Industrial cases

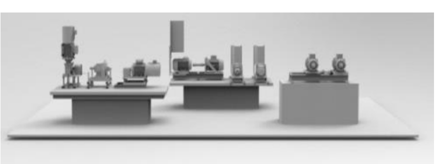
Kurt Stockman

contact

Kurt.Stockman@ugent.be
Steve.Dereyne@ugent.be

www.ugent.be/ea/eesa

IWT Tetra project nr. 130201



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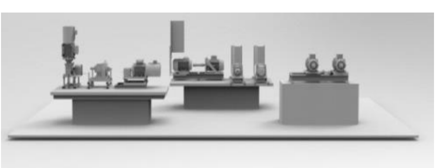
Studienamiddag 17.12.15
Efficiëntieverhoging Elektromechanische Aandrijvingen

IWT

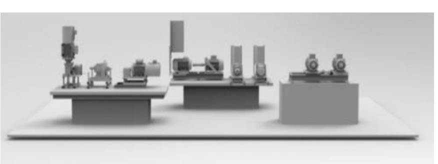
Industrial cases

- What is the **economic benefit** when optimizing the energy efficiency?
- Need for industrial cases to “prove” the value of the research
- What can the **Extended Product Approach** contribute?

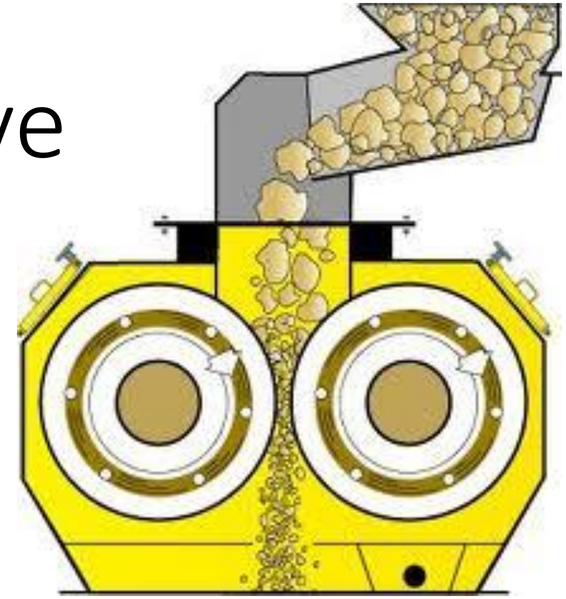


Industrial cases: a systematic approach

- Step 1: collect all relevant process information
  - Company process expert + energy manager + research team
- Step 2: energy measurement “as is” situation
  - Energy manager + research team
- Step 3: analysis and optimization study
  - Estimate potential savings and payback time
  - Research team
- Step 4: implementation
  - Company
- Step 5: validation: energy measurement new situation
  - Energy manager + research team



Case 1: Wienerberger Roller Drive



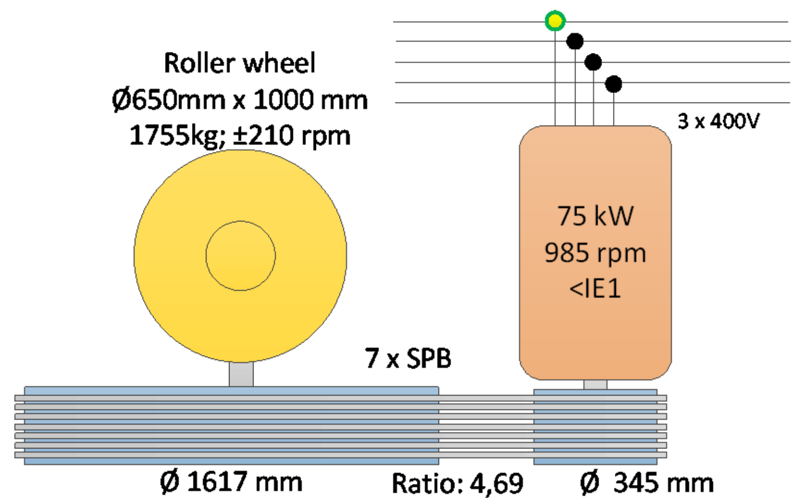
Step 1: collect all relevant process information

Kneading, mixing, creating a homogeneous mixture of the clay

Principle: 2 rollers with adjustable spacing where the clay mixture is rolled in between

Drive: both rolls are driven

- Two DOL induction motors (75kW and 37kW, 6p)
- + belt drive (7 belts)



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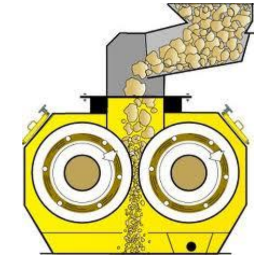
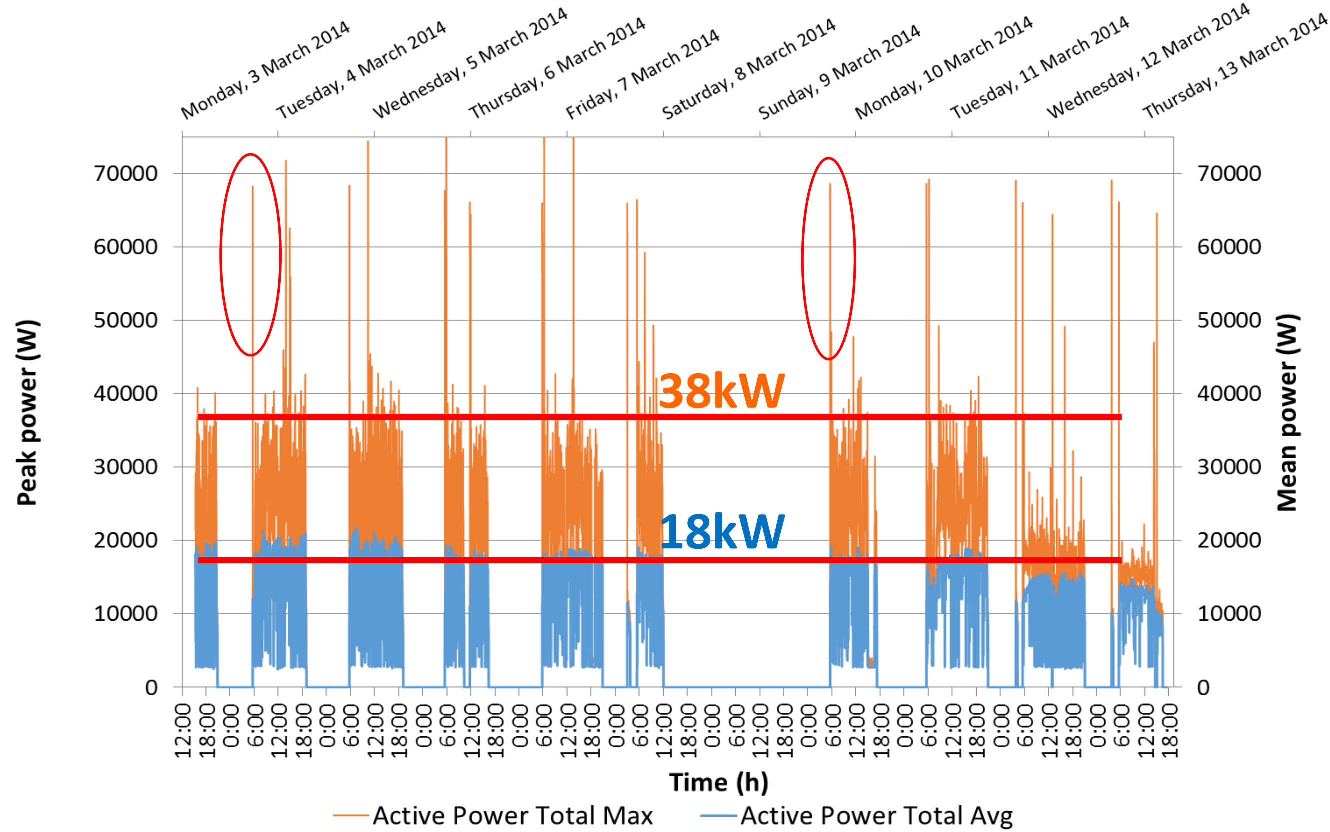
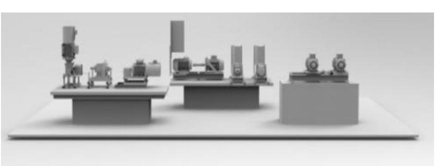


