Optimization of Energy Efficiency in the Process Industries

Madrid
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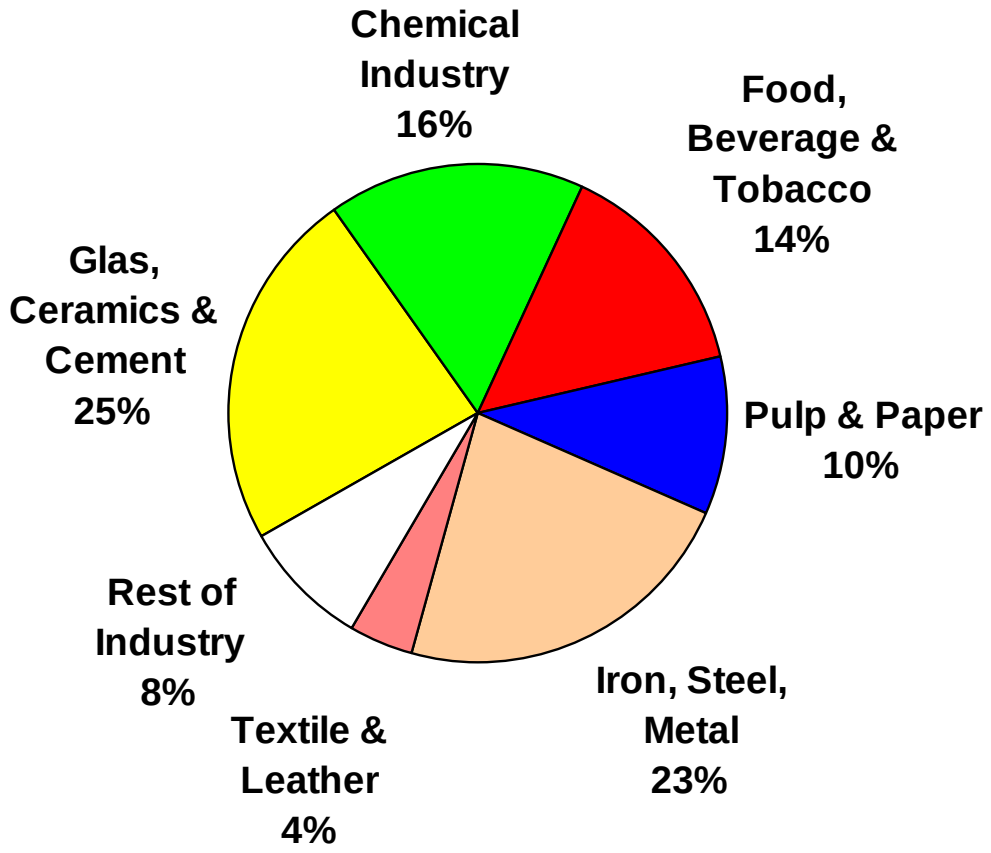
1) Motivation

Energy consumption
in the Spanish Industry
in 2008



- Main energy sources are fossil fuels
- energy imports account for 80% of energy used (EU average 50%)

1) Motivation

„The biggest source of oil can be located within Germany: It is energy efficiency“

„Die größte Ölquelle liegt unter Deutschland: Es ist die Energieeffizienz“

Jürgen Hambrecht, CEO BASF

1) Motivation

„The biggest source of oil can be located within ~~Germany:~~ every country itself: It is energy efficiency“

1) Motivation and Outline

1) Motivation and Outline
2) Energy Efficiency: Why?
3) Energy Efficiency: How?
4) Energy Efficiency: Why else?
5) Summary

2) Energy Efficiency: Why?

1) Motivation and Outline

2) Energy Efficiency: Why?

3) Energy Efficiency: How?

4) Energy Efficiency: Why else?

5) Summary

2) Energy Efficiency: Why?

- Estrategia de Ahorro y Eficiencia Energética en España 2004-2012 (E4 2008-2012)
- E.g.: Energy audits for the execution of measures to increase the energy efficiency
- The Spanish state takes up to 75% of the costs for such audits

3) Energy Efficiency: How?

1) Motivation and Outline

2) Energy Efficiency: Why?

3) Energy Efficiency: How?

4) Energy Efficiency: Why else?

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3) Energy Efficiency: How?

Fields of Optimization

3) Energy Audits: Fields for Optimization

- Process technology
  - Heat integration
  - „Waste heat recovery“
  - Thermal & Mechanical process engineering
  - Reaction engineering
  - Process intensification
- Component Efficiency
  - Facilities for Heating and Cooling
  - Heat Exchangers
  - Dryers
  - Mills
  - Agitators, Kneaders
  - Pumps
  - Compressors, vacuum pumps
  - Lifting, conveying and transport
  - Motors and Drives
  - Lifecycle costs / total cost of ownership
- Usage of energy sources
  - cogeneration
  - steam (pressure levels)
  - condensate return and reuse
  - water (river, city, cooled)
  - compressed air
  - natural gas
- Production buildings
  - Insulation
  - HVAC (heating, ventilation & air conditioning)
  - lighting
- Process control and operation
  - Automation
  - Production planning
  - Information management
  - Energy management
- Management
  - Energy contracting
  - New methods for project financing

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  - New methods for project financing

3) Energy Efficiency: How?

<u>Example 1:</u> Component efficiency and usage of energy sources:

compressed air

3) Energy Efficiency: How? Example 1: compressed air

Results of EU studies imply that **pressurized** air **plants** in the EU consume 80 billion kWh per year (80,000,000,000 kWh/a). This equals **10%** of the **industrial power consumption** in the EU.

3) Energy Efficiency: How? Example 1: compressed air

$$w_{12} = \frac{\kappa}{\kappa - 1} p_1 v_1 \left[\left(\frac{p_2}{p_1} \right)^{\frac{\kappa-1}{\kappa}} - 1 \right] = h_2 - h_1 = cp(T_2 - T_1)$$

$$w_{12} \cong 3{,}5\, p_1 v_1 \left[\left(\frac{p_2}{p_1} \right)^{0{,}3} - 1 \right] \qquad w_{12} = K \left[\left(\frac{p_2}{p_1} \right)^{0{,}3} - 1 \right] = cp(T_2 - T_1)$$

Thermodynamics of compressed air

3) Energy Efficiency: How? Example 1: compressed air

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$$P = \dot{m} w_{12} = \dot{m} * f\left(\frac{p_2}{p_1} \right)$$

$$(T_2 - T_1) = f\left(\frac{p_2}{p_1} \right)$$

- The specific work or power needed when multiplied with mass flow rate is a function of the pressure ratio.
- The temperature increase is a function of pressure ratio

3) Energy Efficiency: How? Example 1: compressed air

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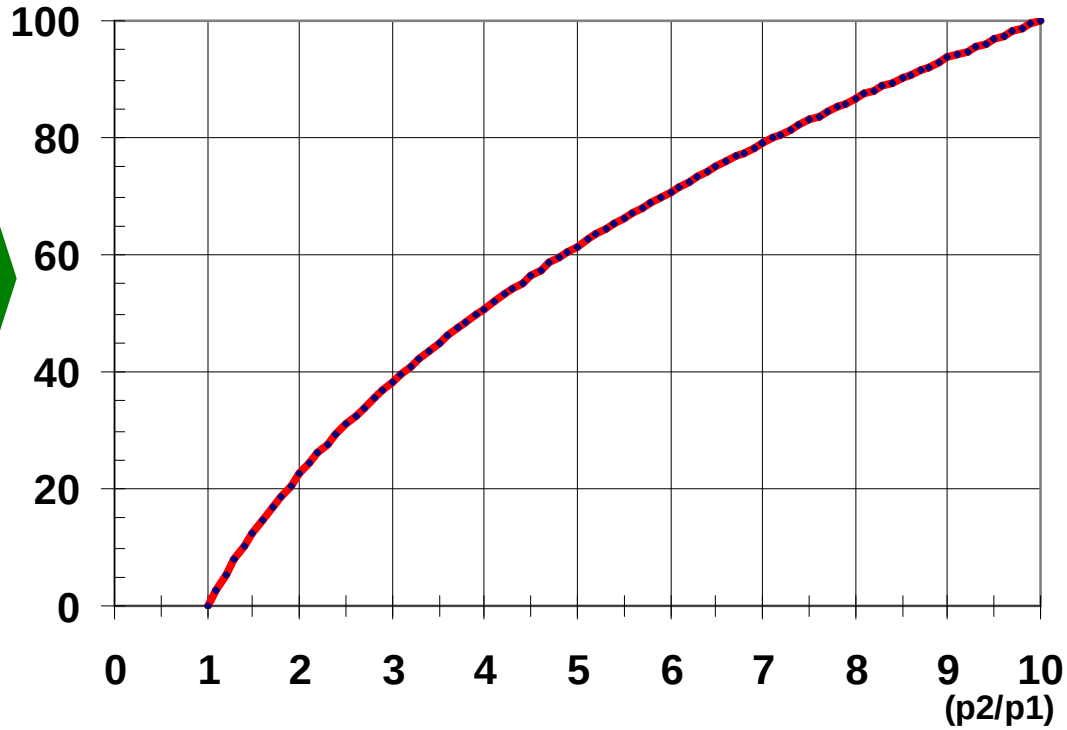

