Electric or Pneumatic? Comparing Electric and Pneumatic Linear Drives with Regard to Energy Efficiency and Costs

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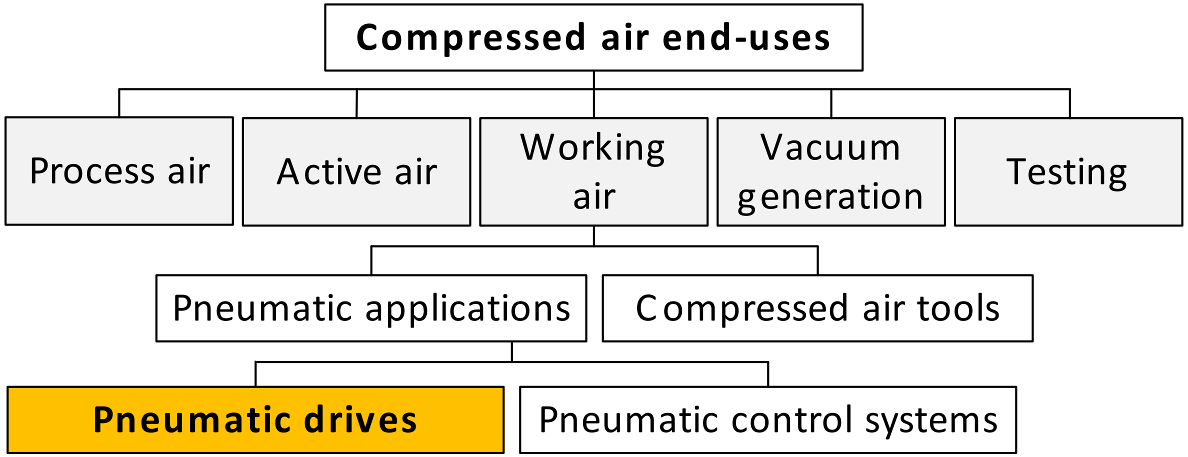
Outline

1. Background & aim
2. Methodology
3. Outline of the analysis
4. Results
5. Discussion, Conclusions & Outlook

Background

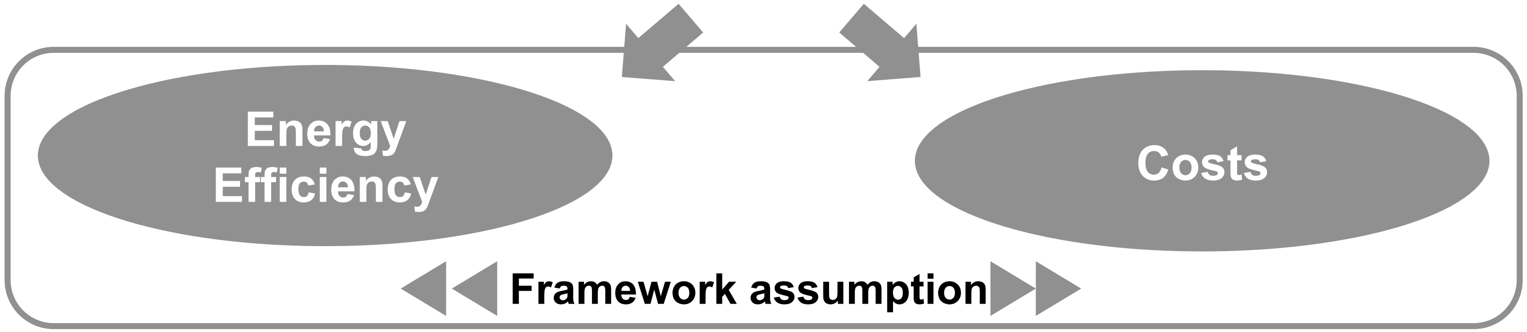
- **Relevance:** Compressed air is an important energy consumer (~10 % of industrial electricity demand)
- **Literature:** Efficiency of compressed air usage approximately about 10 %
- **Result:** Discussion about the performance of compressed air usage