Step 2: energy measurement “as is” situation

- Average power: 18kW
- Peak power / torque spikes: 38kW !!!
- Motor overdimensioned





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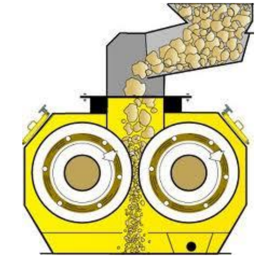
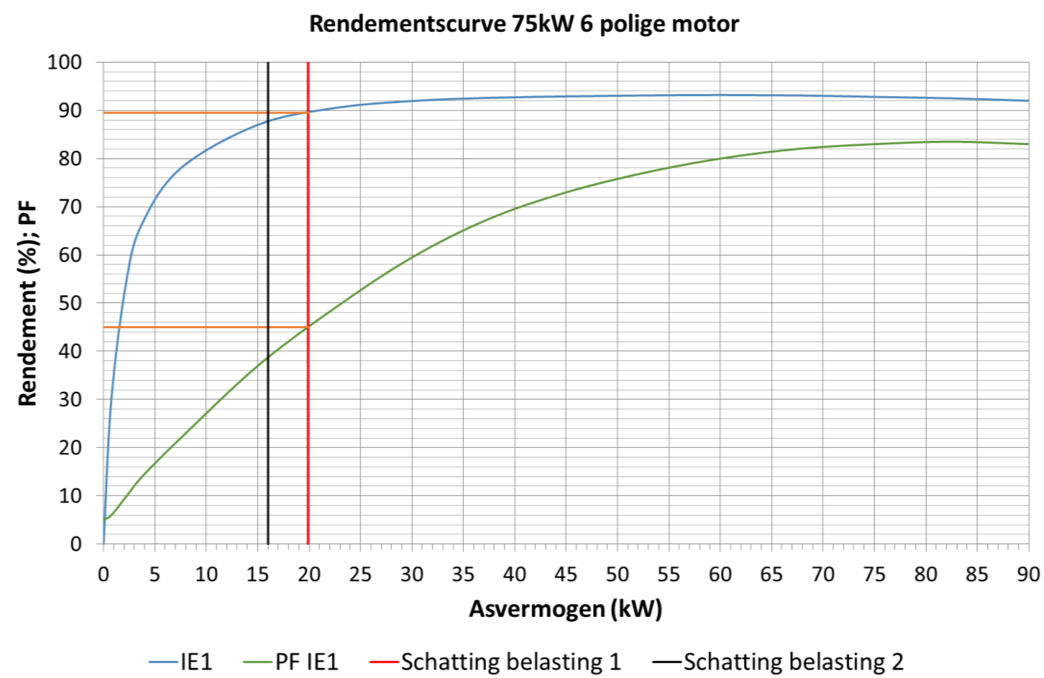


Step 3: analysis and optimization study: change MOTOR

- Old motor : 75kW, overdimensioned, unknown IE class
- Measured electric power 18kW, PF ≈ 0,45
- Estimation of motor eff based on IE1 motor
  - η = 87,5 %, P_{as} = 18,3 kW
- Possible options:
  - 75kW IM IE3
    - Same power but better efficiency class
  - 37kW IM IE3 (designed on peak power)
    - Better dimensioned, high efficiency
  - *18,5kW IM IE3 (designed on mean power)*
    - *'Correctly' dimensioned, high efficiency*
  - *37kW Permanent magnet motor with VSD*
    - *Motor with highest efficiency*
  - *Direct drive*



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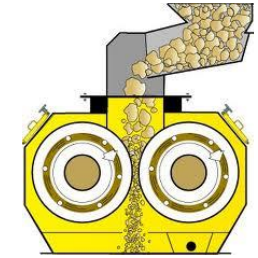
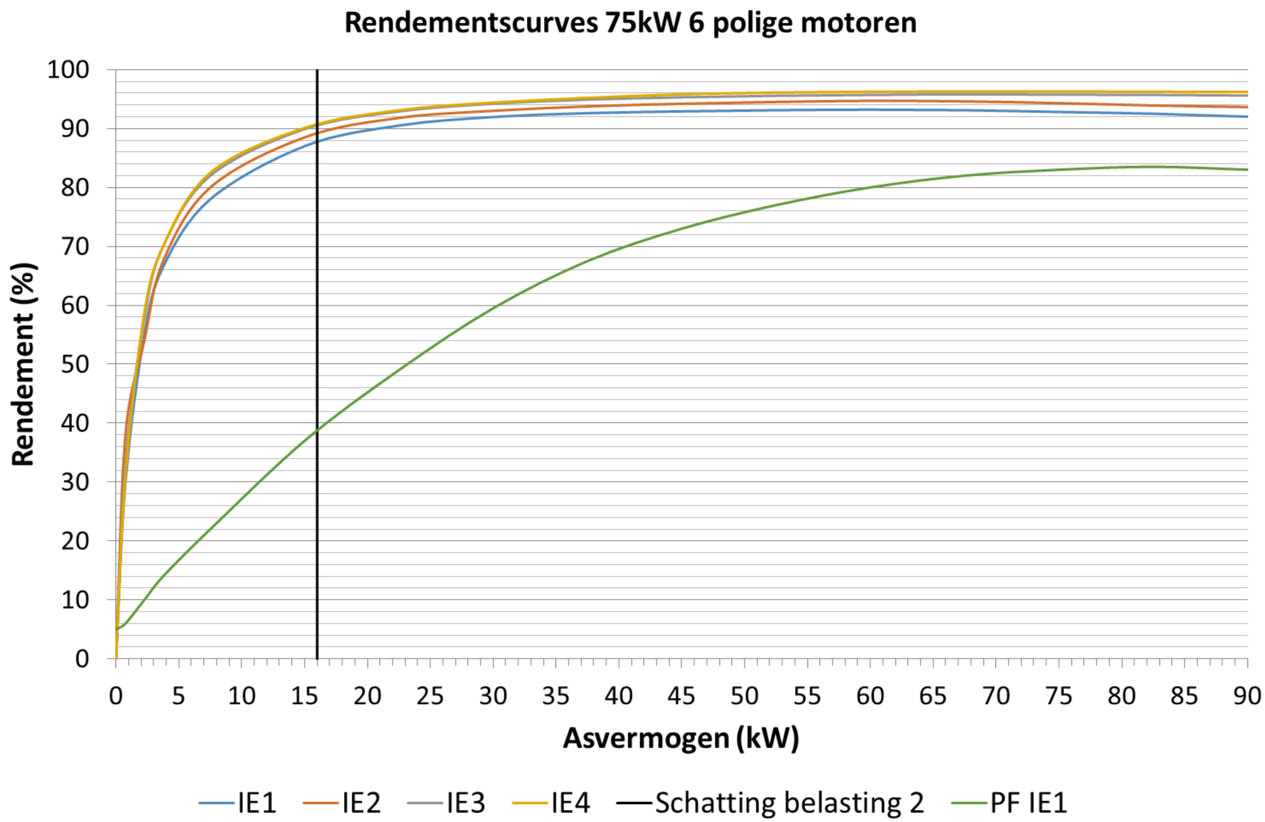


Step 3: analysis and optimization study: change MOTOR

- 75kW IM IE3



η_{IE1}=87,5%

η_{IE2}=89,1%

η_{IE3}=90,5%

η_{IE4}=90,7%

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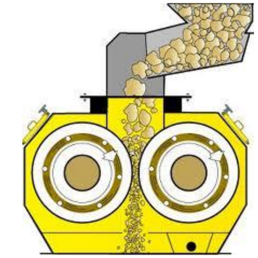
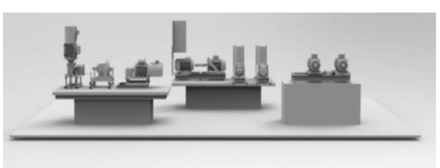


Step 3: analysis and optimization study: change MOTOR

- 75kW IM old → IE3 (3750 h/year @ €0,10/kWh)