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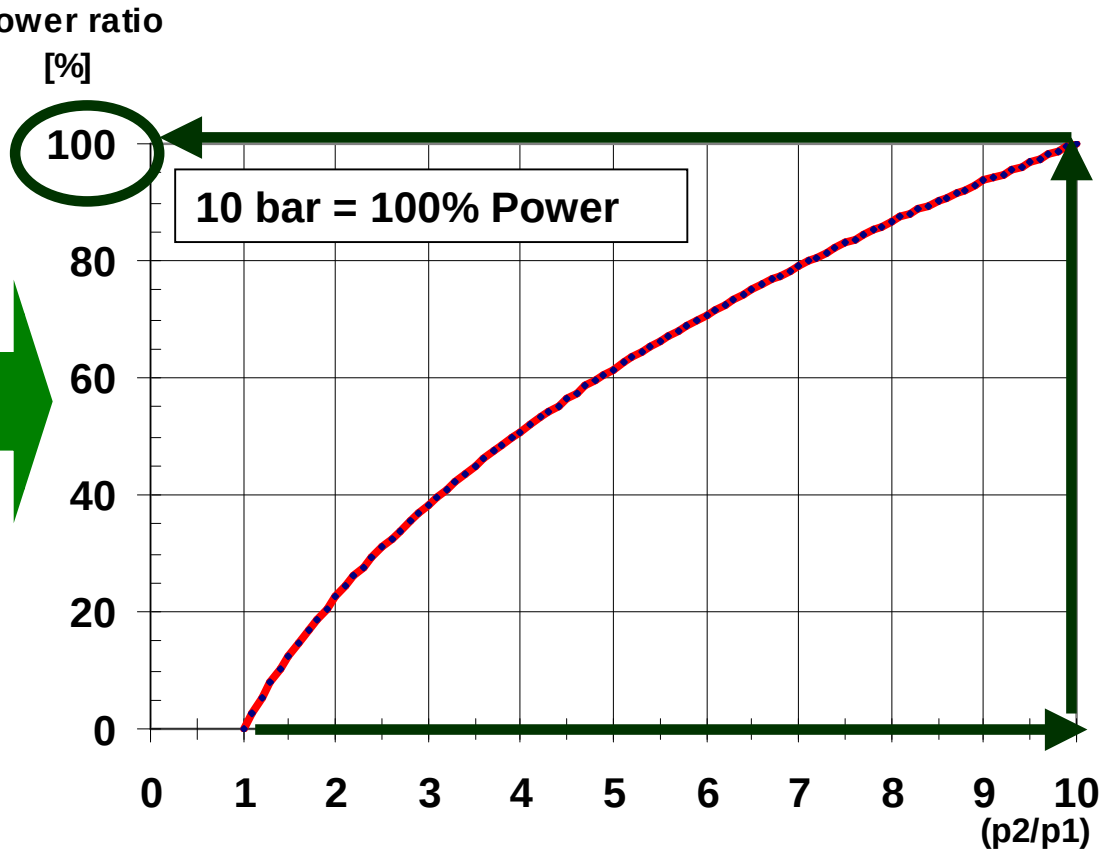
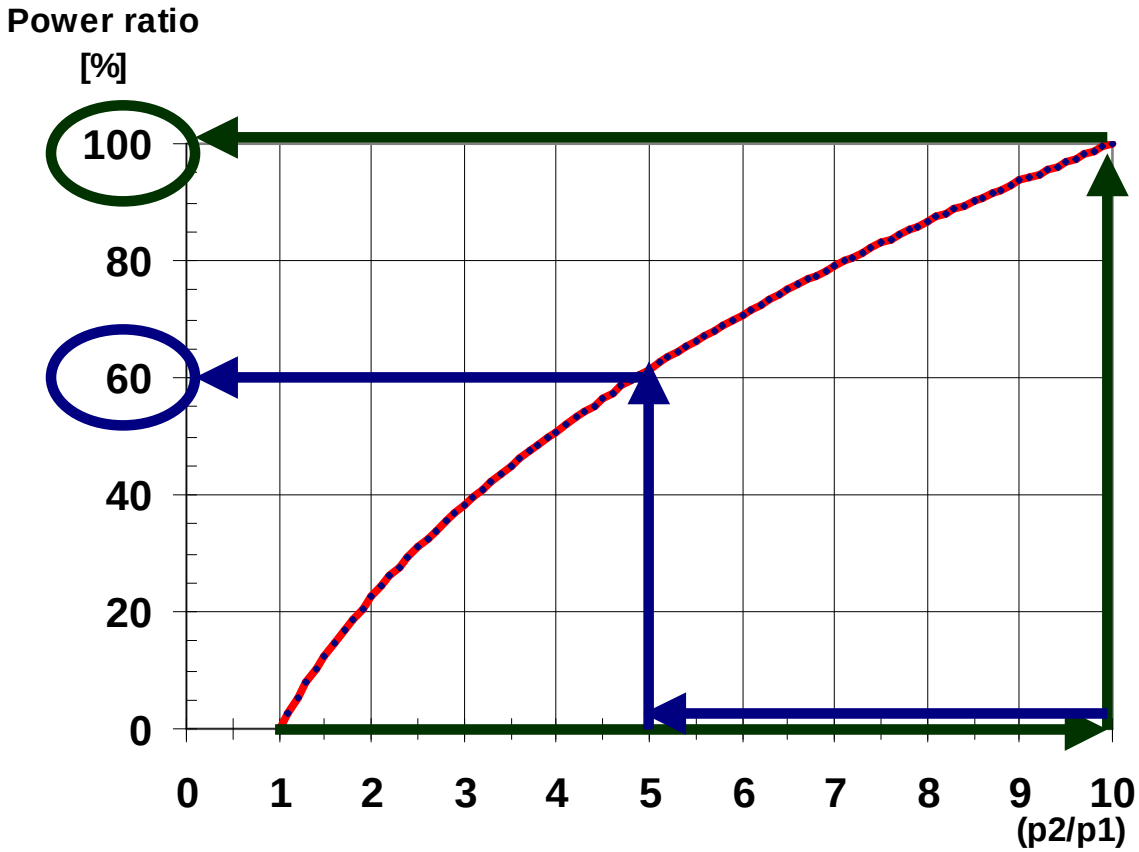


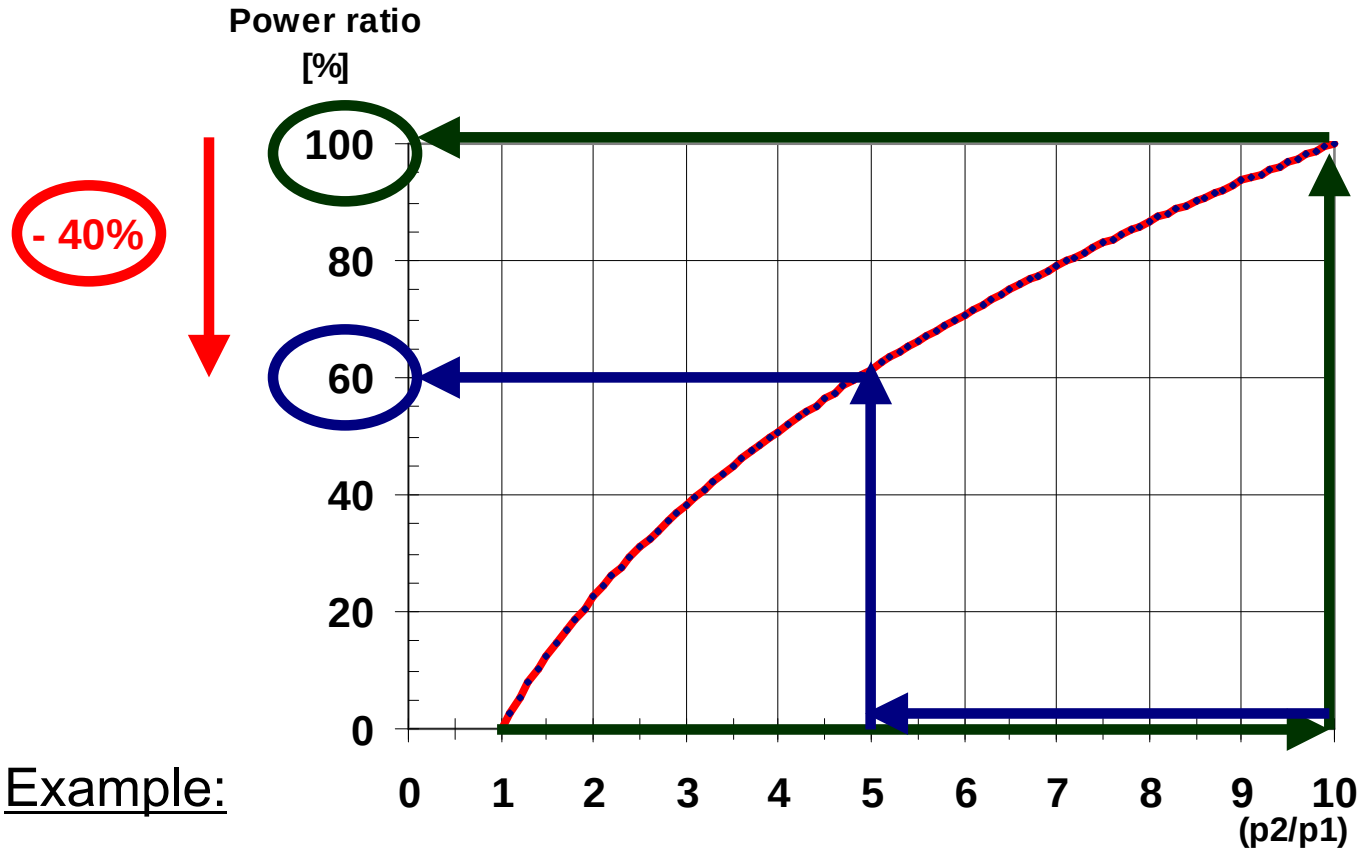
3) Energy Efficiency: How? Example 1: compressed air



Example:

Produce compressed air with 10 bar: $p_2/p_1 = 10$, energy needed = 100%
Reduce (throttle) pressure to 5 bar, energy equivalent = 60%

