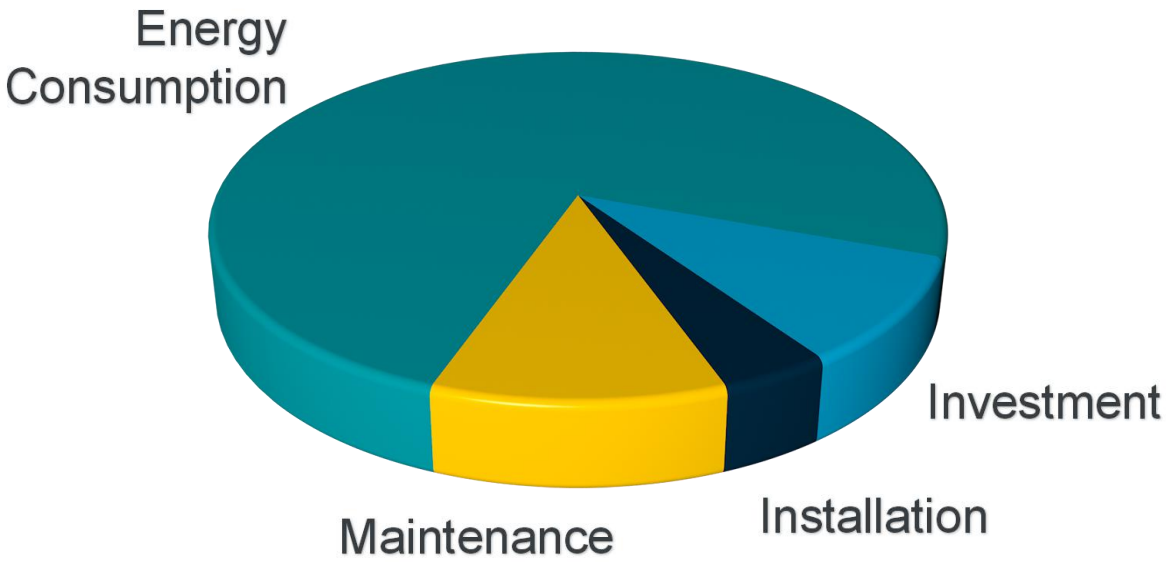
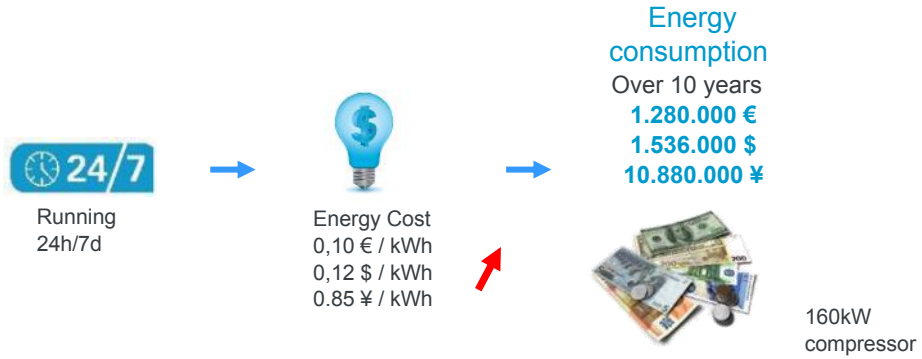
Compressor Cycle Energy Requirement

Carl Wouters

Compressor Industry Energy Consumption

Compressed Air Systems contribute to +/- 9.5% of the total electricity consumption in China*