	P_{as} (kW)	Rendement	P_{elek} (kW)	Jaarlijks verbruik (kWh)	Jaarlijkse kostprijs (€)	Jaarlijkse winst (€)
REF 75kW IE1	16	87,5%	18,3	68571,4	6857,1	0,0
75kW IE2	16	89,1%	18,0	67340,1	6734,0	123,1
75kW IE3	16	90,5%	17,7	66298,3	6629,8	227,3
75kW IE4	16	90,7%	17,6	66152,1	6615,2	241,9

Motor	Prijzen (€)	Procentueel (IE2=ref.)	PB indien nu vervangen	PB indien motor kapot
75kW IE1 ref	3118	89%	Ref.	Ref.
75kW IE2	3512	100%	+28,5	3,8
75kW IE3	4039	115%	+17,8	4,9
75kW IE4	4953	141%	+20,5	10,3



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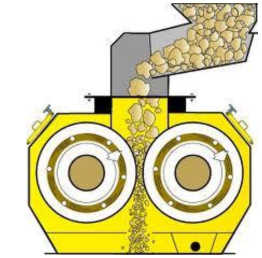
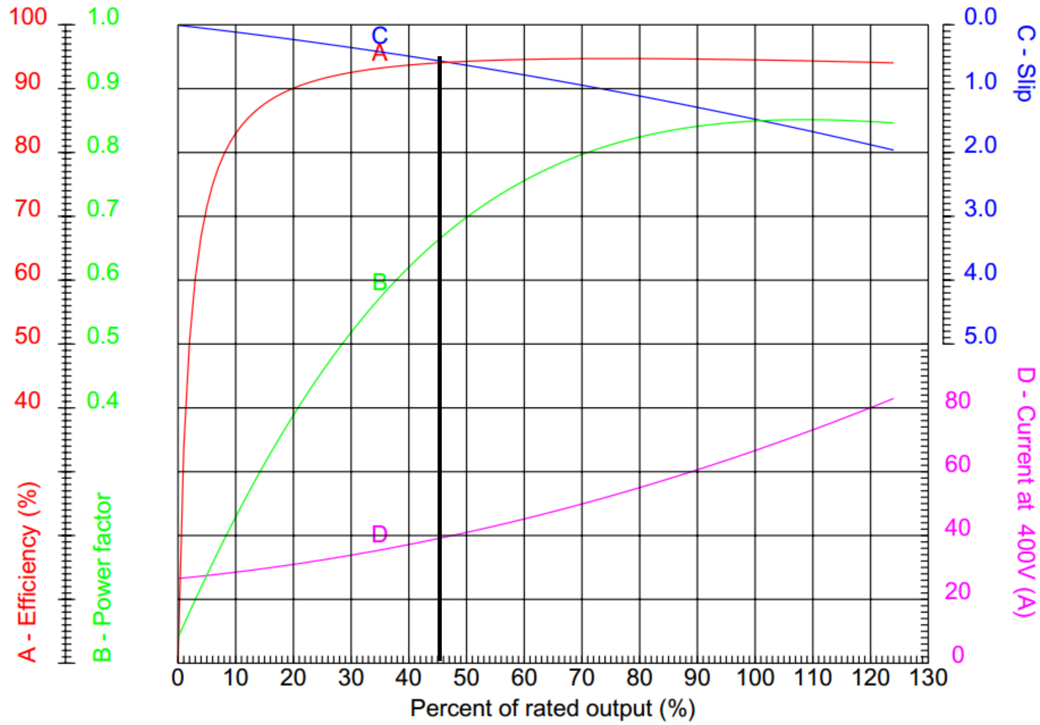


Step 3: analysis and optimization study: change MOTOR

- 37kW IM IE3, less part load operation, still acceptable overload capabilities

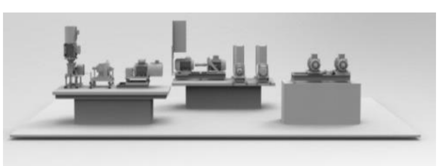


η_{IE1}=91,7%

η_{IE2}=93,0%

η_{IE3}=94,0%

η_{IE4}=94,3%



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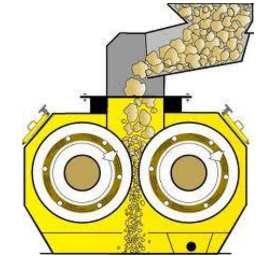


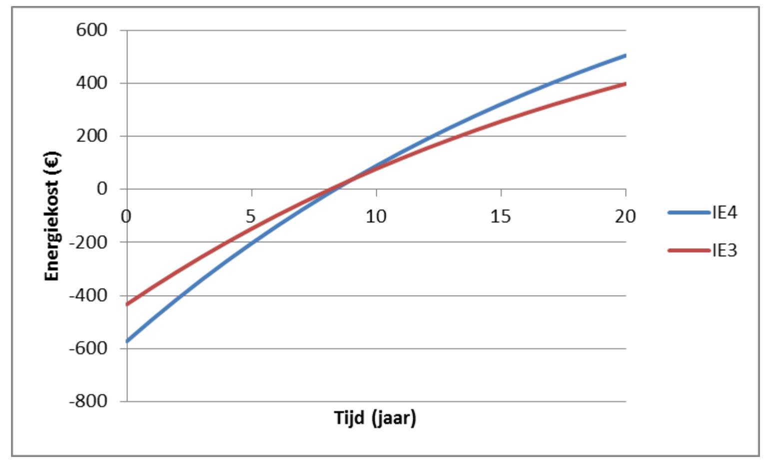
Step 3: analysis and optimization study: change MOTOR

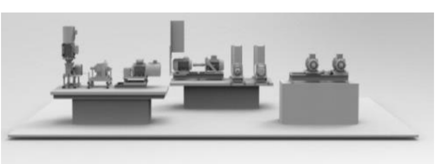
- 37kW IM IE2, less part load operation, still acceptable overload capabilities
  - Only change when 75 kW motor is end of lifetime !!

Motor	Efficiency	Prices (€)	% (IE2=ref.)	PB Motor broken	Profit after 10 years
75kW IE2	89,1%	3512	183%	Ref.	
37kW IE2	93,0%	1915	100%	-3,88	€3200

  - IE2, IE3 or IE4 37 kW motor ?

Motor	Efficiency	Prices (€)	PB Motor broken
37kW IE2	93,0%	1915 (100%)	Ref.
37kW IE3	94,0%	2348 (123%)	8,2
37kW IE4	94,3%	2488 (130%)	8,4





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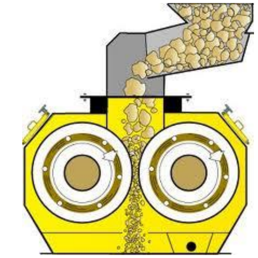
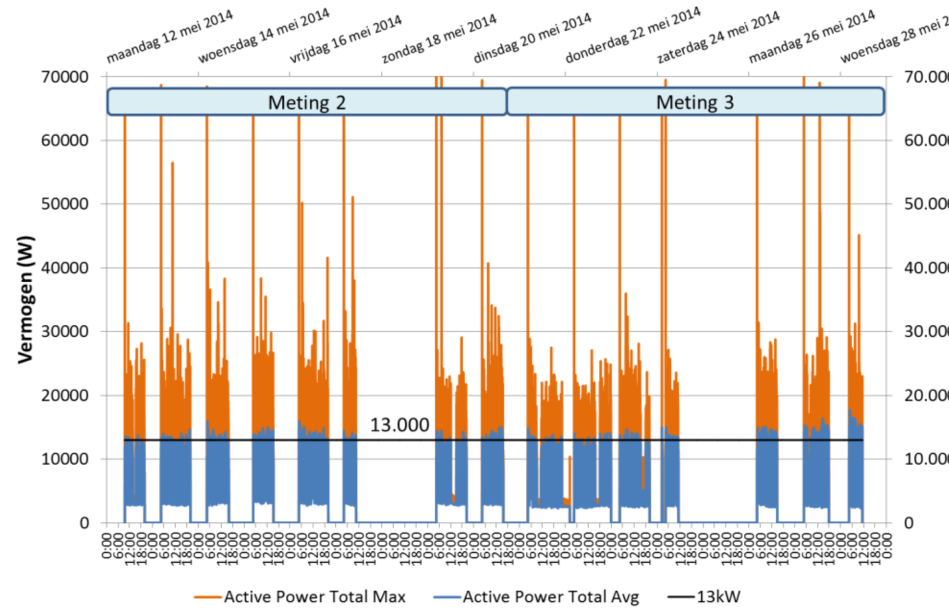
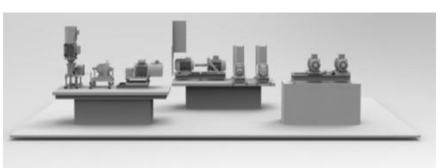