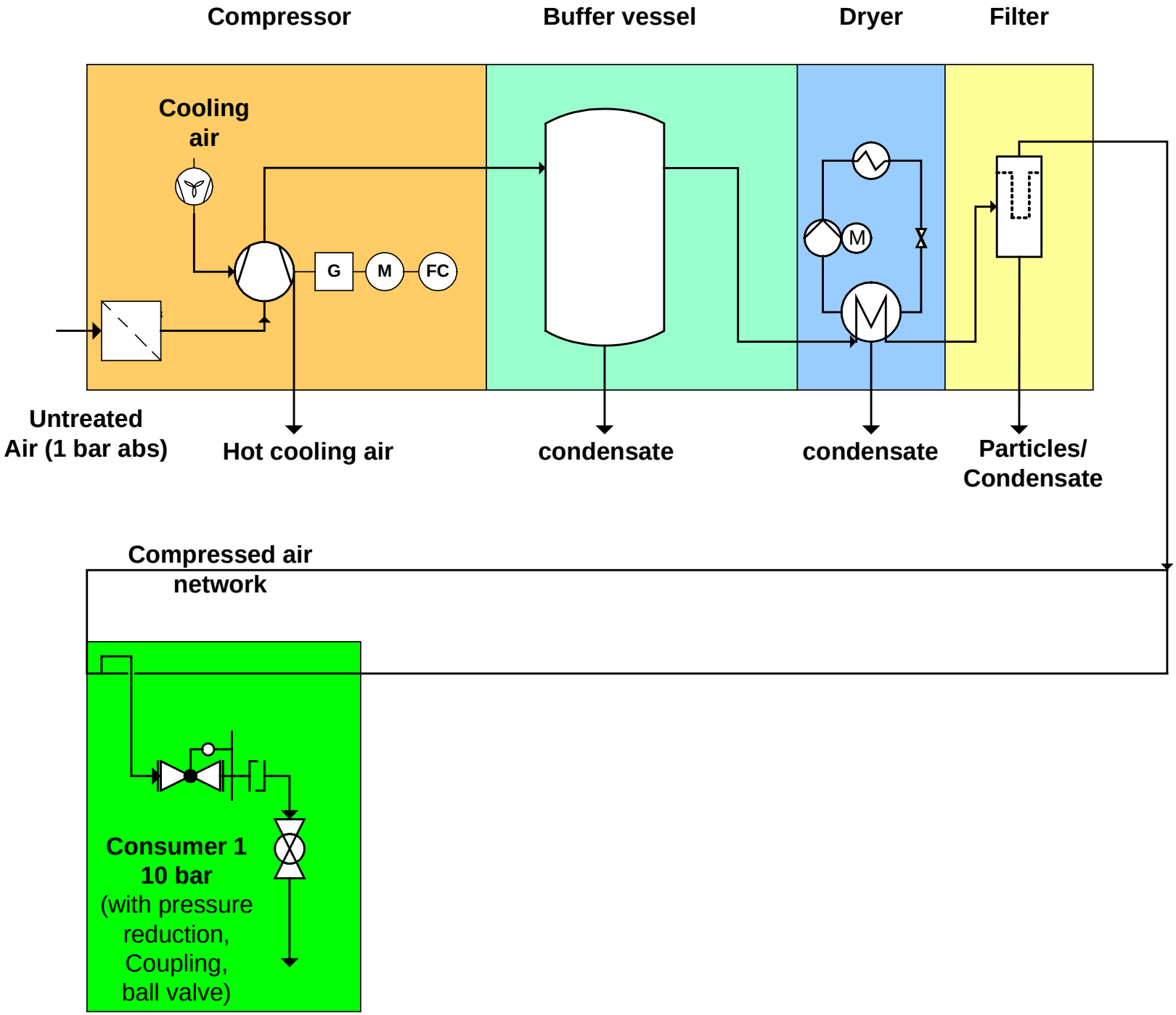
3) Energy Efficiency: How? Example 1: compressed air

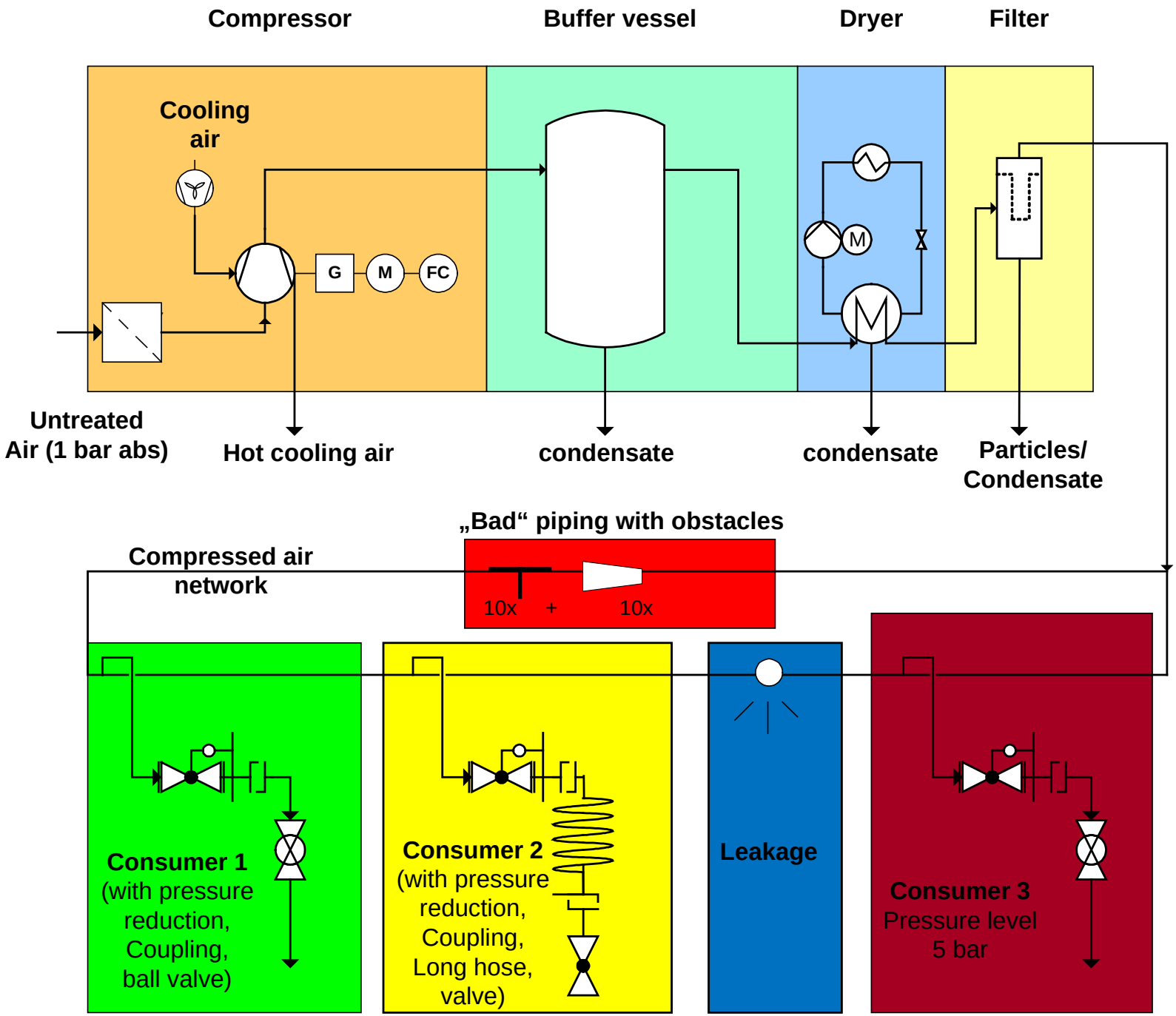


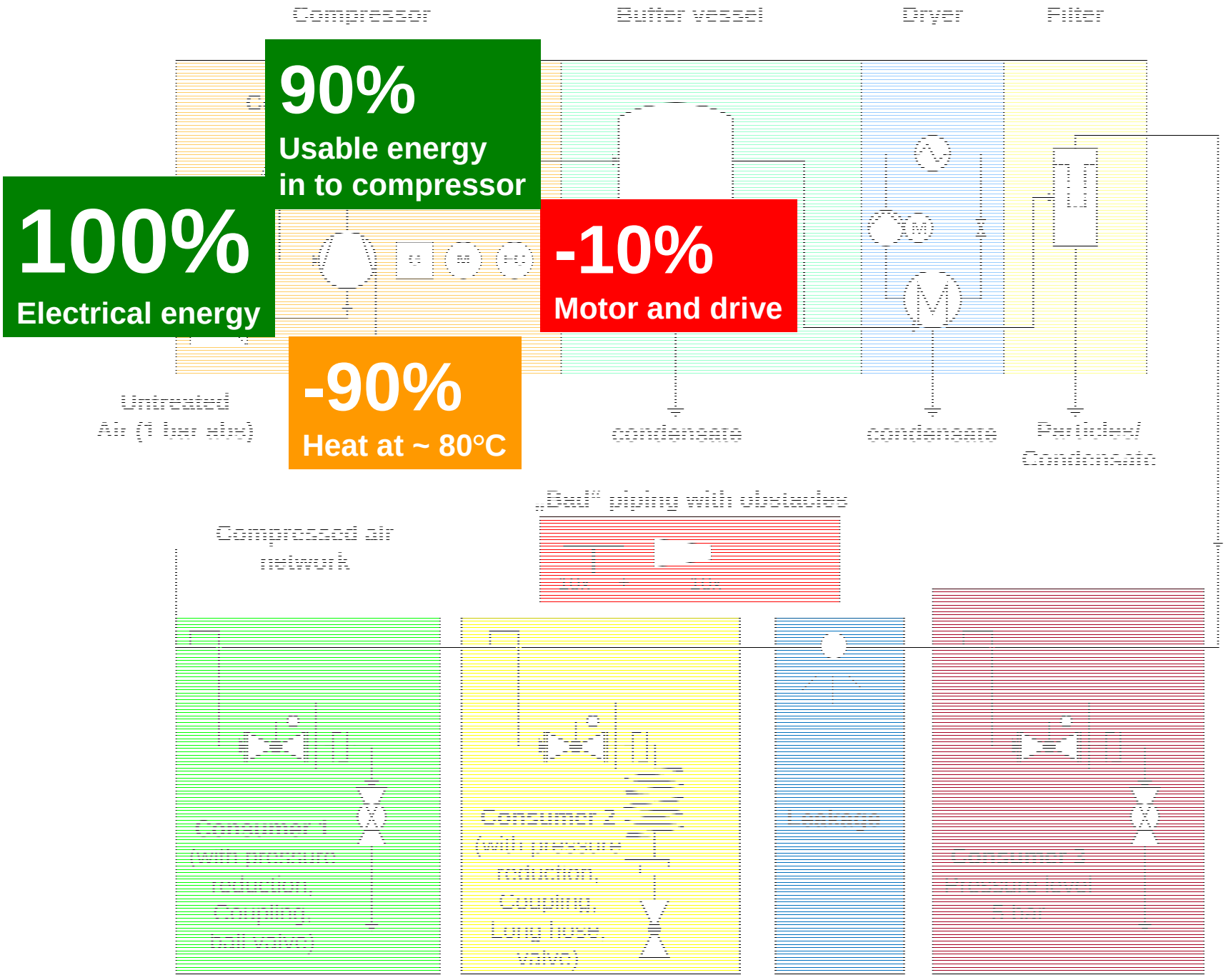
Example:

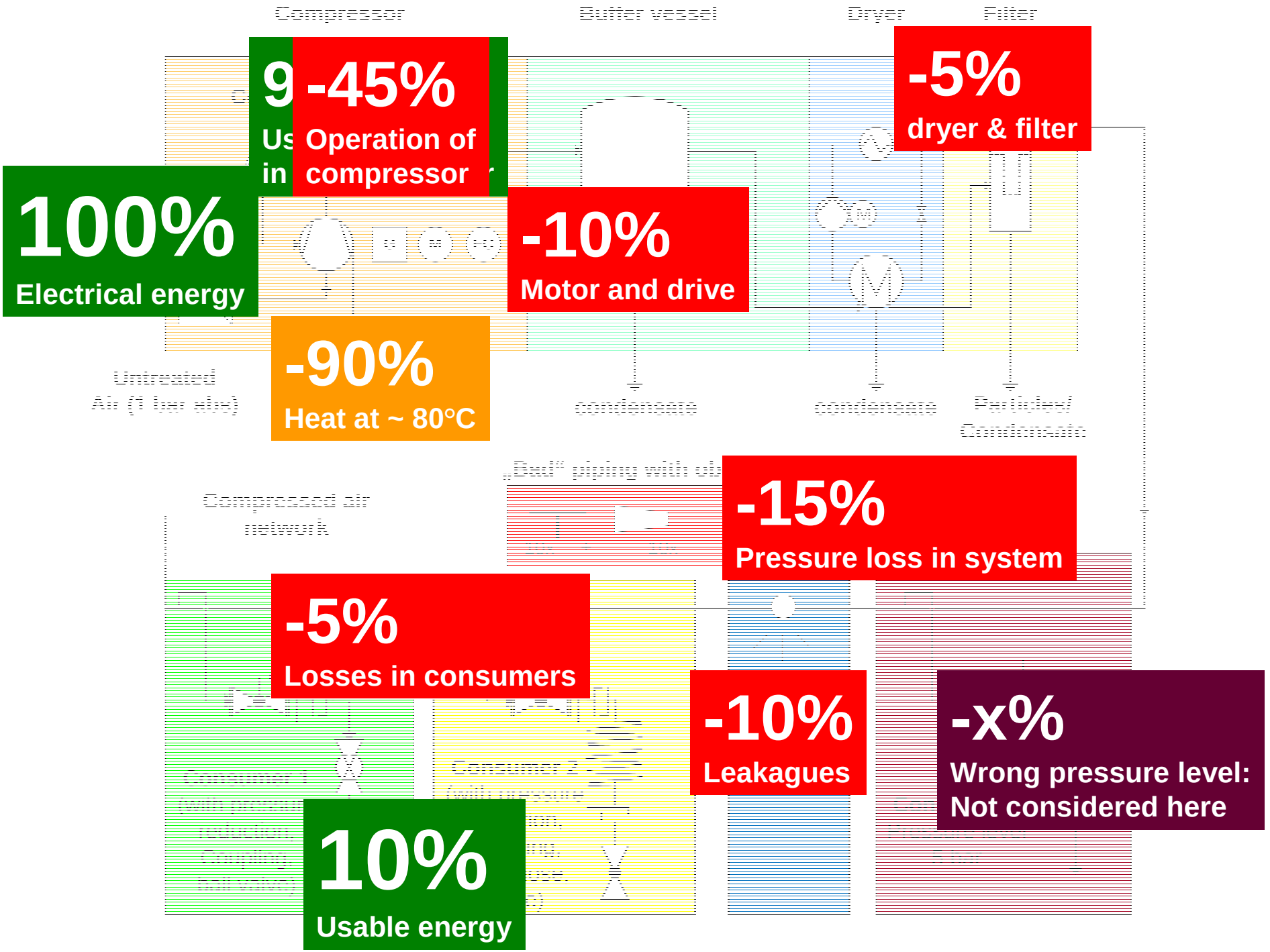
Produce compressed air with 10 bar: $p_2/p_1 = 10$, energy needed = 100%
Reduce (throttle) pressure to 5 bar, energy equivalent = 60%

= „Destroy“ 40% of energy input!

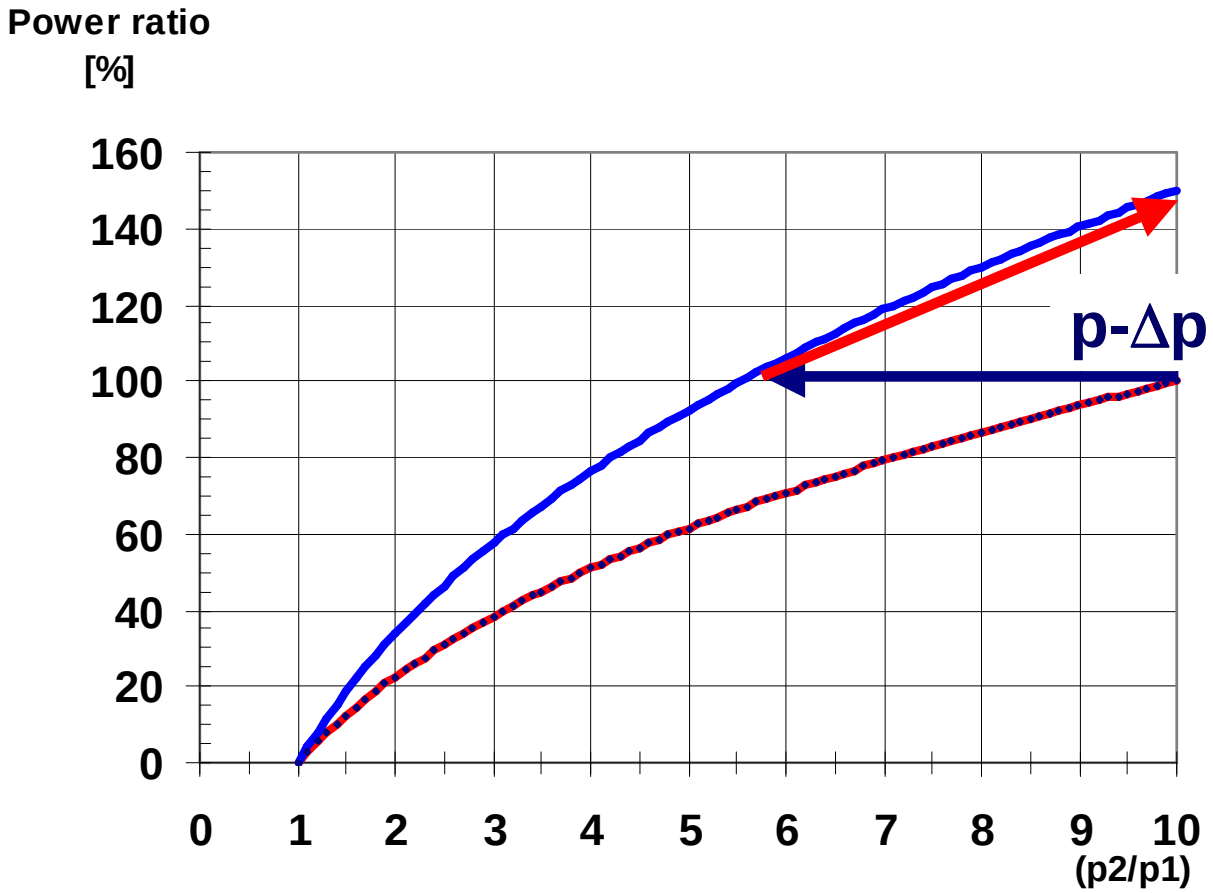

Compressor
Buffer vessel
Dryer
Filter
Cooling air
G
M
FC
M
Untreated Air (1 bar abs)
Hot cooling air
condensate
condensate
Particles/ Condensate
Compressed air network
Consumer 1
10 bar
(with pressure reduction, Coupling, ball valve)


Compressor
Buffer vessel
Dryer
Filter
Cooling air
G
M
FC
M
Untreated Air (1 bar abs)
Hot cooling air
condensate
condensate
Particles/ Condensate
„Bad“ piping with obstacles
Compressed air network
10x
+
10x
Consumer 1
(with pressure reduction, Coupling, ball valve)
Consumer 2
(with pressure reduction, Coupling, Long hose, valve)
Leakage
Consumer 3
Pressure level 5 bar


Compressor
Buffer vessel
Dryer
Filter
90%
Usable energy
in to compressor
100%
Electrical energy
-10%
Motor and drive
-90%
Heat at ~ 80°C
Unheated
Air (1 bar abs)
condensate
condensate
Purified
Condensate
„Dual" piping with obstruction
Compressed air
network
Consumer 1
(with pressure
reduction,
Coupling,
Long hose,
ball valve)
Consumer 2
(with pressure
reduction,
Coupling,
Long hose,
valve)
Receiver


100%
Electrical energy
9
Us
in
-45%
Operation of compressor
-10%
Motor and drive
-90%
Heat at ~ 80°C
-5%
dryer & filter
-15%
Pressure loss in system
-5%
Losses in consumers
-10%
Leakagues
-x%
Wrong pressure level:
Not considered here
10%
Usable energy

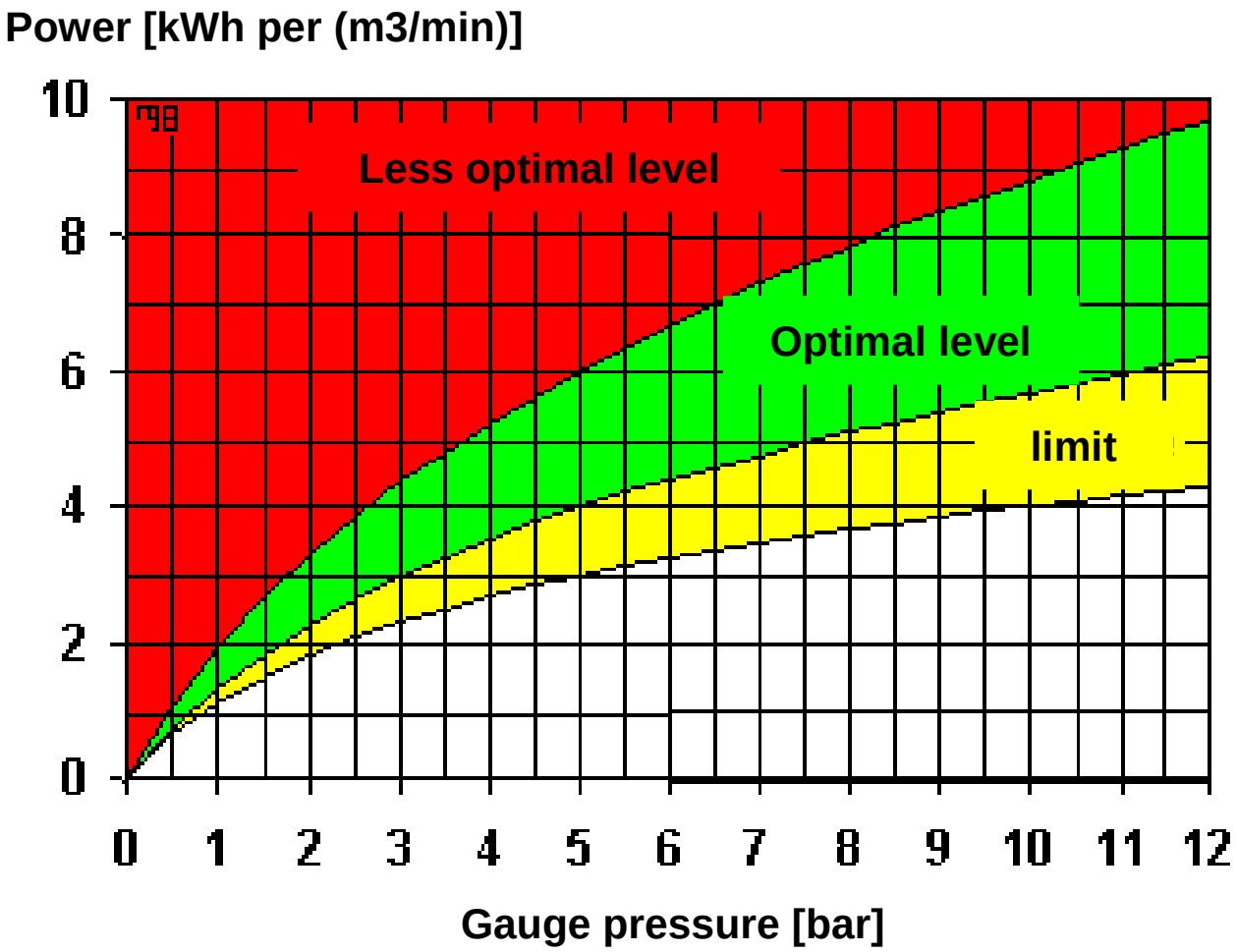
3) Energy Efficiency: How? Example 1: compressed air



Example:

Pressure losses in system (obstacles, leakages, etc., see above)
account for more power need
-> How good is my system? Measure? Benchmark?