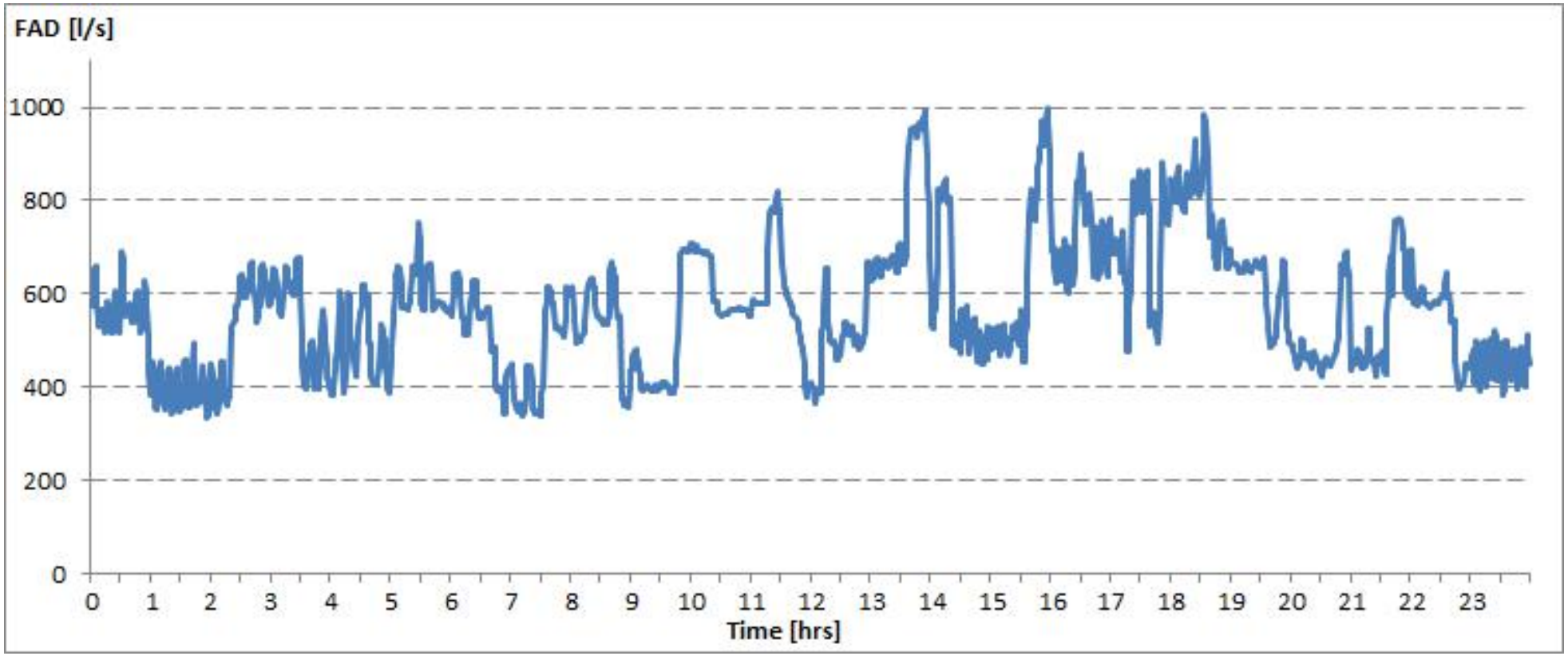




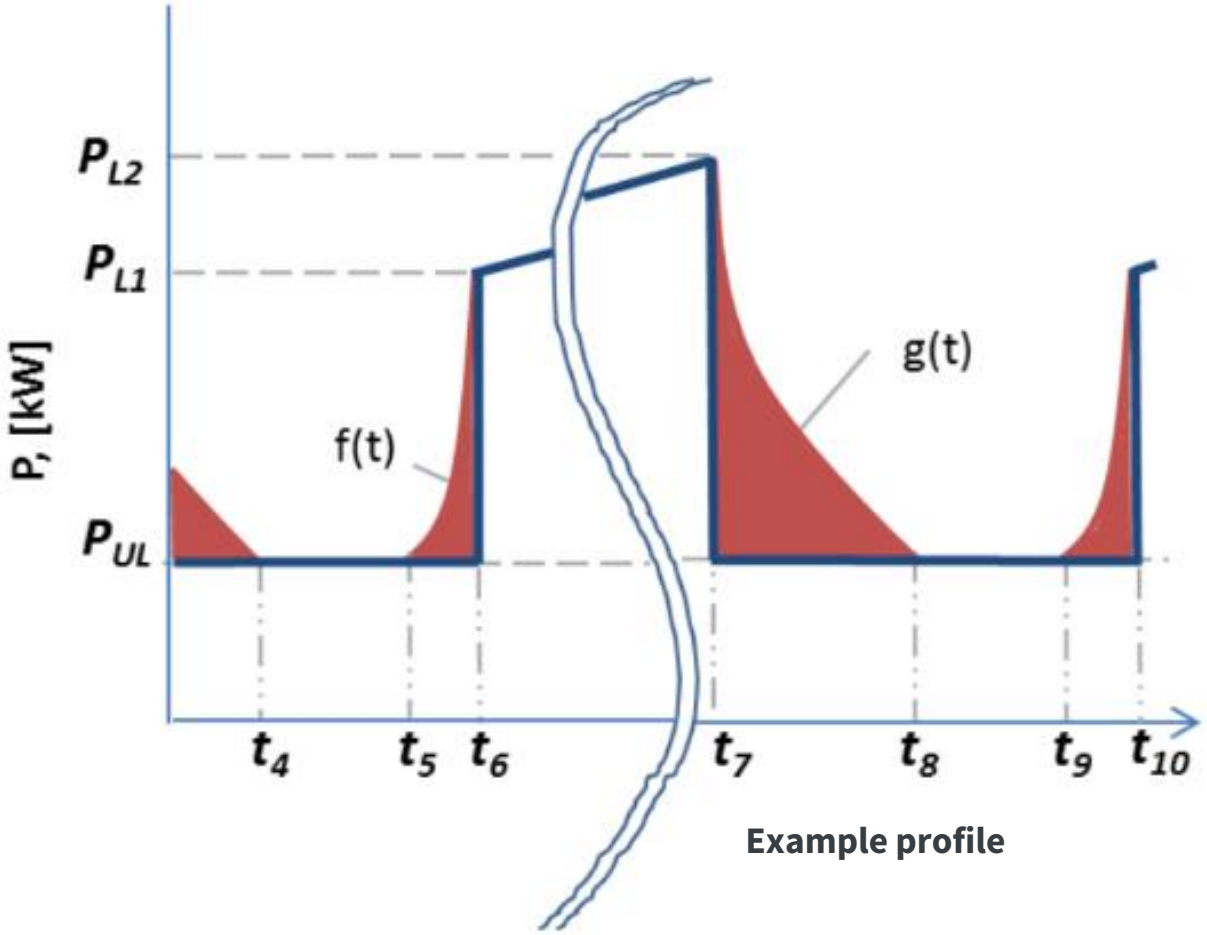
* A review on compressed-air energy use and energy savings
R. Saidur, N.A. Rahim, M. Hasanuzzaman

Atlas Copco

How much does my compressor consume in real life?