Step 3, 4 and 5: Modified belt drive

- Overdimensioned system → reduce the number of belts
  - Redimensioning @ present max power (37kW)
  - 3 belts according to belt calculation software
  - Choice: 4 belts (safety margin)
- Old setup 75kW 7 x SPB 8000,
  - Listprice: €1018
- 37kW alternative 3 x SPB 8000
  - Listprice: €509





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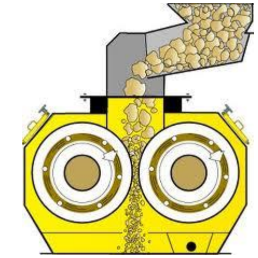
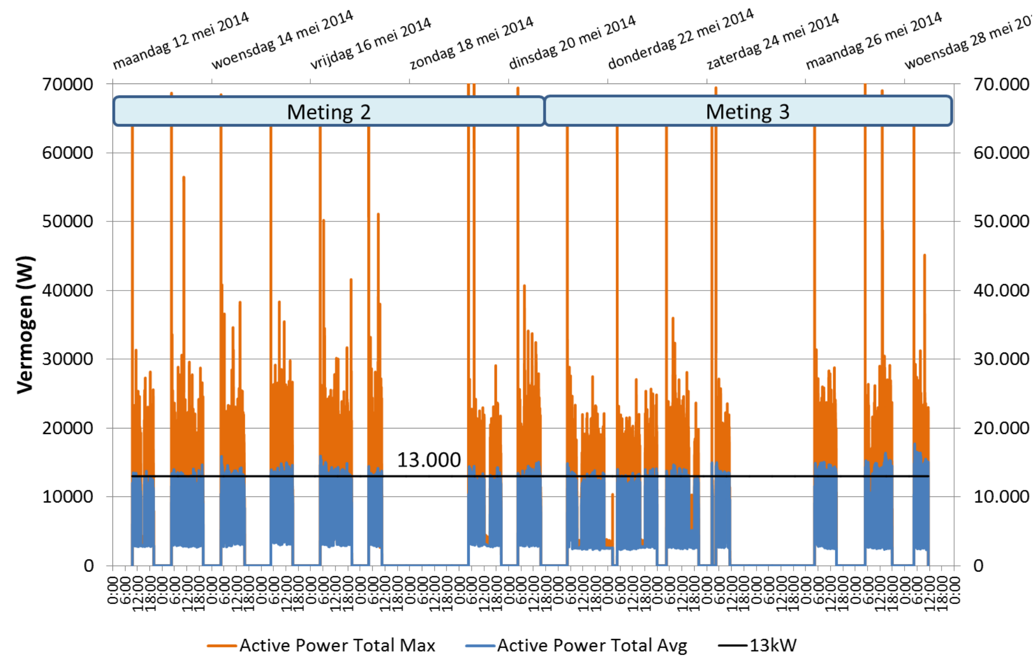
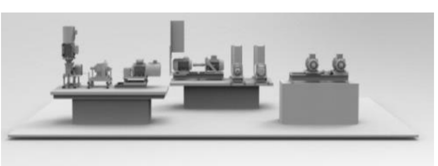


Step 3, 4 and 5: Modified belt drive

- Testbench results: part load operation
    - 2% more efficient (measurement 3)
- Possible savings 4 versus 7 belts:
    - ± €150 yearly energy savings
    - Lower purchace costs – 57%
    - Less maintenance costs





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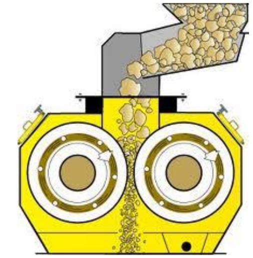
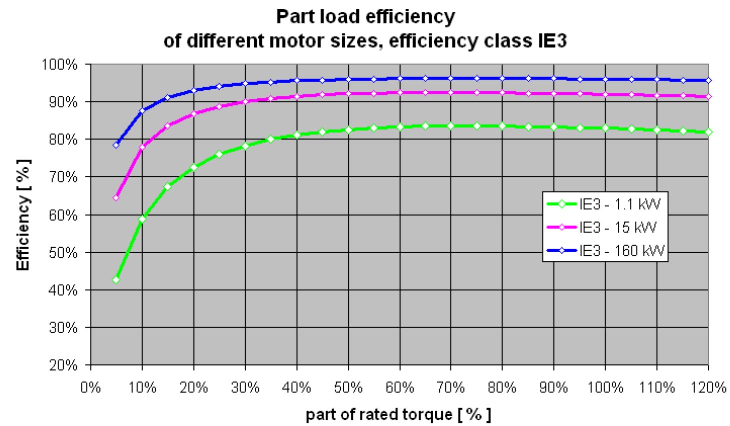
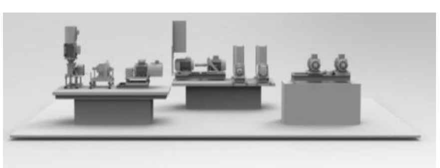


Lessons learned ?

- Measure/calculate the actual loading of the motor !



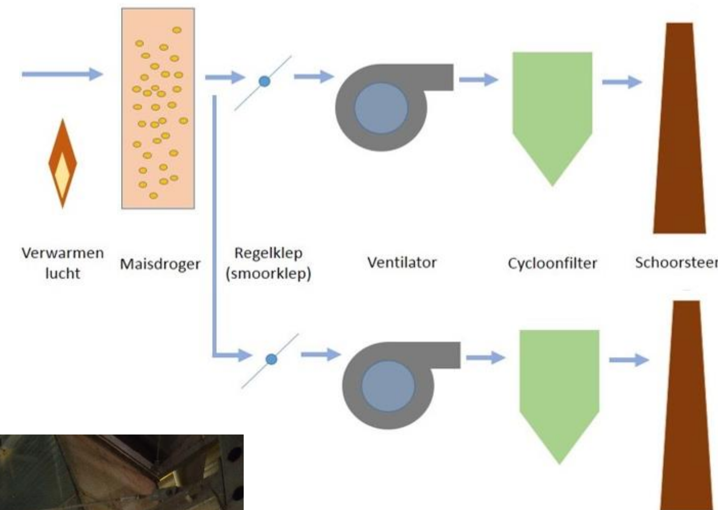
- When replacing a motor:
  - Correct motor sizing is most crucial (> 50% rated P)
  - Next, higher IE classes become interesting
- Limited savings when only optimizing the motor … (5%), WHY ?
- Only replace motors when they reach end of life for acceptable pay back times !
- Also redesign your belt drive when changing to a smaller motor !



Case 2: Aveve Corn Dryer (Laborelec/Typhoon)

Step 1: collect all relevant process information

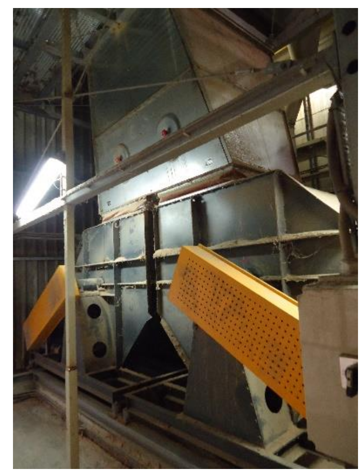
- Corn is dried during three months a year
- Two IE2 55 kW DOL motors drive two fans
- Belt transmission (1500 rpm → 1000 rpm)
- Designed for 2000 Pa (total) and 80000 m³/h each