Problem & Aim

- **Problem:**
  - Analyses on compressed air performance across all end-uses
  - Sample investigations of specific applications
  - Heterogeneous technological solutions
  - Numerous technological parameters to be considered

Aim: Discuss the performance of electric and pneumatic drives



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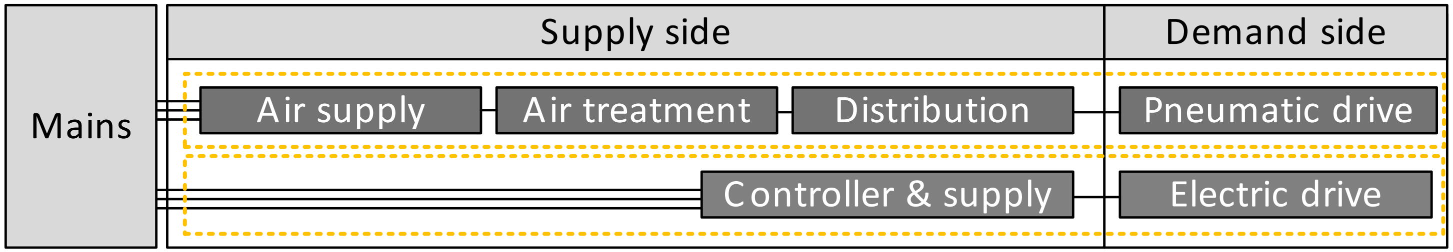
Conditions for a comparison

- **Prerequisites:**
  - Similar technological performance
    (i.e. maximum loads, acceleration, velocity, cycle times)
  - Environmental requirements fulfilled
    (robustness, explosion protection, hygienic standards)

- **Remarks:**
  - Difference in the structure of the upstream energy supply system → allocation problem



  - All costs relevant for a decision-maker have to be considered

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Methodology: Comparing energy demand

- **Equality of demand:** Drives perform equally well if their energy demand is equal

$$E_{pn} = E_{el}$$

E	Energy demand for one operating cycle
pn	Pneumatic drive
el	Electric drive

- **Cycle consumption:** Split into three states

$$E_{pn,m} + E_{pn,h} + E_{pn,s} = E_{el,m} + E_{el,h} + E_{el,s}$$

m	Drive moving (*pn* resp. *el*)
h	Drive holding (*pn* resp. *el*)
s	Drive idle waiting (*pn* resp. *el*)

	Pneumatic linear d	Electric linear drive
Moving	$E_{pn,m} = \overbrace{\left[V_{pn,m,cyl} + V_{pn,m,pipe} + v_{pn,loss} \cdot t_m\right]}^{\text{Volume}} \cdot \overbrace{e_{pn}}^{\text{Specific demand}}$	$E_{el,m} = \frac{E_{el,m,cyl}}{\eta_{el}}$
Holding	$E_{pn,h} = \left[v_{pn,h} + v_{pn,loss}\right] \cdot t_h \cdot e_{pn}$	$E_{el,h} = \frac{p_{el,h} \cdot t_h}{\eta_{el}}$
Stand-by	$E_{pn,s} = v_{pn,loss} \cdot t_s \cdot e_{pn}$	$E_{el,s} = \frac{p_{el,loss} \cdot t_s}{\eta_{el}}$

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Methodology: Comparing costs

- **Equality of costs:** Drives perform equally well if their overall costs are equal

$$C_{pn} = C_{el}$$

C	Overall costs (*pn* resp. *el*)

- **Split of overall costs:** Investment and operation

$$I_{pn} + c_{pn} \cdot T = I_{el} + c_{el} \cdot T$$

I	Investment (*pn* resp. *el*)
c	Annual operating costs (*pn* resp. *el*)
T	Lifetime (identical)