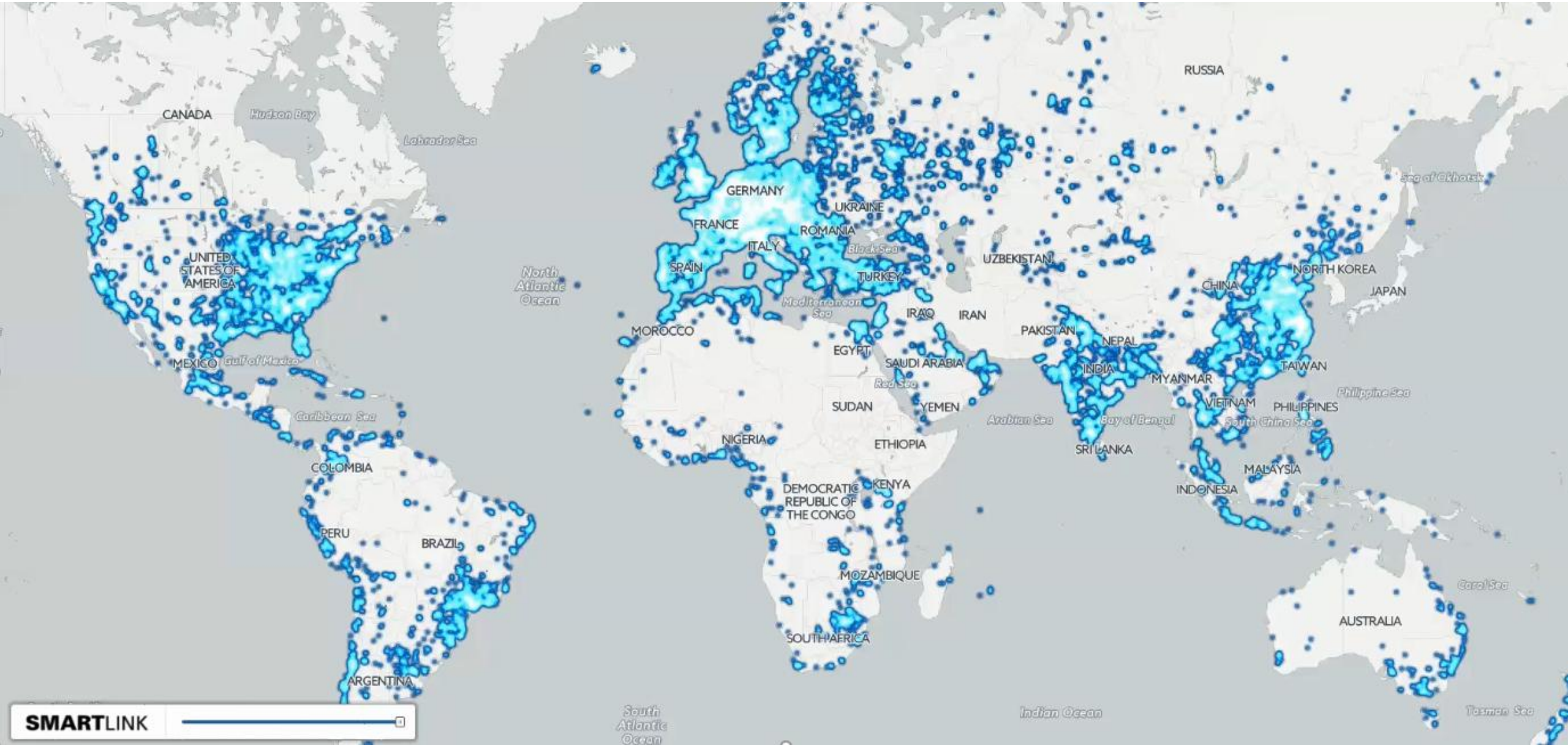
Compressor Cycle Energy Losses



Example profile

- **Steady state conditions** are typically used in energy consumption calculations, documentation and standardized measurement procedures
- **Cycle/Transient losses** are typically **neglected**
- To analyze the significance, an understanding is needed **how air compressors are running in the field**