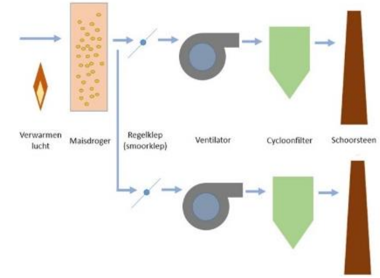


- Motor data
  - 55 kW IM motor
  - Efficiency: 93,5%

- Throttling valve: adjusted in order not to overload the motors

- Goldsaat fan, 80.000 m³/h

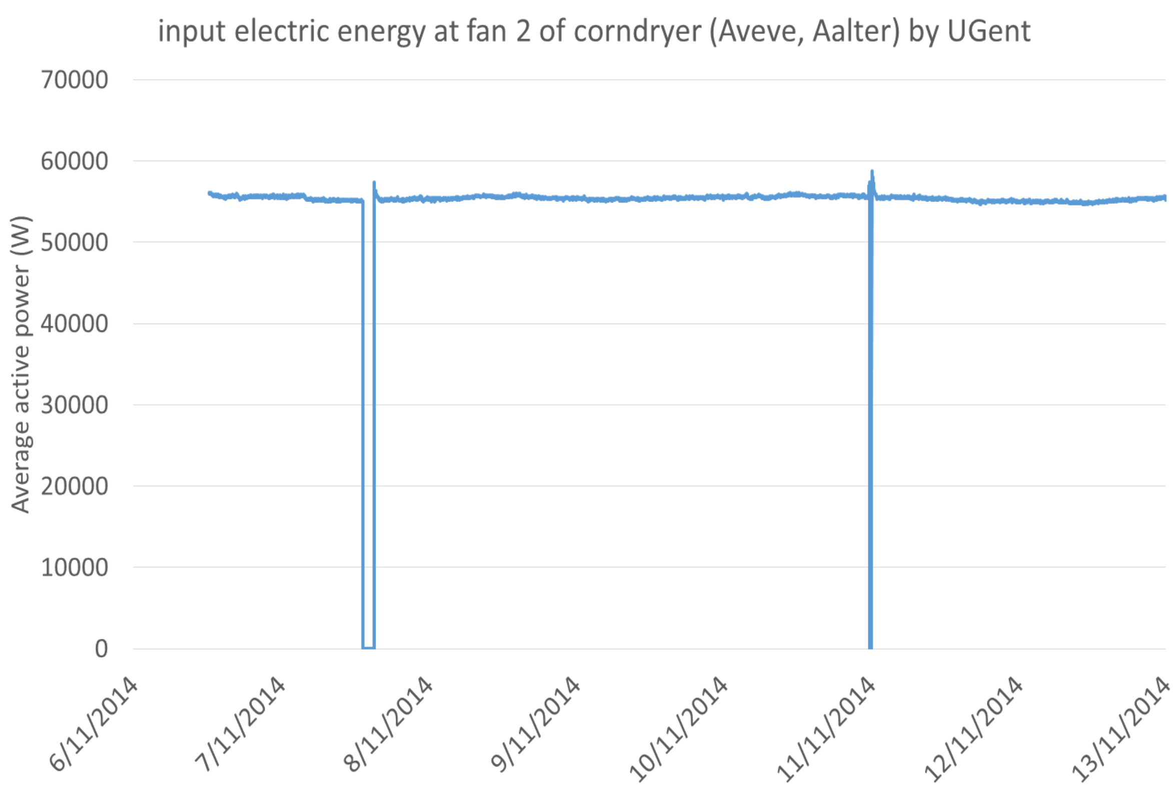


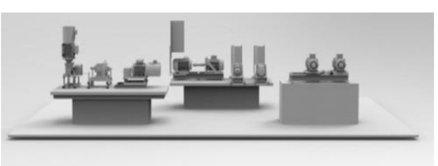


Case 2: Aveve Corn Dryer (Laborelec/Typhoon)

Step 2: energy measurement "as is" situation

Electric power: 56 kWe and stable (1 motor)





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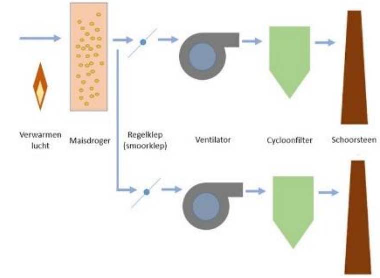
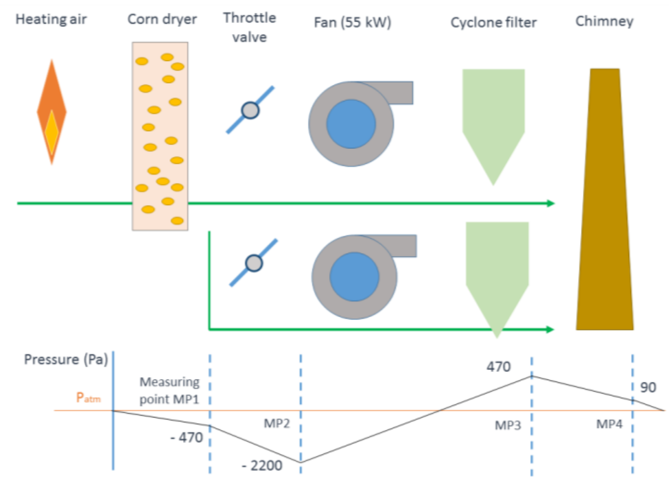


Step 2: energy measurement “as is” situation

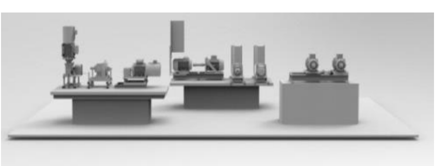
- Total hydraulic power

  - Pressure p: 2700 Pa measured versus 2000 Pa stated
  - Flow Q: 58.000 m³/h versus 80.000 m³/h stated

$P_h = Q.p = 44$ kW



- System efficiency “as is” :
  - η = 44kW/56 kWe .100% = 78% (fulfills fan directive)



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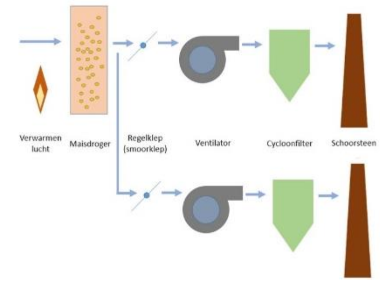
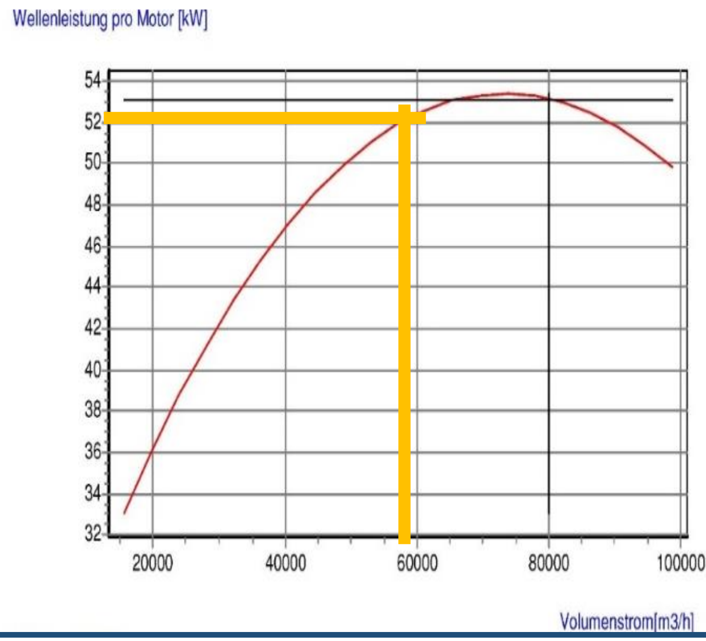
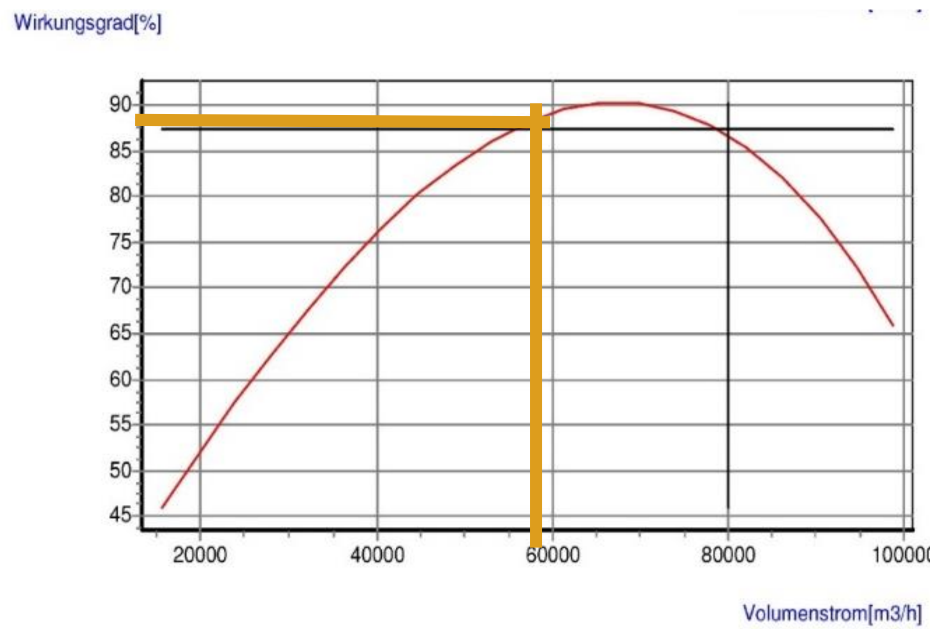
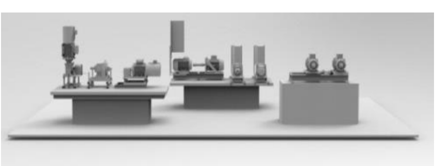