- **Investments:** Price of the axis plus mark-up for additional components

$$I_{pn} = I_{pn,cyl} \cdot \left(1 + \beta_{pn}\right)$$

I_{cyl}	Investment pneumatic cylinder (*pn* resp. *el*)
β	Mark-up for additional components (*pn* resp. *el*)

- **Operation:** Energy-related costs based on cycle consumption

$$c_{el} = E_{el} \cdot \frac{t_{year}}{t_{cyc}} \cdot p_{el}$$

t_{year}	Annual operating time (identical)
p	Price for electric energy (similar approach for *pn*)

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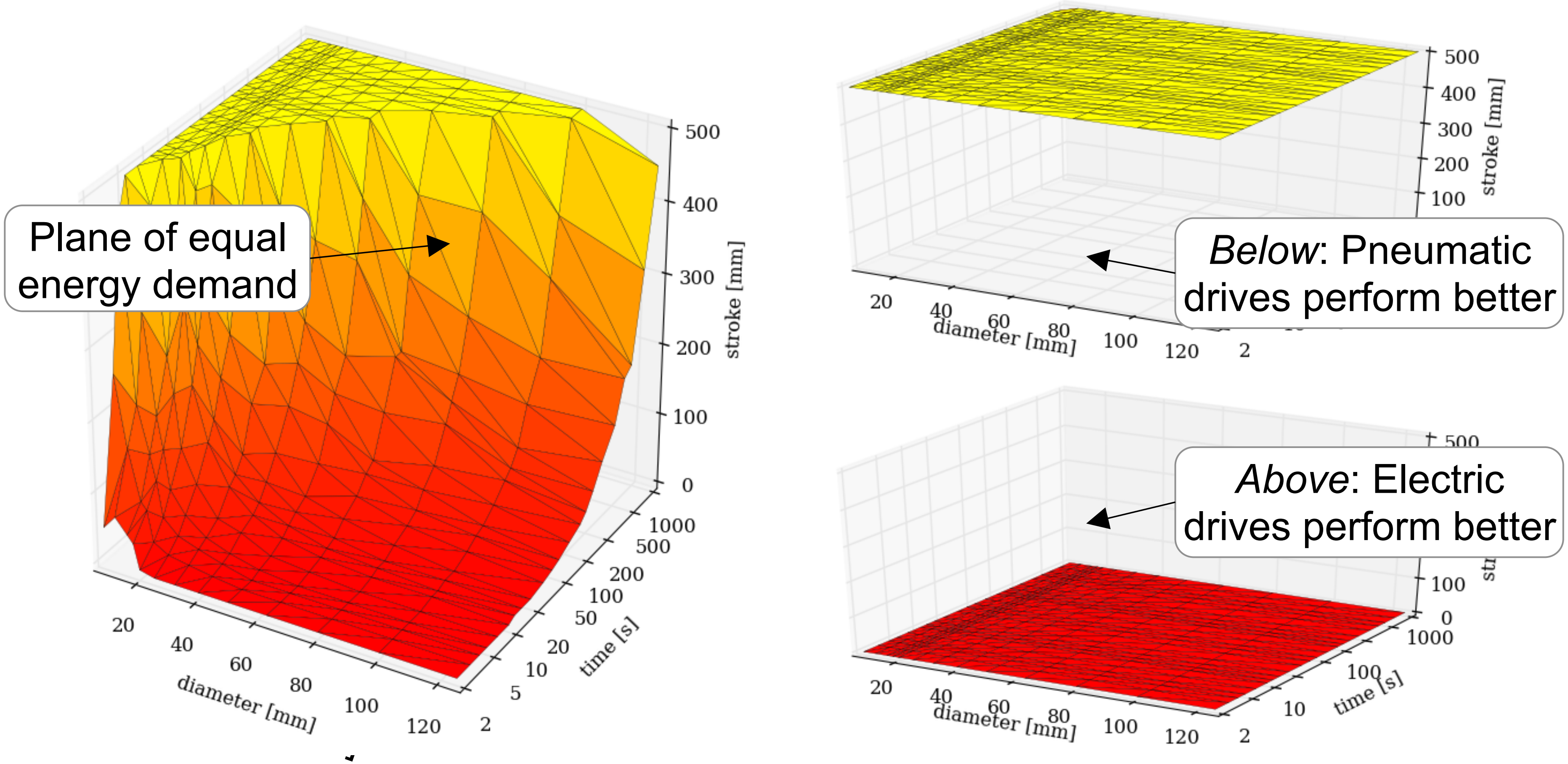
Illustration of concept