> 120.000 Machines Connected



Compressor Data collection

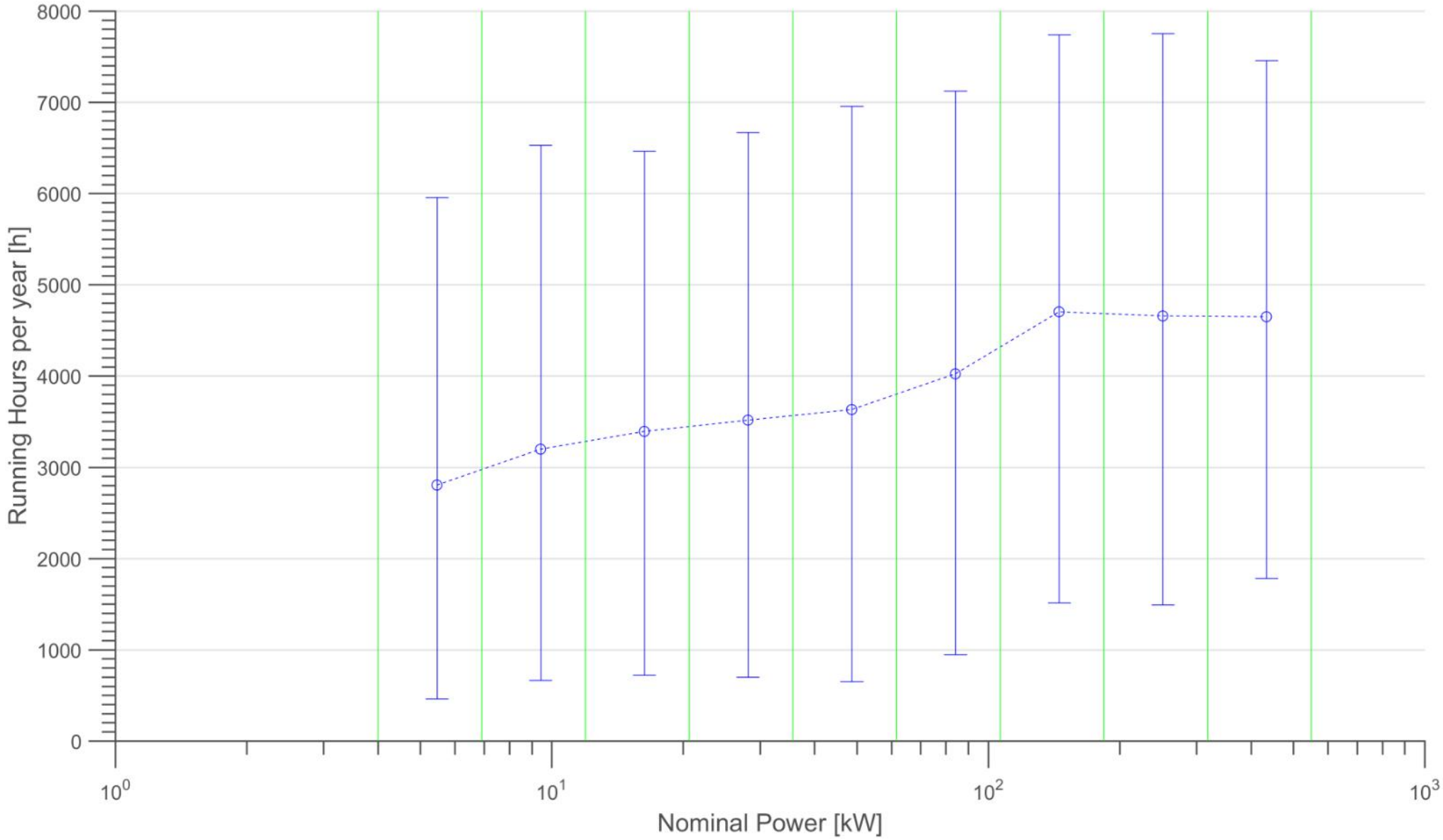
- Analysis based on more than 30.000 fixed speed oil injected screw compressors over a time period of two years
- Key Definitions

  - **Running hours per year**
    The total time the machine is running during a full year. Time when stopped for example in standby not included