3) Energy Efficiency: How? Example 1: compressed air



Benchmarking for compressed air systems

(Source: http://www.energie.ch/)

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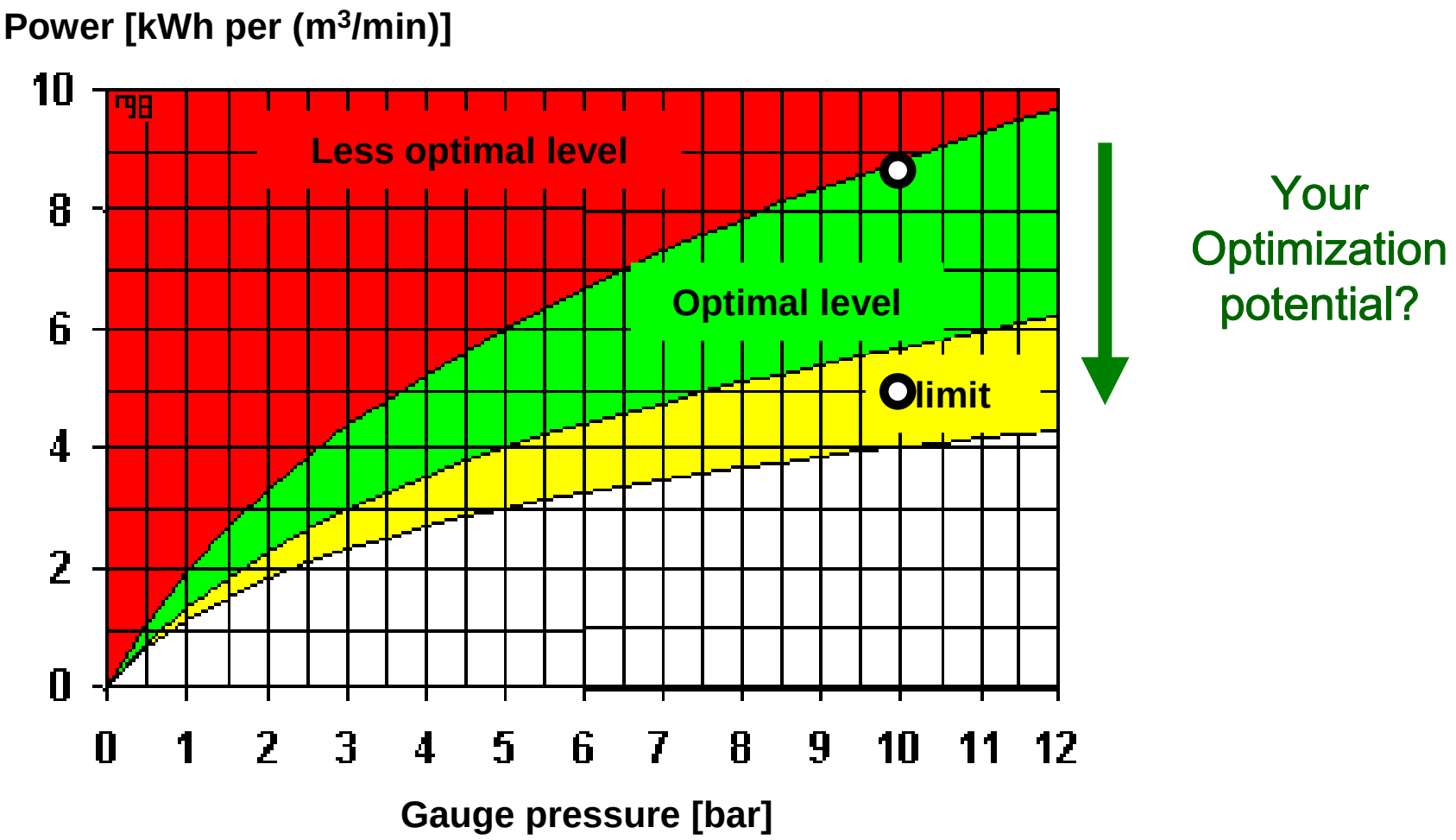


Benchmarking for compressed air systems

(Source: http://www.energie.ch/)

Optimization of compressed air systems:

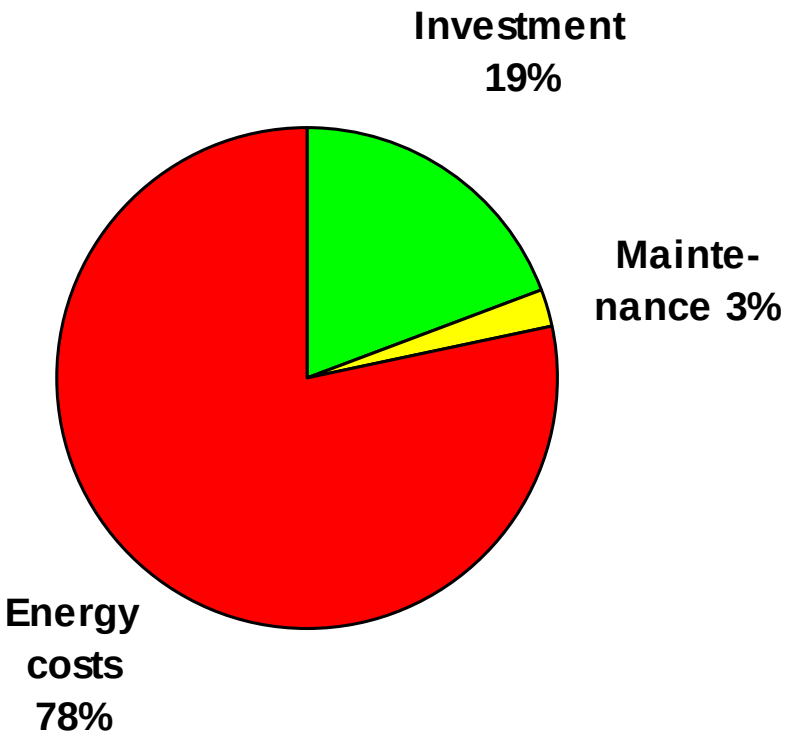
- ✓ Optimize operation of compressor
- ✓ Controls of compressor
- ✓ Use waste heat of compressor where possible
- ✓ Optimize filter and dryer (e.g. exchange filter regularly)
- ✓ Reduce obstacles in pipe system
- ✓ Reduce leakages
- ✓ Use efficient consumers
- ✓ Train the operators: increase awareness!