Result: Possibility to calculate configurations of equal energy demand / costs



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Definition of the baseline

- **Analysis:** Double acting pneumatic cylinders and spindle-type electric axes
- **Baseline parameters for the comparison:**

Parameter	Value
Specific demand of air supply	0.120 [kWh/m³]
Compressed air leakage	0 [m³/s]
Pneumatic holding demand	0 [m³/s]
Holding time	0 [s]
Length of piping	1 [m]
Efficiency of electric supply	80 [%]
Stand-by of electric supply	25 [W]
Ambient pressure	1 [bar_a]
Operating pressure	7 [bar_a]

Parameter	Value
Ambient temperature	293.15 [K]
Norm temperature	273.15 [K]
Electricity price	0.10 [€/kWh]
Costs of compressed air	0.15 [€/m³]
Annual operating time	4,000 [h]
Lifetime	5 [a]

- **Pneumatic drives:** Calculation of air demand based on geometrical features
- **Electric drives:** Simulation-based calculation of energy demand (research project)

Definition of the cases

Case	Description
0	Baseline
1	20 % of the cycle time are used for holding operations
2	Length of piping extended to 5 meters
3	Assumed leakage of 0.1 mm
4	Assumed leakage of 0.5 mm
5	Reduction of electric stand-by to 5 Watt
6	Use of a heat recovery at the compressor
7	Single-shift instead of double-shift operation
8	Lifetime extended to 7 years
9	Reduction of investments for electric drives

Outline

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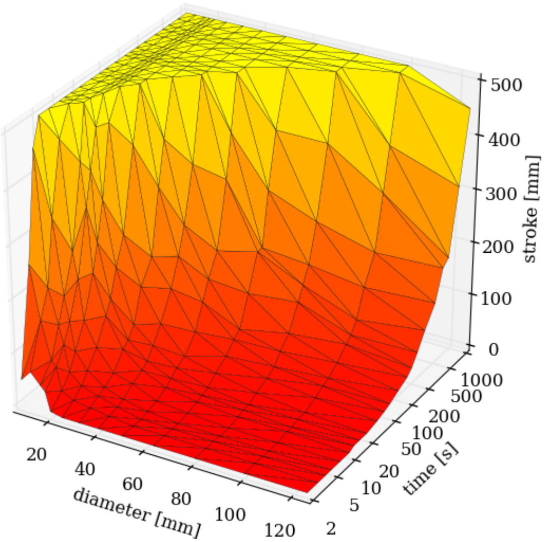
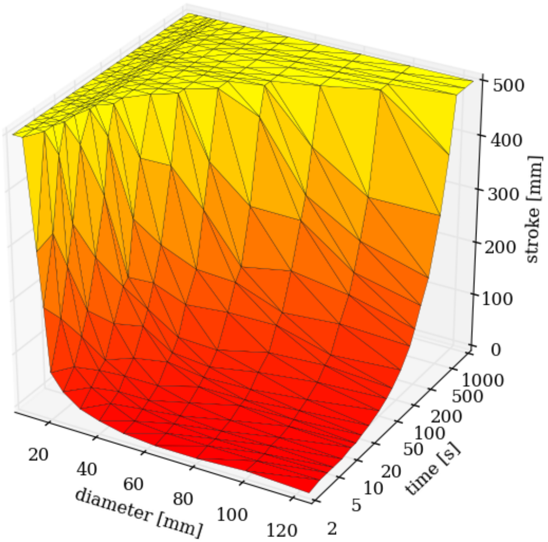
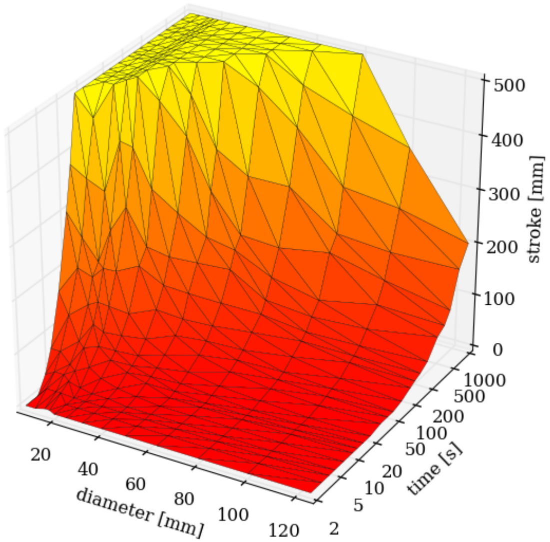
Energy: Baseline and sensitivity