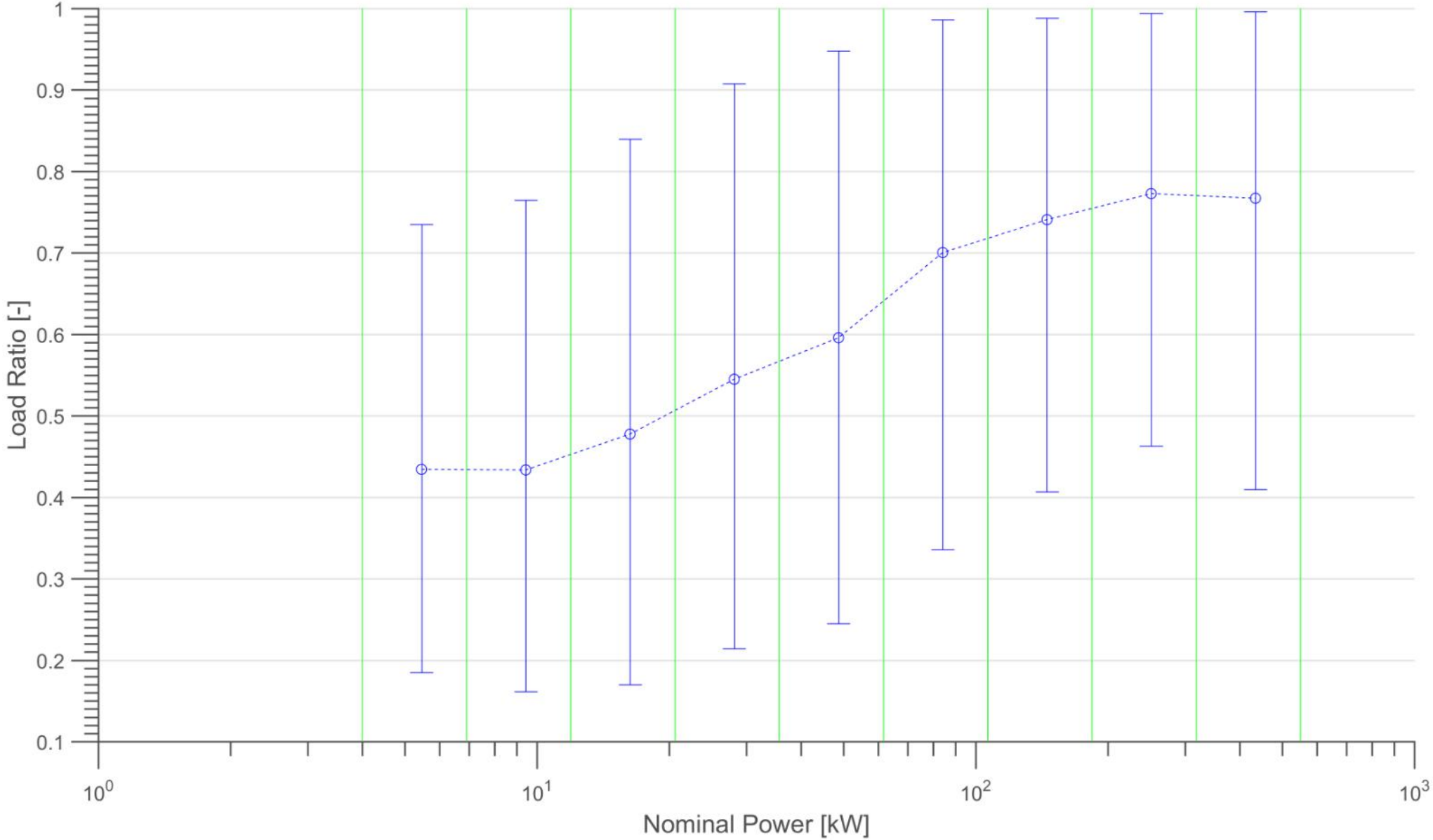
  - **Load Ratio**
    Ratio defined by the time machine running in Load divided by total time the machine is running. It is the time the machine is delivering air to the customer.

  - **Cycles per hour**
    Amount of cyclic operations during an hour running. It is the total amount of cycles during a year divided by the running hours per year.

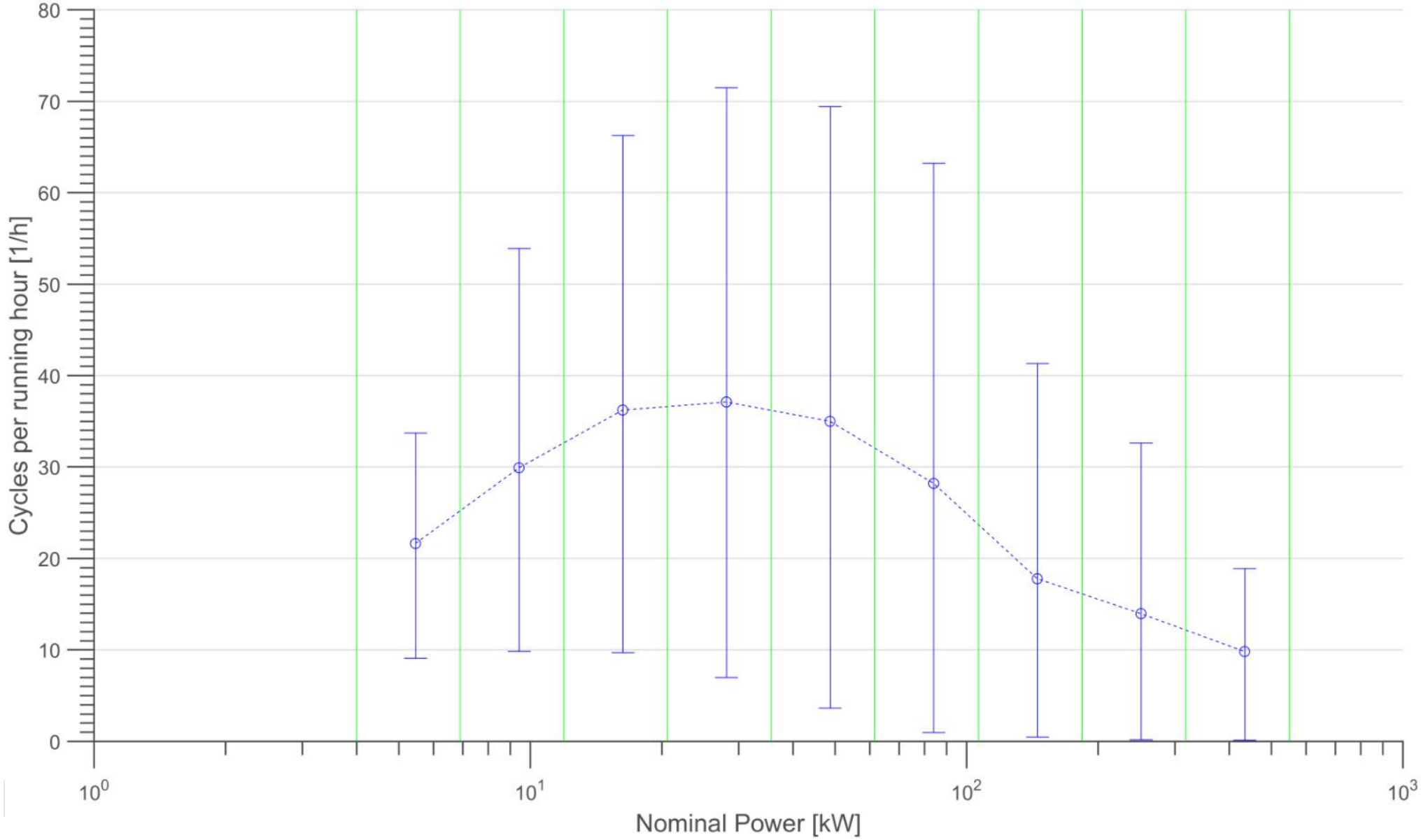
Compressor Data collection – Running Hours



