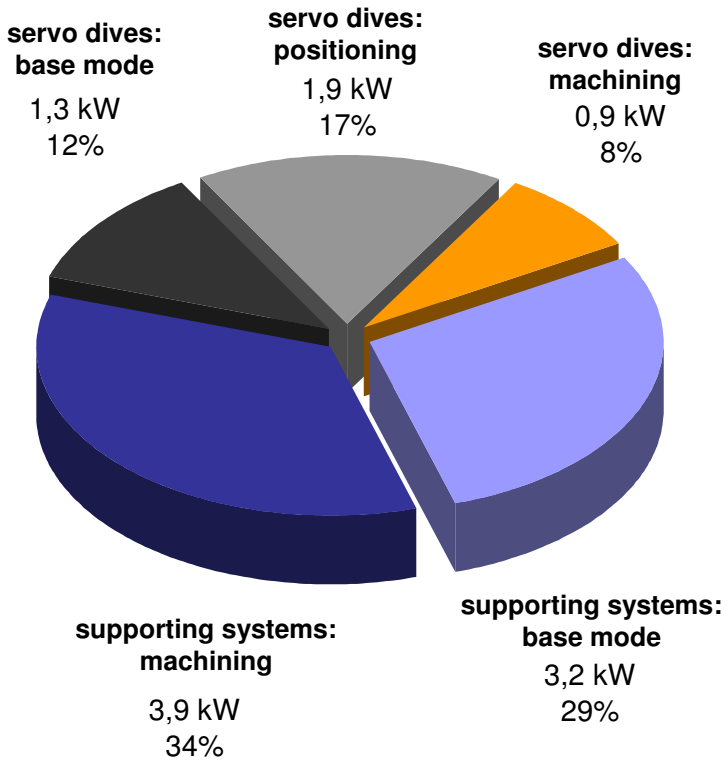


IV Parts
Energy requirement for user-specific part

Example: engine block from aluminum alloy

- Machining time: 4 minutes
- Wet machining
  - milling of functional areas
  - drilling boreholes
  - thread cutting
  - reaming of boreholes
  - milling crankshaft shells

source: Volkswagen



Part-specific power requirement P^* = 11,2 kW/part

Part-specific energy requirement W^* = 0,747 kWh/part

Energy productivity E = 1,34 parts/ kWh

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4 Conclusion

Energy efficiency classification and evaluation of machine tools

Because of very high number of influences and tasks: Should be limited to

A) Qualitative information:

- Availability of efficient components / Realization of more efficient activities

- energy efficient motors
- systems for energy return
- dry machining
- etc.

B) Quantitative information:

- Power / energy requirements P^*, W^*

- machine tool: for ineffective operating conditions (standby, ready for machining)
- subsystems: e.g. energy per cycle (tool changer etc.)

→ EVALUATION only under consideration of individual machine tool parameters by user

- Evaluating efficiency information ε, EEI

- only components and selected subsystems of machine tools

Thank you for your kind attention!

Comparability of energy requirements of production systems

Conclusion:

- Evaluation of machine tools has to include the process
- Variety of production tasks has an influence on energy requirements of production systems
- Comparison of energy requirements needs classification of machine tools which is hardly feasible

Trends:

↑ Effectiveness:	Use the energy for the machining process	(“Do the right thing”)
↑ Efficiency:	Optimize the machining process	(“Do it in the right way”)

…the result has to be a part- and process dependent individualization of production systems:

- Energy effectiveness by **reconfigurability** and **morphability** of machine tools
- Energy efficiency by **adaptive processes** and **components**

That means:

Individualization instead of Classification

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