Baseline



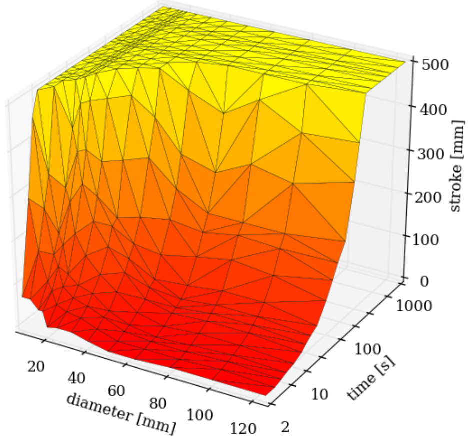
Sensitivity
Energy demand of
pneumatic drives -50 %



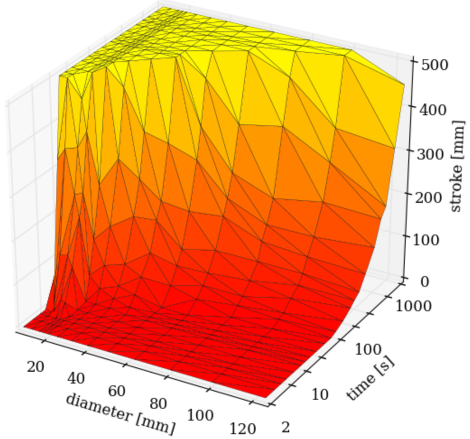
Sensitivity
Energy demand of
pneumatic drives +100 %