Compressor Data collection – Load Ratio



Compressor Data collection - Cycles



Conclusions Compressor Data collection

- Analysis based on more than 30.000 fixed speed oil injected screw compressors over a time period of two years
- **Conclusion data collection**
  - Big spread on data shows wide application and/or implementation range
  - Lower running hours than expected
  - Low load ratio’s
  - High amount of cyclic operations

- **Transient losses can have a big impact on overall efficiency**

Measurement Procedure Standard in development

Cycle Energy Requirement – Acceptance test

1 Scope

This International Standard applies to positive displacement compressors as covered by ISO1217, low pressure compressors as covered by NP22484 and centrifugal compressors as covered by ISO18740.

This International Standard defines and describes the acceptance test for Cycle Energy Requirement of a compressor. It specifies the operating and testing conditions which apply when a full test is specified.

Cycle Energy Requirement is the additional energy required for a single cycle caused by transient conditions.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

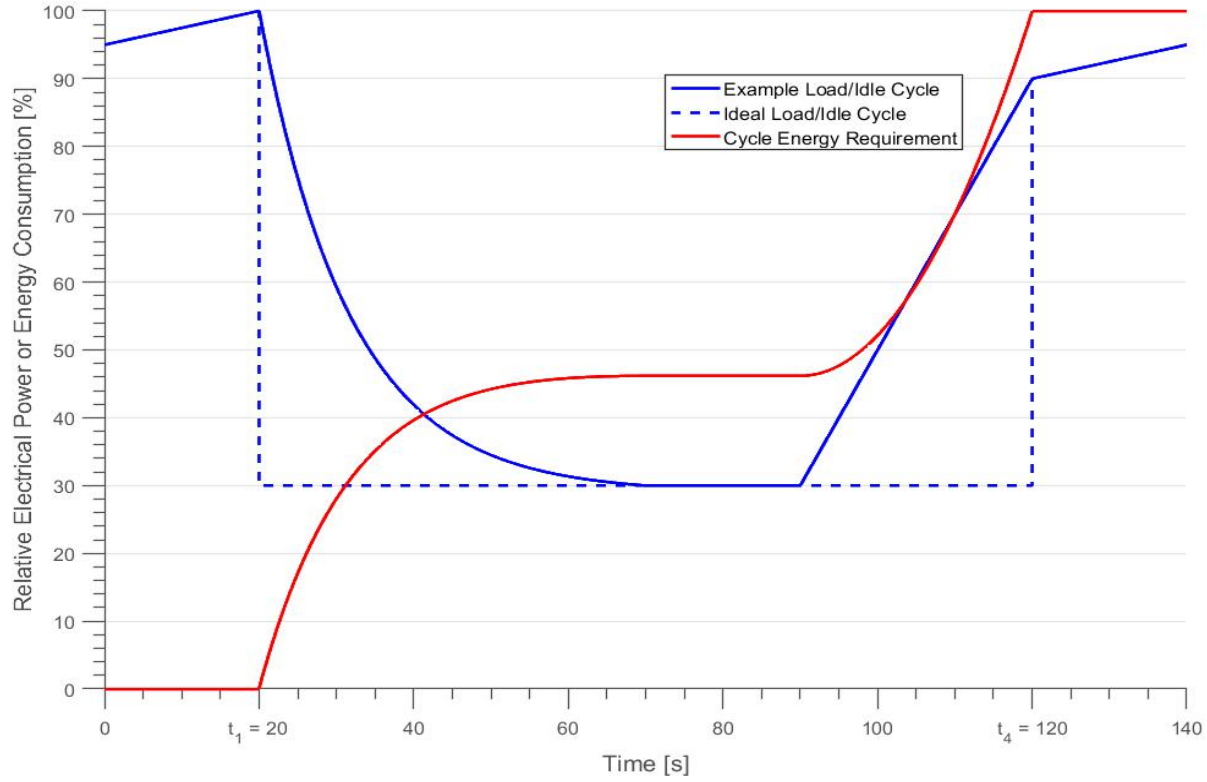
ISO 1217, *Displacement compressors — Acceptance tests*

ISO 18740, *Turbocompressors — Performance test code — Simplified acceptance test*

NP 22484, *Displacement and dynamic compressors — Performance test code for electric driven low-pressure air compressor packages*

ISO 3857-1, *Compressors, pneumatic tools and machines — Vocabulary — Part 1: General*