Step 3: analysis and optimization study

- Goldsaat fan characteristics for 58000 m³/h:
  - requires 52 kW shaft power at 2700 Pa
  - with 88% fan efficiency







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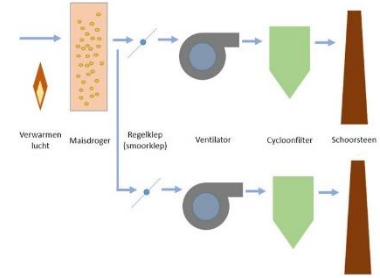


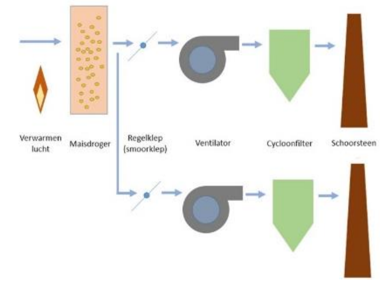
Step 3: analysis and optimization study

- System efficiency based on component efficiency:

  Motor efficiency: 93,5%
  Belt drive efficiency: 94%
  Fan efficiency: 88%
  → System efficiency = **77,3%**

- System efficiency based on measurements: **78%**

Case 2: Aveve Corn Dryer (Laborelec/Typhoon)



Step 3: analysis and optimization study

- System observations and optimizations

  Only 58.000 m³/h required by the process
  Throttling valve adjusted for that purpose: high pressure drop = energy losses

- Solution: speed control to obtain 58.000 m³/h
  According to fan laws:
    - Speed drops 27,5% (from 80,000 to 58,000 m³/h)
    - Hydraulic power drops 62%
    - Savings

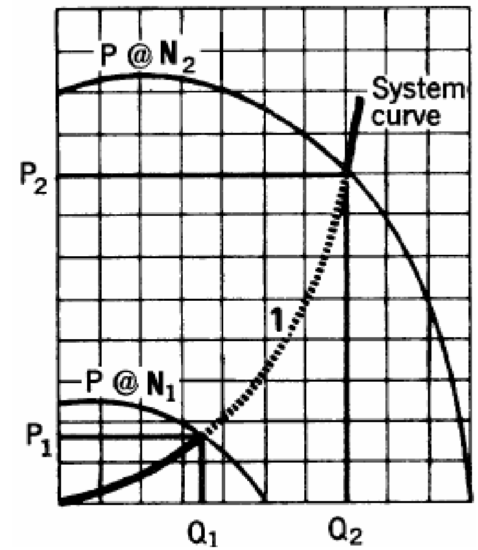
$$Q_2 = Q_1 * \left(\frac{n_2}{n_1}\right)$$

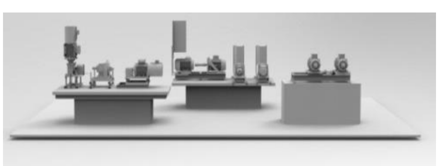
$$p_2 = p_1 * \left(\frac{n_2}{n_1}\right)^2$$

$$P_2 = P_1 * \left(\frac{n_2}{n_1}\right)^3$$

$$62\% \ * 2\ fans * 56\ kW * 2190h/y = €15.200$$

In the Pay Back calculations a more conservative value based on 70,000 m³/h was used.





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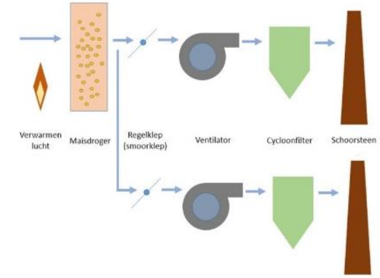


Step 3: analysis and optimization study

Selection of the variable speed drive (±3% additional losses)

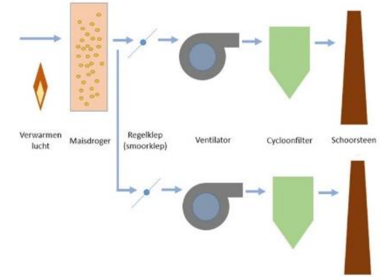
- Several combinations are possible:
- One 110 kW drive for both motors
- Two 45 or 55 kW drives
- One 75 or 90 kW drive for both motors, as required power will drop significantly

Cost of the drives + mounting cost → payback

TOTAL COST (MOUNTING & DRIVES)	
2x 45 kW	€ 16.601
2x 55 kW	€ 18.295
1x 75 kW	€ 11.963
1x 90 kW	€ 12.266
→ 1x 110 kW	€ 13.659

PAYBACK (YEAR)	
2x 45 kW	**2,4**
2x 55 kW	**2,7**
1x 75 kW	**1,7**
1x 90 kW	**1,8**
1x 110 kW	**2,0**

Case 2: Aveve Corn Dryer (Laborelec/Typhoon)

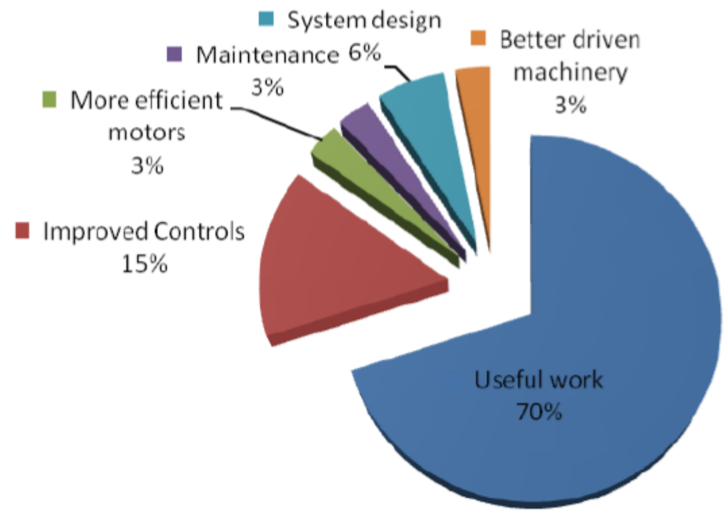


Lessons learned ?

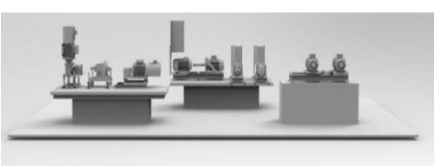
- Total system efficiency by means of Energy/power measurements
- OR by using detailed component efficiency values (if available …)

- 47% reduction in energy consumption measured !!

- Don’t use throttling valves !



The importance of better controls (mainly VSDs) in global motor system energy savings.