Energy: Cases

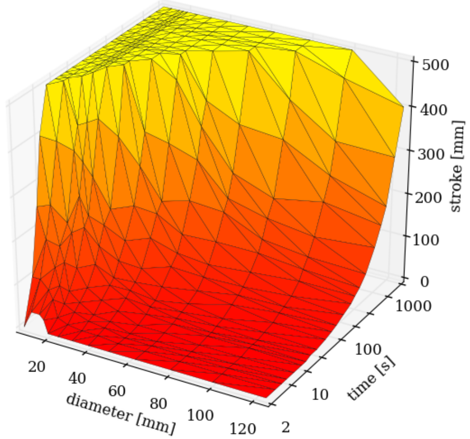
20% holding



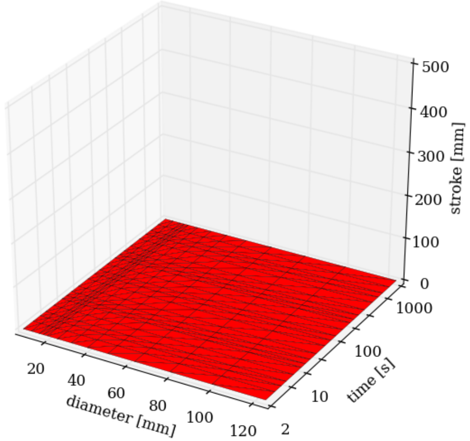
Piping: 5m



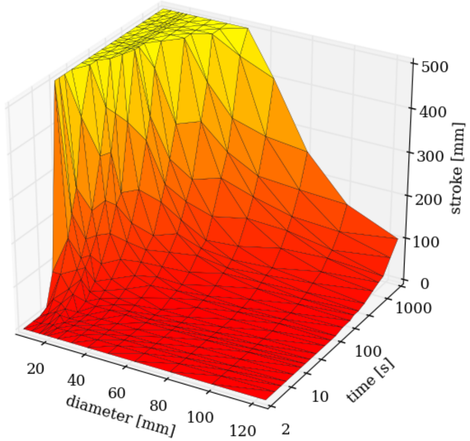
Leakage: 0.1mm