ISO 3857-2, *Compressors, pneumatic tools and machines — Vocabulary — Part 2: Compressors*



Measurements on 4 Compressors in Labaratory

- **Four different technologies** have been tested following **certified test procedures**
  - Oil Injected Screw – Single stage – Fixed Speed
  - Oil Injected Screw – Two stage – Fixed Speed
  - Oil Injected Screw – Single stage – Variable Speed
  - Oil Free Screw – Two stage – Fixed Speed

	Fixed Speed OIS 1stage	Fixed Speed OIS 2stage	Variable Speed OIS 1stage	Fixed Speed OFS
Loaded Electrical Power (kW)	179.3	175.3	188.3	168.4
Idle Electrical Power (kW)	46.6	91.2	0	32.9
Loaded Free Air Delivery (l/s)	507.6	500.7	521.2	482.3
Cycle Energy Requirement (kJ)	2167	478	1256	179

Compressor Efficiency Table - Head to Head

Fixed Speed Oil Injected Screw Single Stage

Overall SER (J/l)		Cycles per running hour (1/hr)				
		0	15	30	45	60
Flow Ratio (%)	100	353.2	-	-	-	-
	85	369.4	390.4	411.3	432.2	453.1
	70	392.6	418.0	443.4	468.8	494.2
	55	428.3	460.7	493.0	525.4	557.7
	40	490.9	535.4	579.9	624.3	668.8
	25	628.6	699.8	770.9	842.1	913.3
	10	1179.5	1357.4	1535.2	1713.1	1891.0

Elec Cost (kDollar)		Cycles per running hour (1/hr)				
		0	15	30	45	60
Flow Ratio (%)	100	51.9	-	-	-	-
	85	54.3	57.4	60.5	63.5	66.6
	70	57.7	61.4	65.2	68.9	72.7
	55	63.0	67.7	72.5	77.2	82.0
	40	72.2	78.7	85.2	91.8	98.3
	25	92.4	102.9	113.3	123.8	134.2
	10	173.4	199.5	225.7	251.8	278.0

Variable Speed Oil Injected Screw Single Stage

Overall SER (J/l)		Cycles per running hour (1/hr)				
		0	15	30	45	60
Flow Ratio (%)	100	361.3	-	-	-	-
	85	359.5	-	-	-	-
	70	357.2	-	-	-	-
	55	361.8	-	-	-	-
	40	377.9	-	-	-	-
	25	384.0	425.1	466.3	507.5	548.6
	10	384.0	486.9	589.8	692.7	795.6

Elec Cost (kDollar)		Cycles per running hour (1/hr)				
		0	15	30	45	60
Flow Ratio (%)	100	53.1	-	-	-	-
	85	52.8	-	-	-	-
	70	52.5	-	-	-	-
	55	53.2	-	-	-	-
	40	55.6	-	-	-	-
	25	56.4	62.5	68.5	74.6	80.7
	10	56.4	71.6	86.7	101.8	117.0

0.086 dollar/kWh

Compressor Efficiency Table - Head to Head

Fixed Speed Oil Injected Screw Two Stage

Overall SER (J/l)		Cycles per running hour (1/hr)				
		0	15	30	45	60
Flow Ratio (%)	100	350.1	-	-	-	-
	85	382.3	386.9	391.6	396.3	401.0
	70	428.2	433.9	439.5	445.2	450.9
	55	499.1	506.4	513.6	520.8	528.1
	40	623.3	633.3	643.2	653.2	663.1
	25	896.5	912.5	928.4	944.3	960.2
	10	1989.4	2029.2	2069.0	2108.7	2148.5

Elec Cost (kDollar)		Cycles per running hour (1/hr)				
		0	15	30	45	60
Flow Ratio (%)	100	51.5	-	-	-	-
	85	56.2	56.9	57.6	58.3	58.9
	70	62.9	63.8	64.6	65.4	66.3
	55	73.4	74.4	75.5	76.6	77.6
	40	91.6	93.1	94.6	96.0	97.5
	25	131.8	134.1	136.5	138.8	141.1
	10	292.4	298.3	304.1	310.0	315.8

Fixed Speed Oil Free Screw

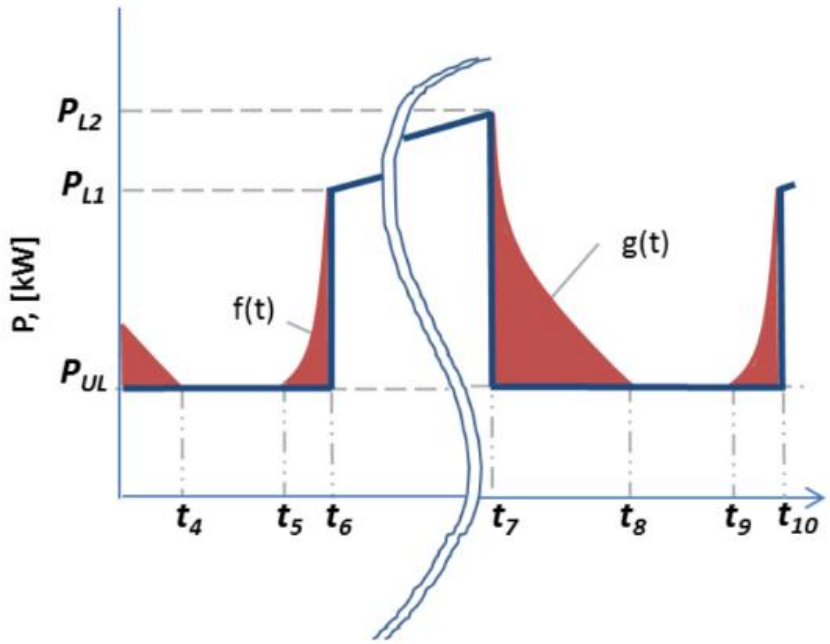
Overall SER (J/l)		Cycles per running hour (1/hr)				
		0	15	30	45	60
Flow Ratio (%)	100	349.2	-	-	-	-
	85	361.2	363.0	364.8	366.7	368.5
	70	378.4	380.6	382.8	385.0	387.2
	55	405.0	407.8	410.6	413.4	416.2
	40	451.5	455.3	459.2	463.1	466.9
	25	553.8	560.0	566.2	572.4	578.5
	10	963.1	978.6	994.0	1009.5	1024.9