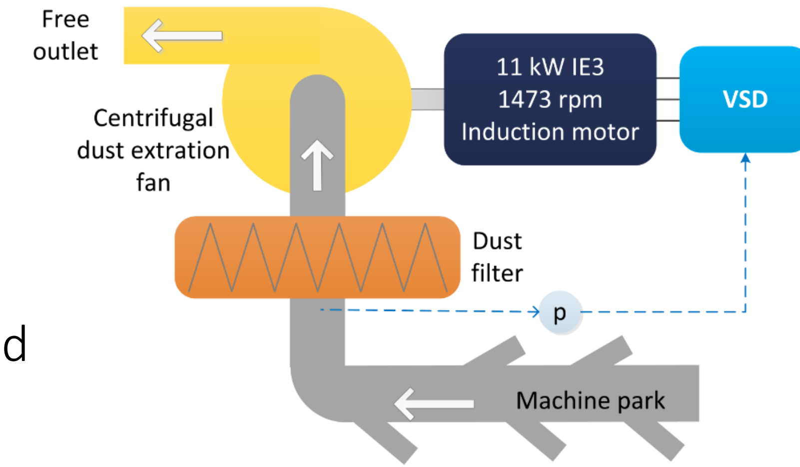


Case 3: Aveve Dust Extraction (Laborelec)

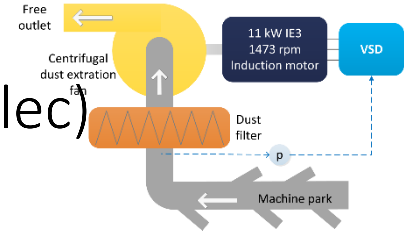
Step 1: collect all relevant process information

- Previously an axial direct driven fan was used
  - Not the appropriate fan for dust extraction
- VSD direct driven modern centrifugal fan was installed
  - In cooperation with Laborelec and Typhoon

But is this the optimal solution?



Case 3: Aveve Dust Extraction (Laborelec)

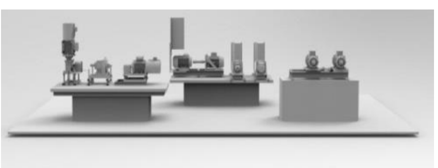


Step 1: collect all relevant process information

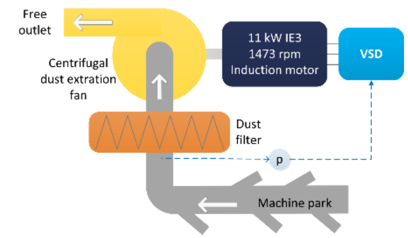
- In old situation no pressure feedback before filter
  - → different load point
  - No exact comparison in terms of output possible

- Surely large energy saving due to correct fan type for installation and high efficiency motor

	Old axial fan	New centrifugal fan
Surface area pipe	0,4 m²	0,3 m²
Mean air speed	5,8 m/s	11,6 m/s
Air flow	2,3 m³/s	2,9 m³/s
$P_{(el)\ fan\ motor}$	9 kW(el)	6 kW(el)
Spec. P(el)	$3{,}7\ \frac{kW(el)}{m^3/s}$	$2{,}0\ \frac{kW(el)}{m^3/s}$



Case 3: Aveve Dust Extraction (Laborelec)



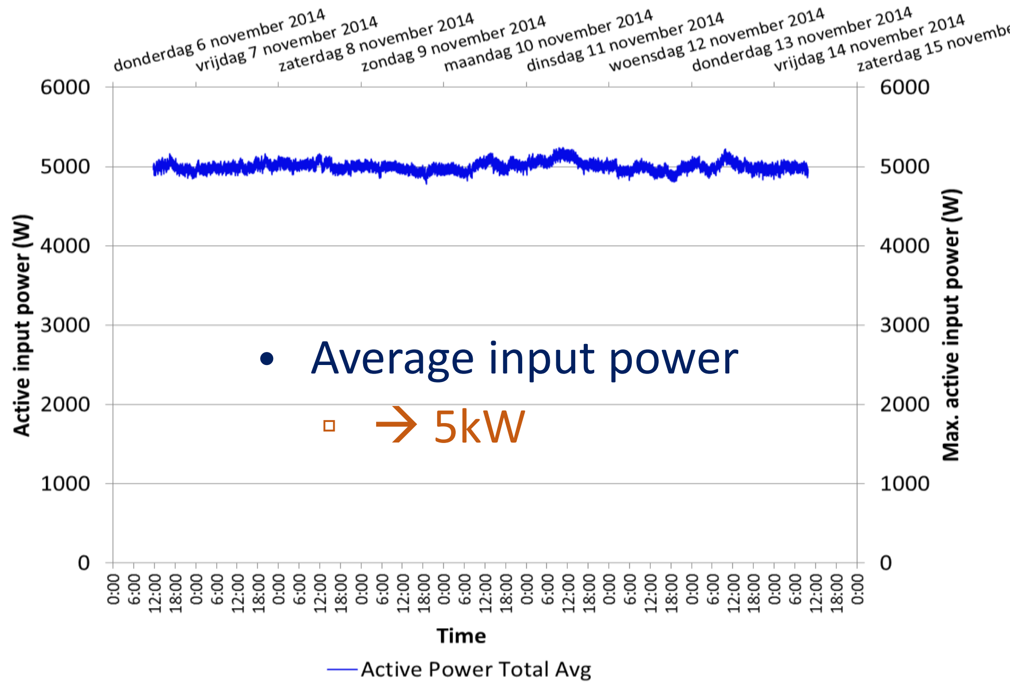
Step 2: energy measurement “as is” situation

Power logging during 1 week

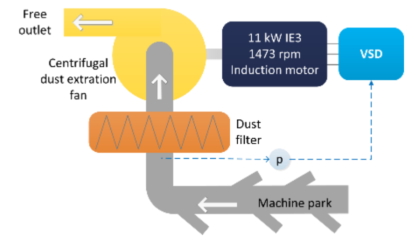
- Motor = 11kW 4p IE3 IM
- Info about motor load

Motor speed regulated with pressure feedback

- 800 Pa underpressure
- Motor frequency is 32Hz



Case 3: Aveve Dust Extraction (Laborelec)



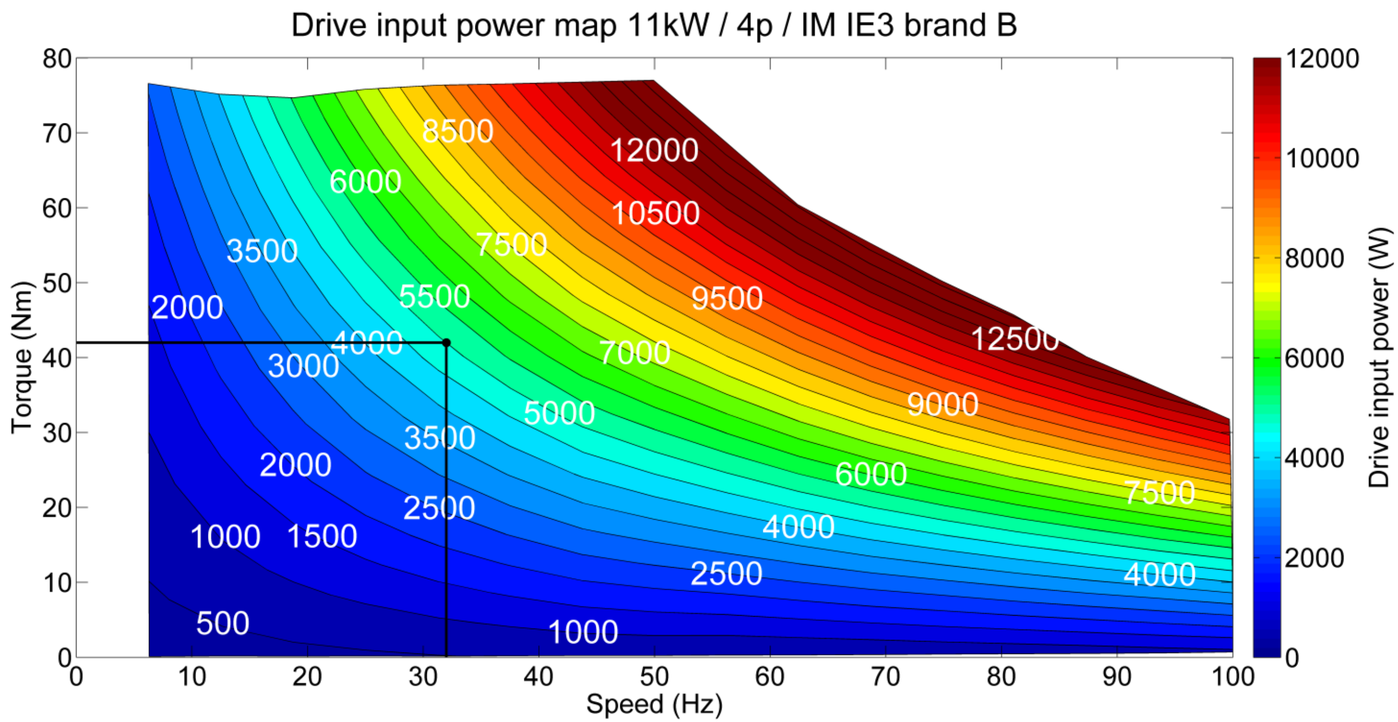
Step 3: analysis and optimization study

Trace back work point on drive input power map

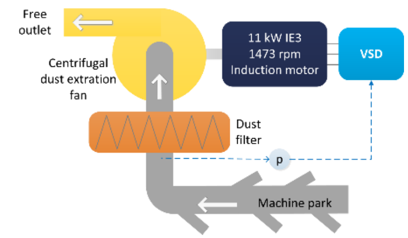
→Input power = 5000W

→Motor speed = 32Hz

→Torque = 42Nm



Case 3: Aveve Dust Extraction (Laborelec)