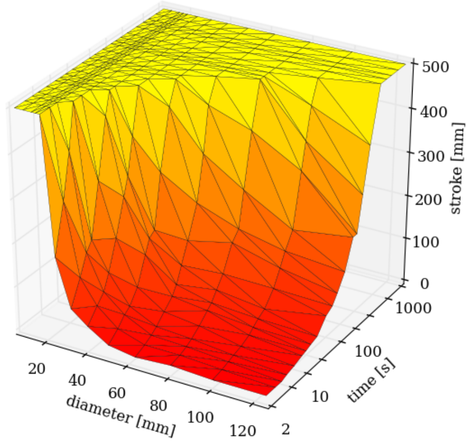
Leakage: 0.5mm



Stand-by: 5W



Heat recovery



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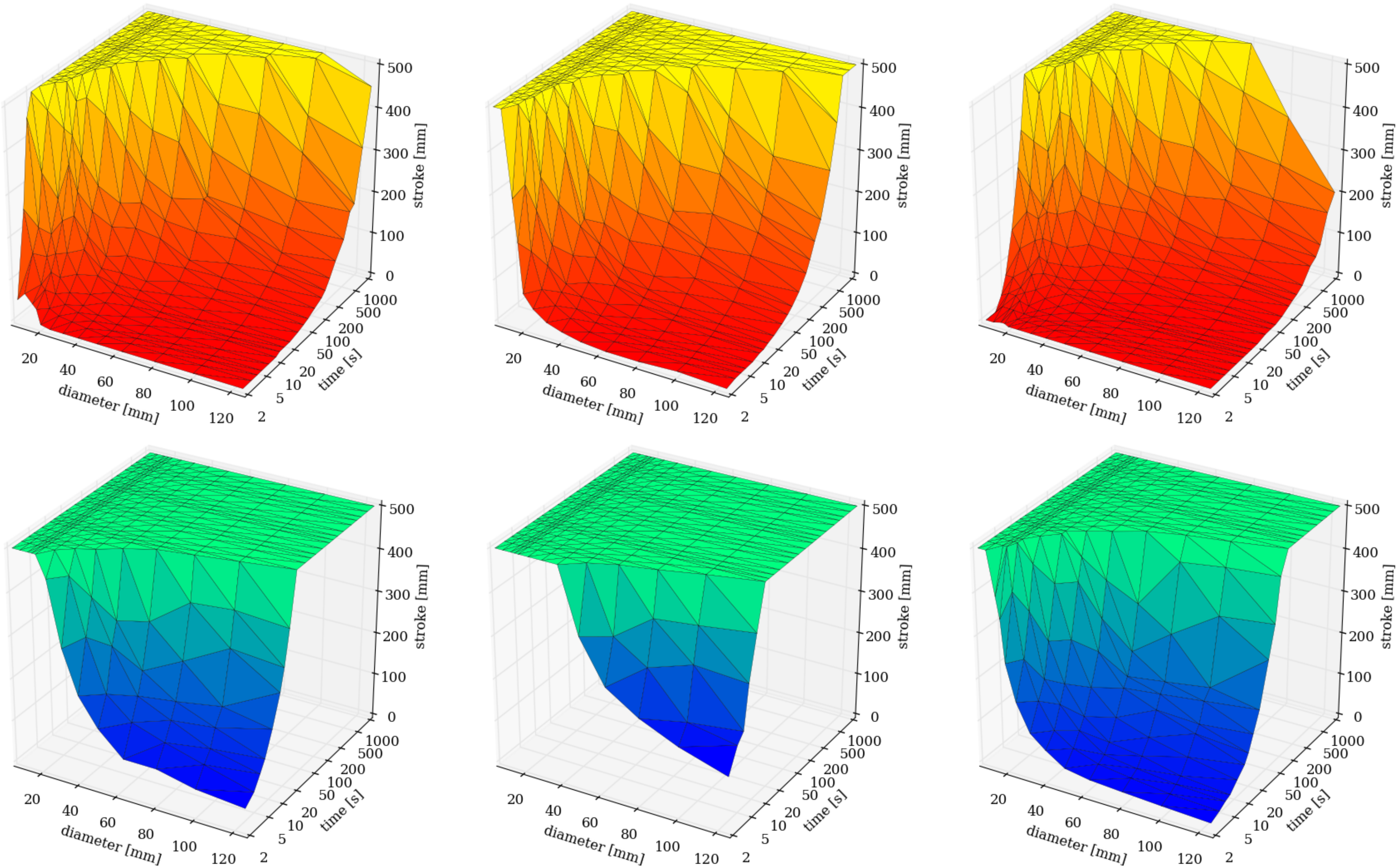
Costs: Baseline and sensitivity