3) Energy Efficiency: How? Example 1: compressed air

Typical Life cycle cost of a compressed air system

- Life-Cycle Costs

- Total Cost of Ownership

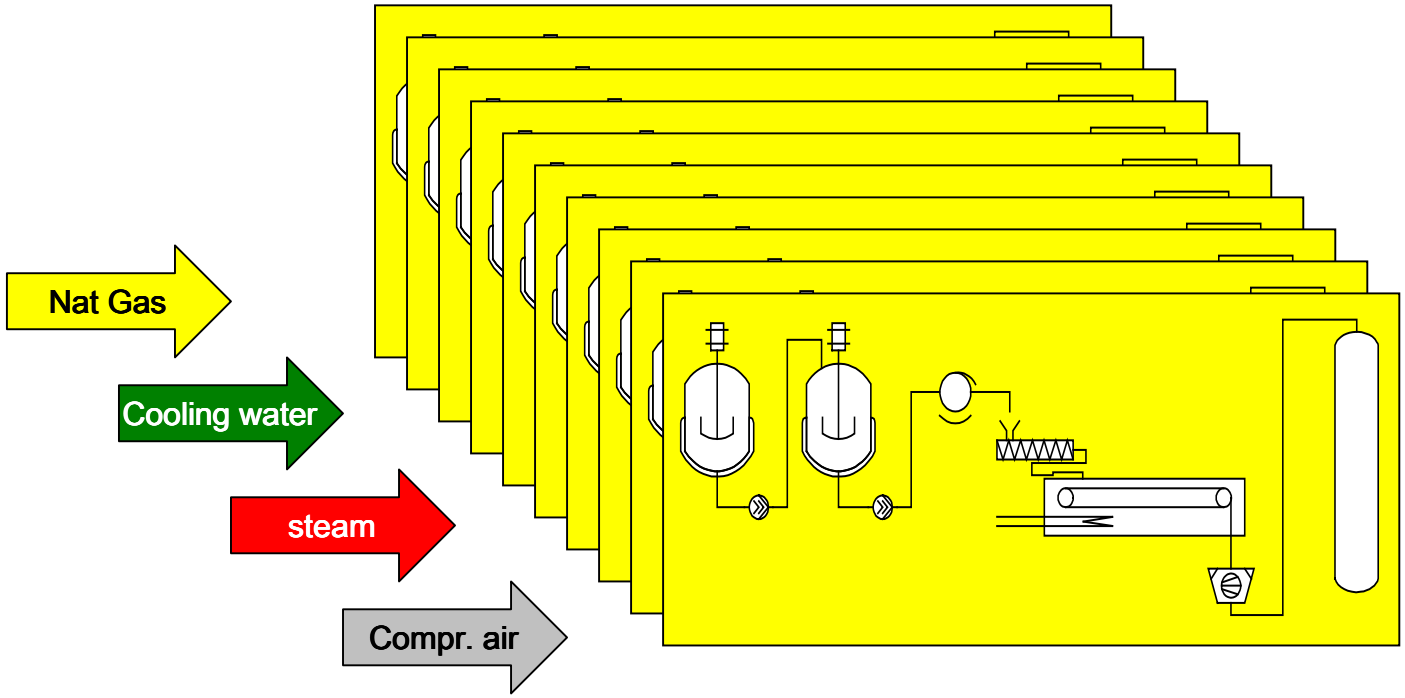


Use life-cycle costs as basis
for decisions,
not total investment

Source: Bayrisches Landesamt für Umwelt

Example 2:
Production Planning

3) Energy Efficiency: How? Use of utilities in batch plant

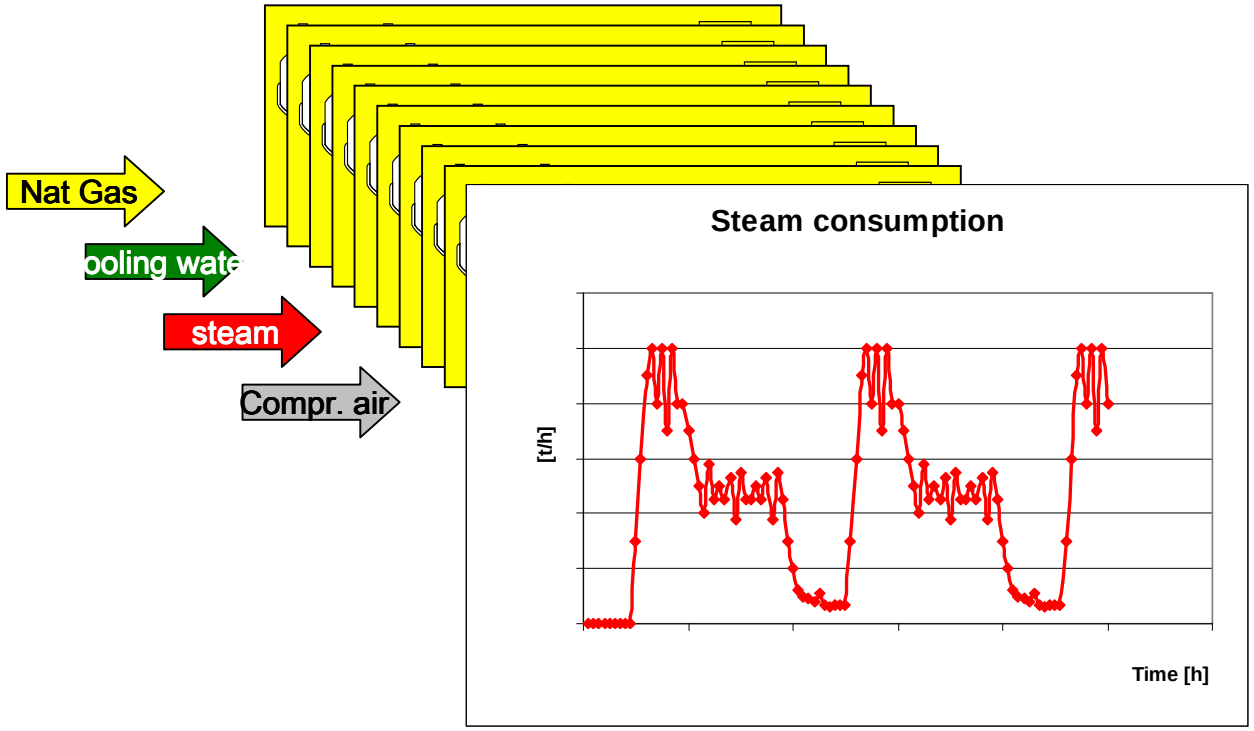


- Use of utilities/ energies
  - natural gas
  - cooling water
  - steam
  - compressed air

- ➢ How much?
- ➢ When?
- ➢ Base load?
- ➢ Peak load?
- ➢ Efficient use of equipment?

3) Energy Efficiency: How? Use of utilities in batch plant

1) Measure/ Record!

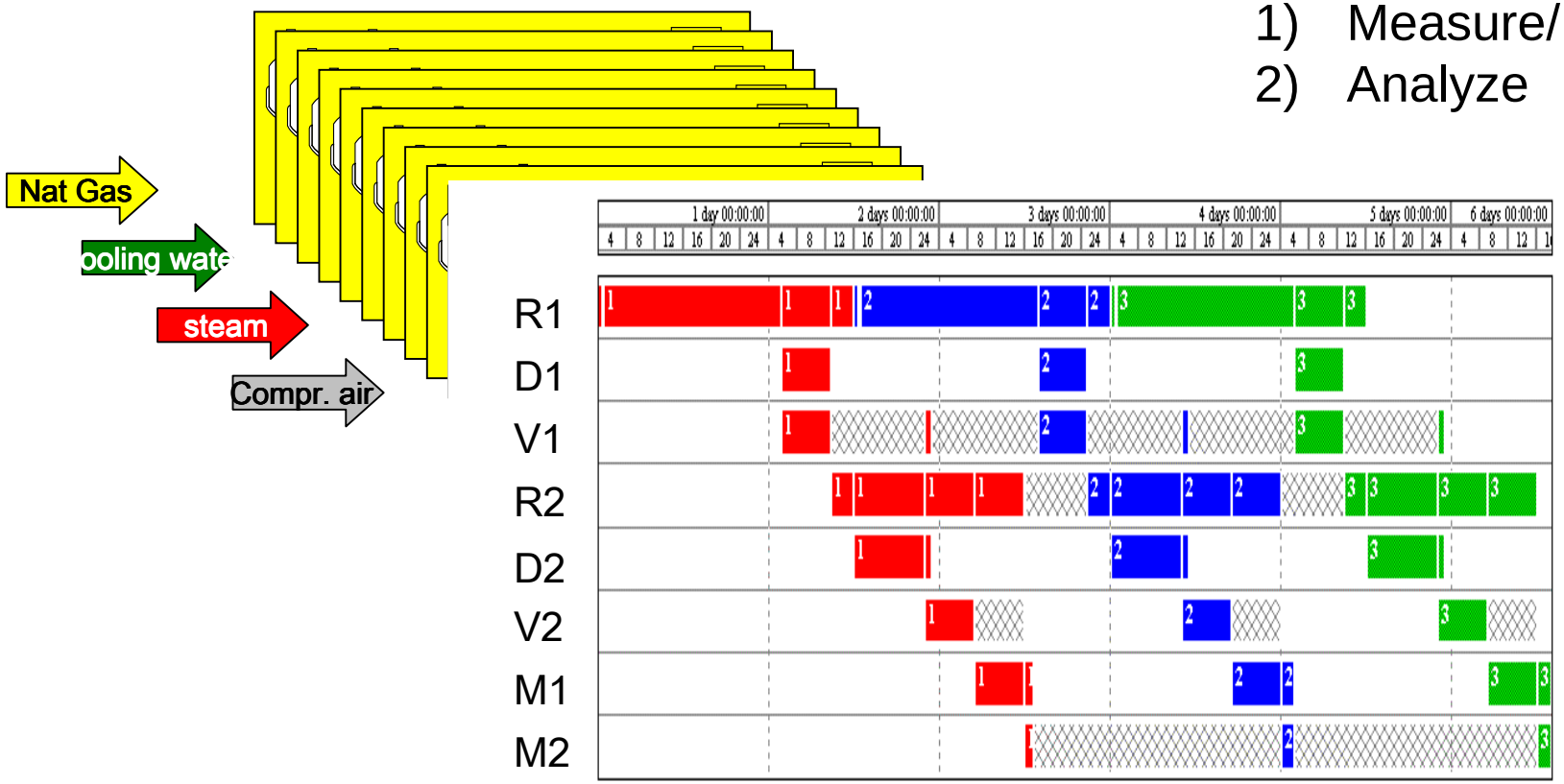


Measurement gives: high peak load

- Equipment is too big!
- Equipment utilization and specific costs high!
- Equipment design is inefficient!
- Peak-load price is very expensive

3) Energy Efficiency: How? Use of utilities in batch plant

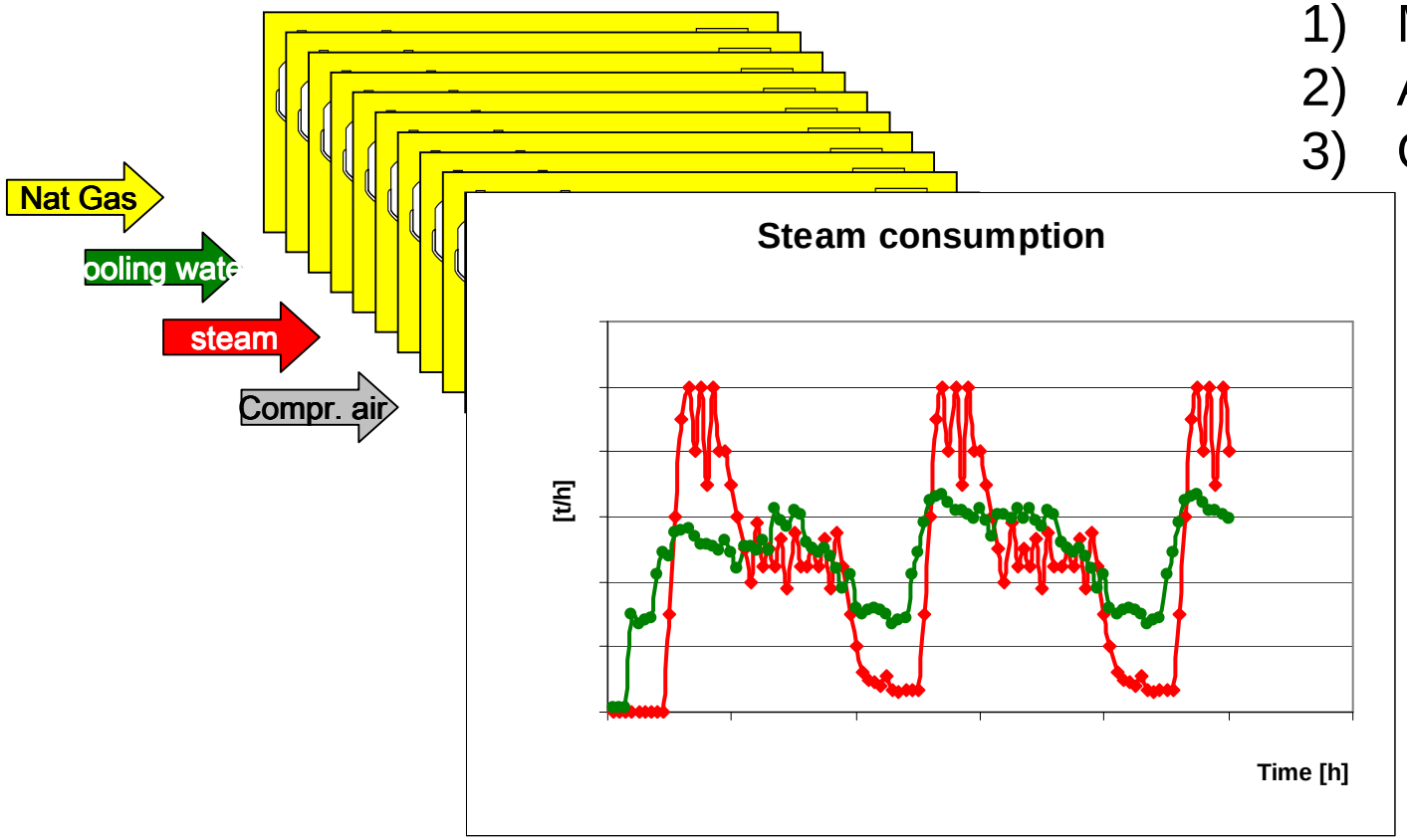
1) Measure/ Record!
2) Analyze



Perform capacity analysis (i.e. batch mass balance):