Elec Cost (kDollar)		Cycles per running hour (1/hr)				
		0	15	30	45	60
Flow Ratio (%)	100	51.3	-	-	-	-
	85	53.1	53.4	53.6	53.9	54.2
	70	55.6	55.9	56.3	56.6	56.9
	55	59.5	59.9	60.4	60.8	61.2
	40	66.4	66.9	67.5	68.1	68.6
	25	81.4	82.3	83.2	84.1	85.0
	10	141.6	143.8	146.1	148.4	150.7

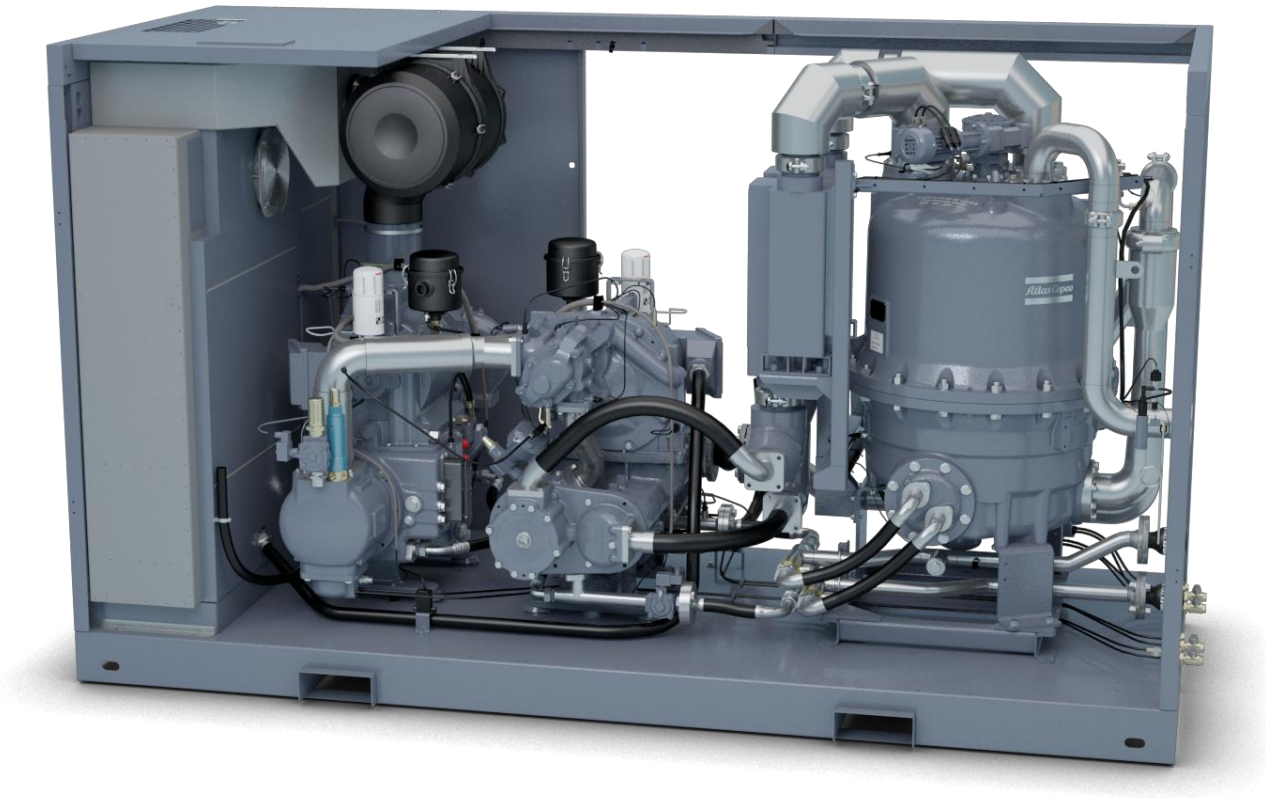
0.086 dollar/kWh

Conclusions

- To **improve energy efficiency** of compressed air installations, the **real life behaviour** needs to be analyzed and optimized
- **Cycle/Transient losses** should **not be neglected**
- **Compressor efficiency tables** should be used to **evaluate products**



Questions & Answers



Atlas Copco