Energy

Costs



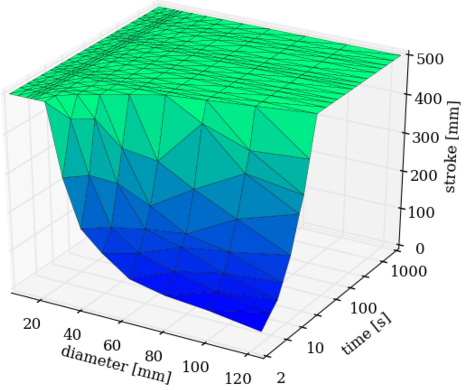
Baseline

Sensitivity: -50 %

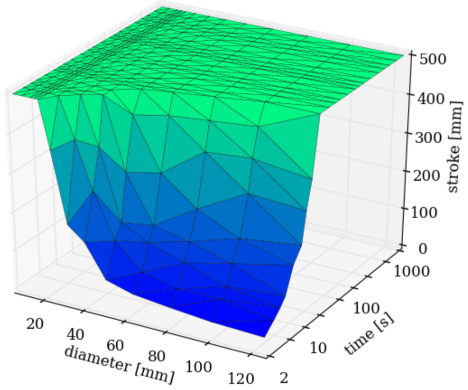
Sensitivity: +100 %

Costs: Cases

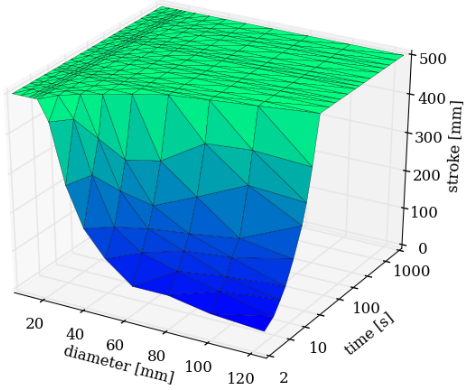
20% holding



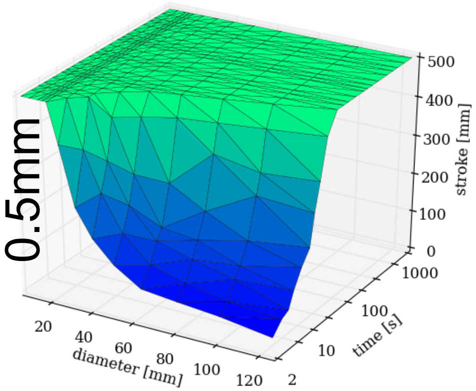
Piping: 5m



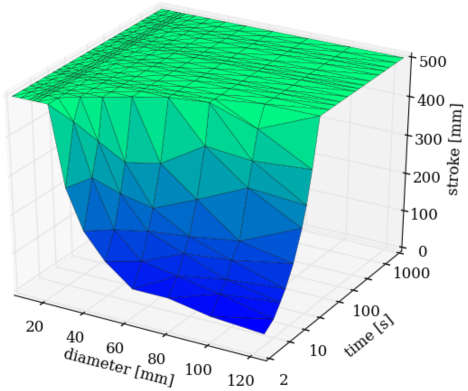
Leakage: 0.1mm



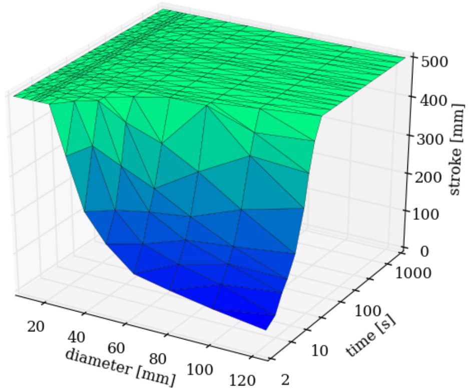
Leakage: 0.5mm



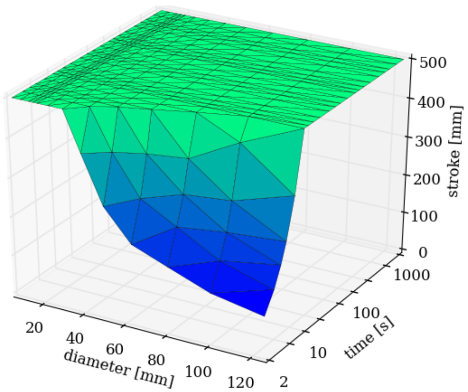
Stand-by: 5W



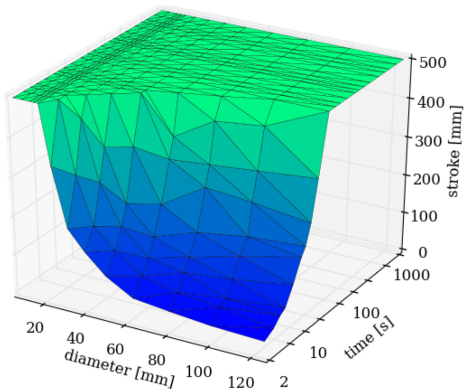
Heat recovery



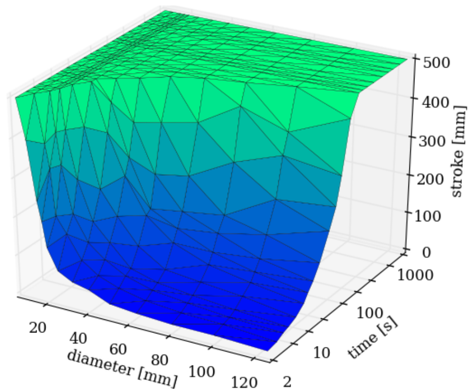
Single-shift



Lifetime: 7 years



Investment



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Discussion, Conclusions & Outlook

Discussion

- Discussion of ordinal statements (no differences in intensity)
- Analysis is subject to uncertainty

Conclusions

- Generalizing statements on the performance of electric and pneumatic linear drives difficult
- Awareness on dependence of assumptions necessary
- Performance-oriented not technology-oriented discussion required

Outlook

- Analysis of other drives and technological parameters
- More detailed picture on usage and energy demand
- Detailed analysis of energy-saving potentials
- Investigation on decision-making behaviour for drive selection

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Thank you for your attention !