- Detailed view of process possible
- Equipment utilization
- Basis for optimization

3) Energy Efficiency: How? Use of utilities in batch plant



1) Measure/ Record!
2) Analyze
3) Optimize

Optimized process:

- Better equipment utilization
- Better energy efficiency of pumps and heat exchangers
- No more peak load: reduced energy price

Example 3: Optimization Projects (=Energy Audit?)

3) Energy Efficiency: How?

Optimization Projects to increase energy efficiency:

- People involved: Decision makers, specialists, engineers and internal energy consultants
- These people know best about weak points and strength
- about their problems/ the areas of optimization
- Why use external assistance?
- Audit = „one of these typical consulting projects“ ???

3) Energy Efficiency: How?

Optimization Projects to increase energy efficiency:

- There exist long “punsh lists”
  “for years we wanted to…”

But it is often unknown/ not available:

- Time to find and analyze optimization potentials
- Time to priorize actions
- Time to define projects
- Time to implement new measures.

3) Energy Efficiency: How?

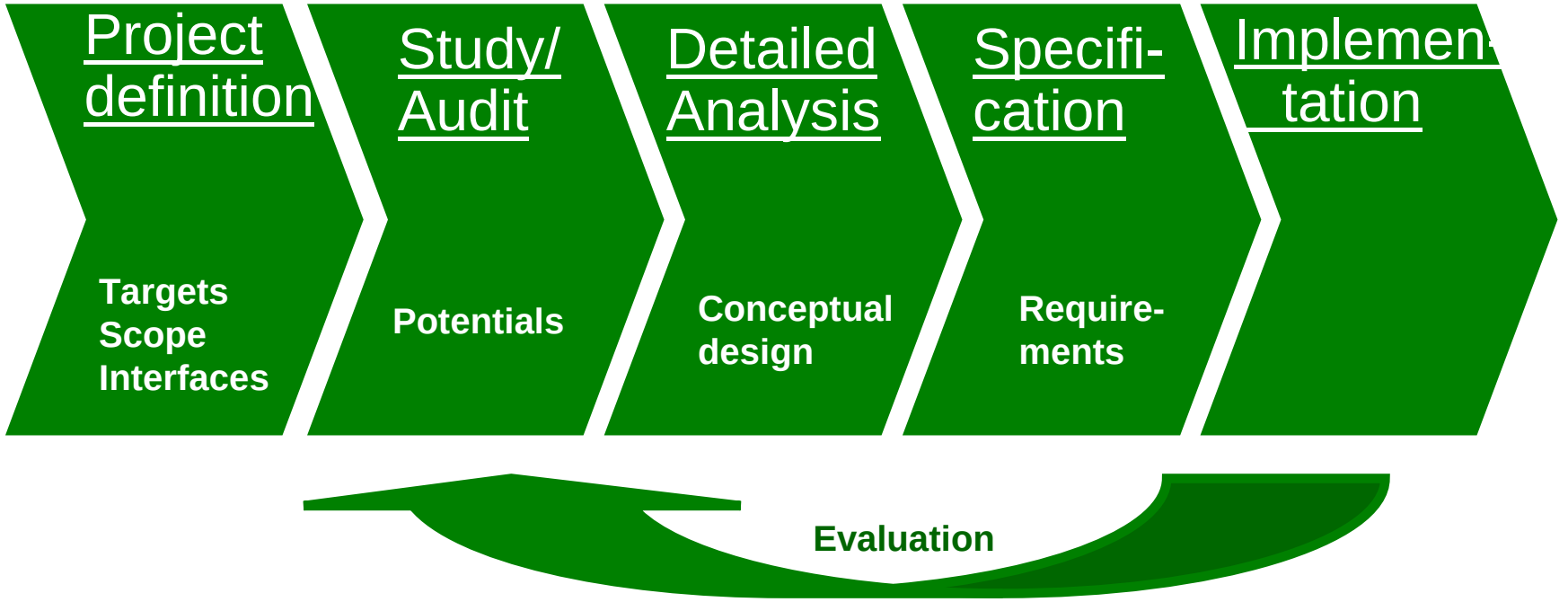
Optimization projects = Energy audits answer:

- ✓ How much energy can be saved
- ✓ What is the best available technology
- ✓ How to evaluate optimization potentials
- ✓ How to implement new technologies
- ✓ How to sensibilise employees

Together with people involved

3) Energy Efficiency: How?

Optimization projects/ Energy audits: procedure



3) Energy Efficiency: How? Example 1: compressed air

Tabelle 1: Interne Verzinsung in Abhängigkeit von der Nutzungsdauer und in Relation zur Amortisationszeit

geforderte Amortisationszeiten (Jahre)	Interne Verzinsung in % pro Jahr [1]							
	Anlagennutzungdauer (Jahre)							
	3	4	5	6	7	10	12	15
2	24%	36%	41%	46%	47%	48%	48,50%	50%
3	0%	13%	20%	26%	27%	31%	32%	33%
4		0%	8%	13%	17%	22%	23%	24%
5			0%	6%	10%	16%	17%	18,50%
6		unrentabel		0%	4%	10,50%	12,50%	14,50%
8						4,50%	7%	9%

[1] unterstellt wird eine kontinuierliche Energieeinsparung über die gesamte Anlagennutzungsdauer

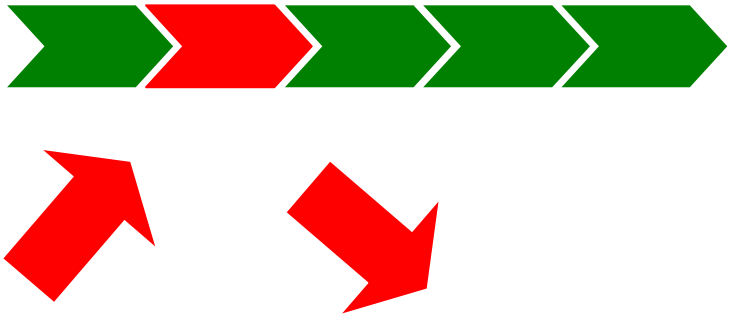
abgeschnittene rentable Investitionsmöglichkeiten: Chancen des Contracting

Quelle: DOE, 1982

IRR, Internal Rate of Return
Economic value added

Any other means to calculate cost effectiveness

3) Energy Efficiency: How?



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BEUTH HOCHSCHULE FÜR TECHNIK BERLIN University of Applied Sciences

Chemical and Environmental Technology
Prof. Dr.-Ing. Bernd Bungert

11

Nr.	Field of optimization	Current Status	Measure	Potential	Tasks for detailed analysis	implementation [months]	Estimated benefit [€/a]	Estimated Investment Costs [€]	Amortisationszeit [a]	Service life [years]	Rentability [%/a]
1	**Process Technology**										
1	**Component efficiency**	Pumps are operated in bypass mode	Install new drive with FC, automate, change piping	Reduce energy consumption by 30%	Conceptual design and cost estimation	6	4.200	9.300	2,2	5	20%
4	**Supply and Usage of Energy Sources**	compressed air									
5	**Production Buildings**										
2	**Process Control and Operation**	Parallel operation of dryers causes peak load and inefficiency of equipment	Change production planning, implement visualization	Increase equipment efficiency by 10%, reduce peak load costs	Perform Capacity analysis	4	#####	#####	1,1	6	46%
7	**Management-tools**										

3) Energy Efficiency: How?

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7	**Management-tools**										

Systematic analysis gives potentials and priorities

- ➢ at an early stage
- ➢ for low cost

4) Energy Efficiency: Why else?

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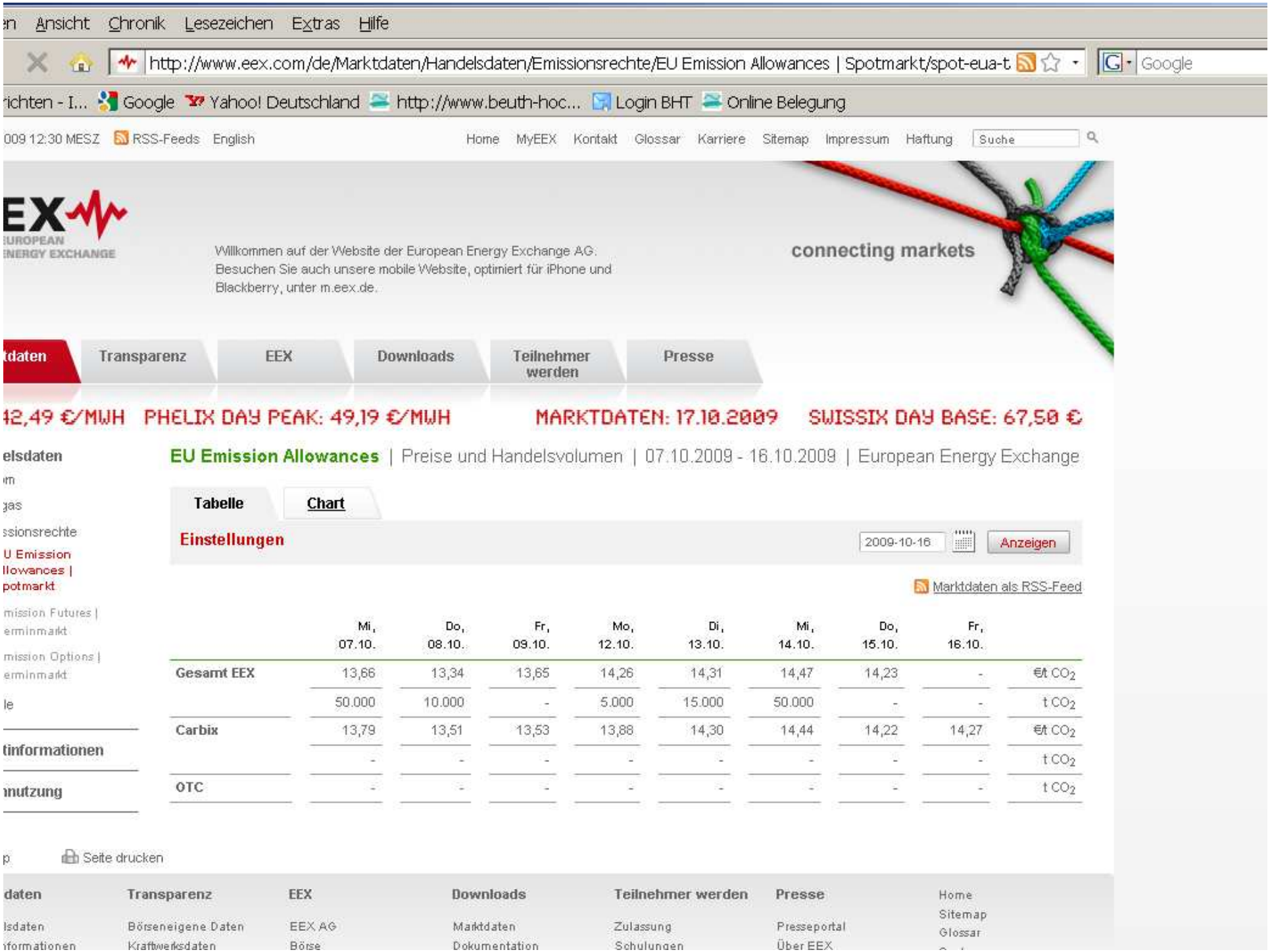
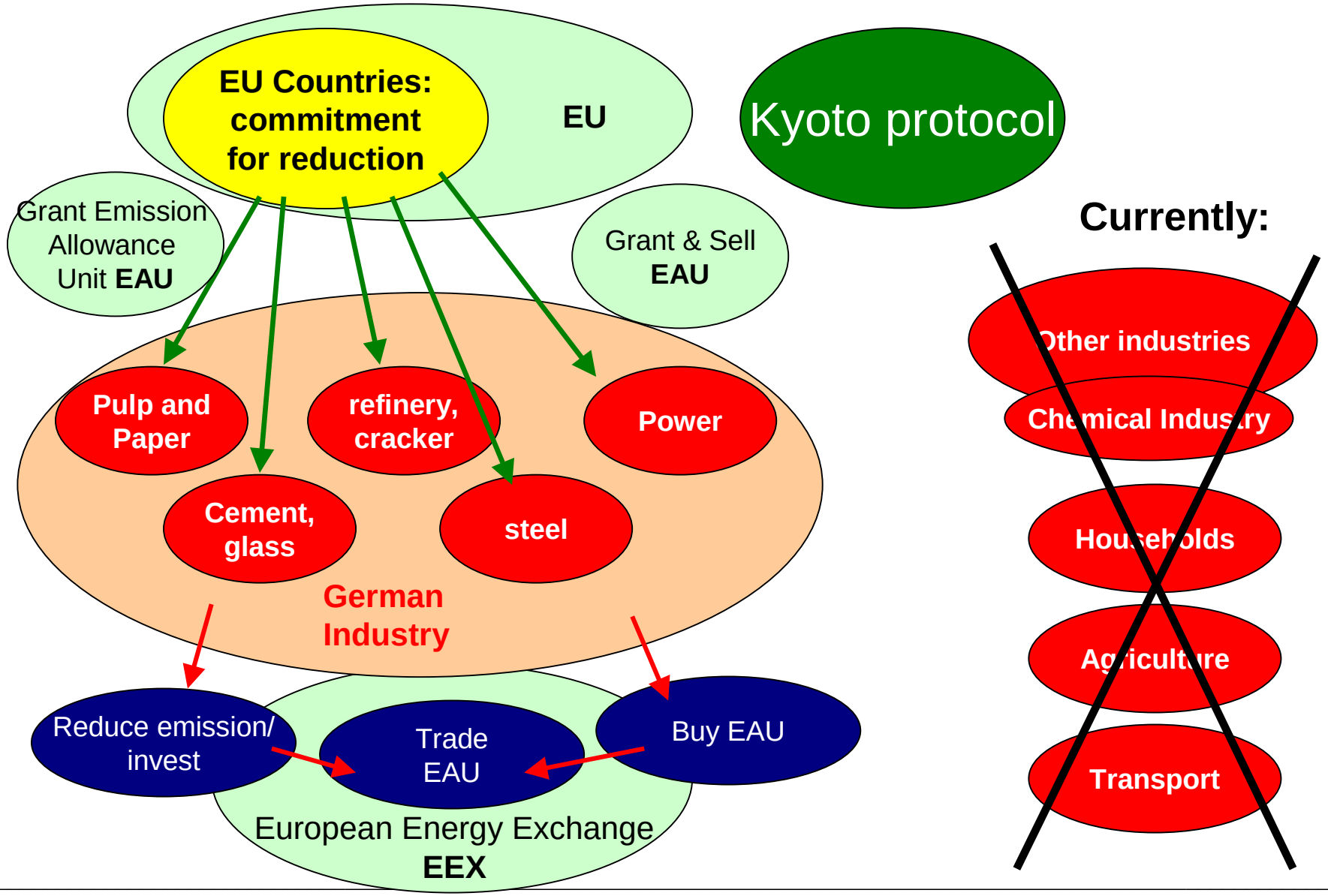


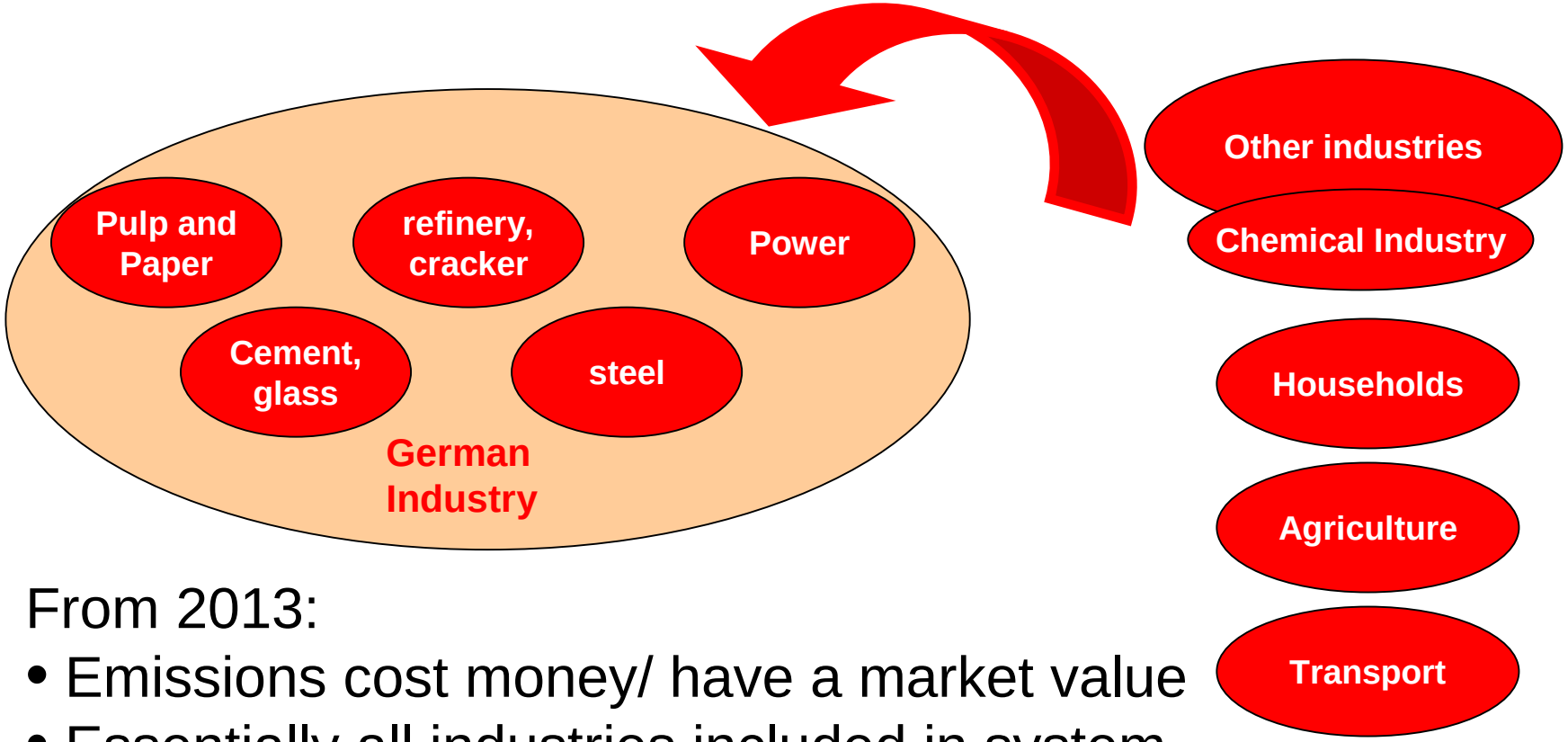
	Mi, 07.10.	Do, 08.10.	Fr, 09.10.	Mo, 12.10.	Di, 13.10.	Mi, 14.10.	Do, 15.10.	Fr, 16.10.	
Gesamt EEX	13,66	13,34	13,65	14,26	14,31	14,47	14,23	-	€/t CO_2
	50.000	10.000	-	5.000	15.000	50.000	-	-	t CO_2
Carbix	13,79	13,51	13,53	13,88	14,30	14,44	14,22	14,27	€/t CO_2
	-	-	-	-	-	-	-	-	t CO_2
OTC	-	-	-	-	-	-	-	-	t CO_2

4) Energy Efficiency: Why else?



4) Energy Efficiency: Why else?

Third phase of emission trading from 2013:



From 2013:

- Emissions cost money/ have a market value
- Essentially all industries included in system

5) Summary

Energy Efficiency

- Can decrease Spains dependence on fossil fuels
- Projects are therefore funded by the Government
- Earns Money
- Reduces CO_2 emissions

Further information and detailed references, examples under

- http://prof.beuth-hochschule.de/bungert/
- http://www.ib-bungert.de