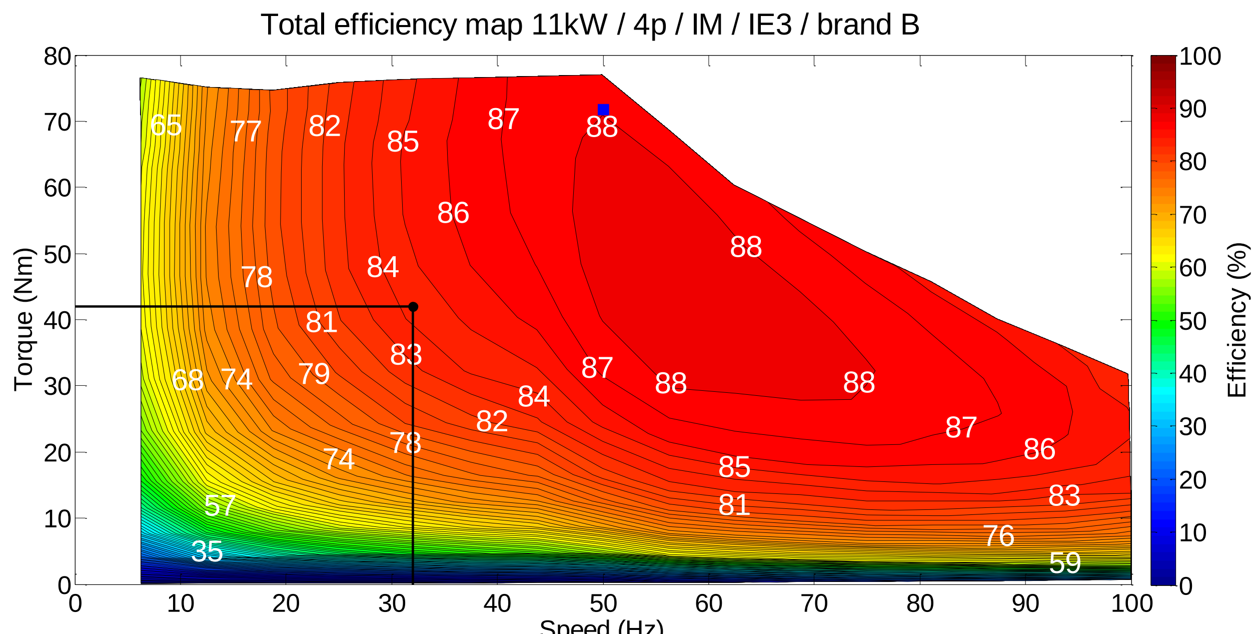


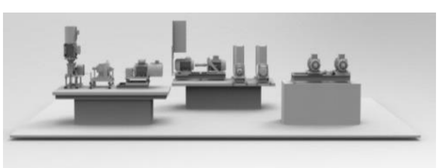
Step 3: analysis and optimization study

Look up efficiency on total efficiency map of motor

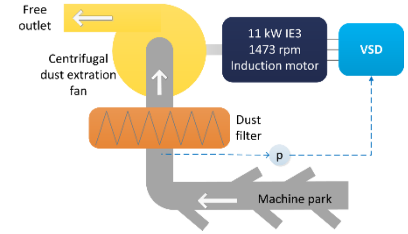
@32Hz and 42Nm → total efficiency = 84,3%

→ Mechanical motor power = 4,2kW





Case 3: Aveve Dust Extraction (Laborelec)



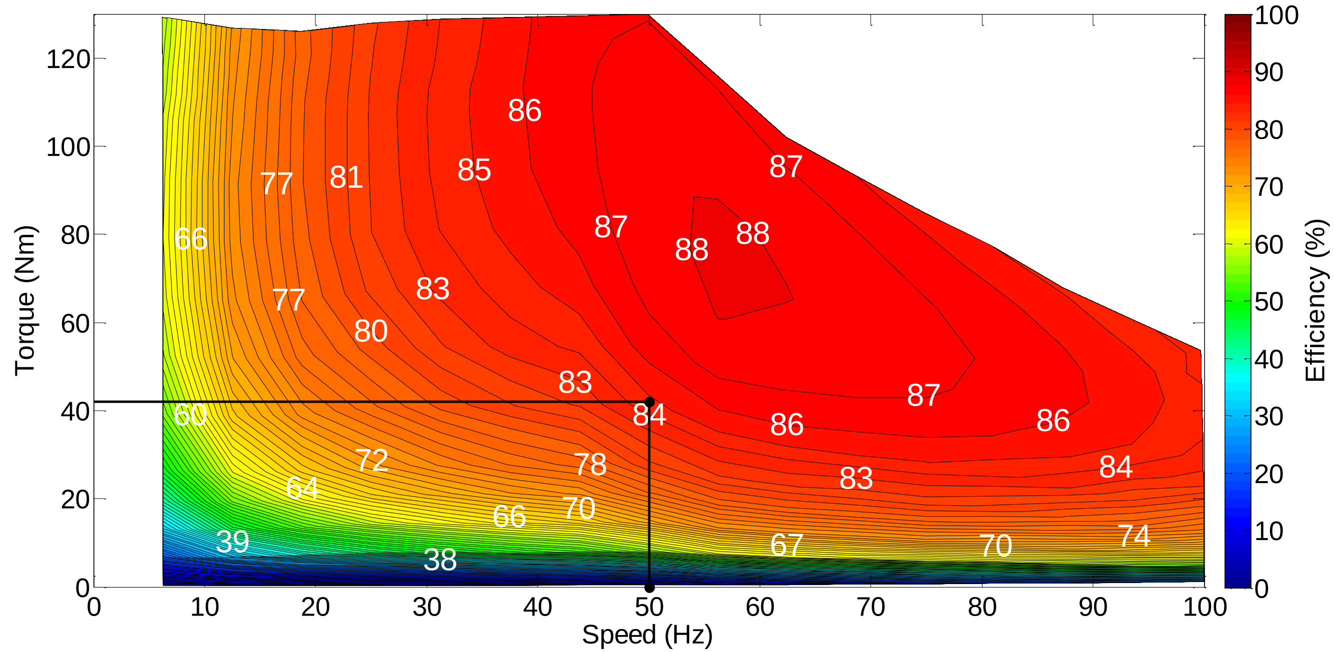
Step 3: analysis and optimization study

→1500 rpm versus 1000 rpm motor ?

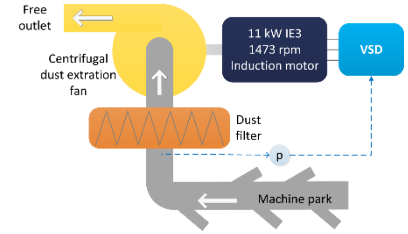
- 4-pole motor @32Hz = 960rpm
- 11kW IE3 IM: 6-pole motor @50Hz = ±960rpm

	11kW IE3 4p IM	11kW IE3 6p IM
Speed (rpm)	1465	975
Torque (Nm)	71,7	108
DOL motor η (%)	91,2	90,5
Total work point η (%)	**84,3**	**84,8**

Total efficiency map 11kW / 6p / IM / IE3 / brand B (calculation)



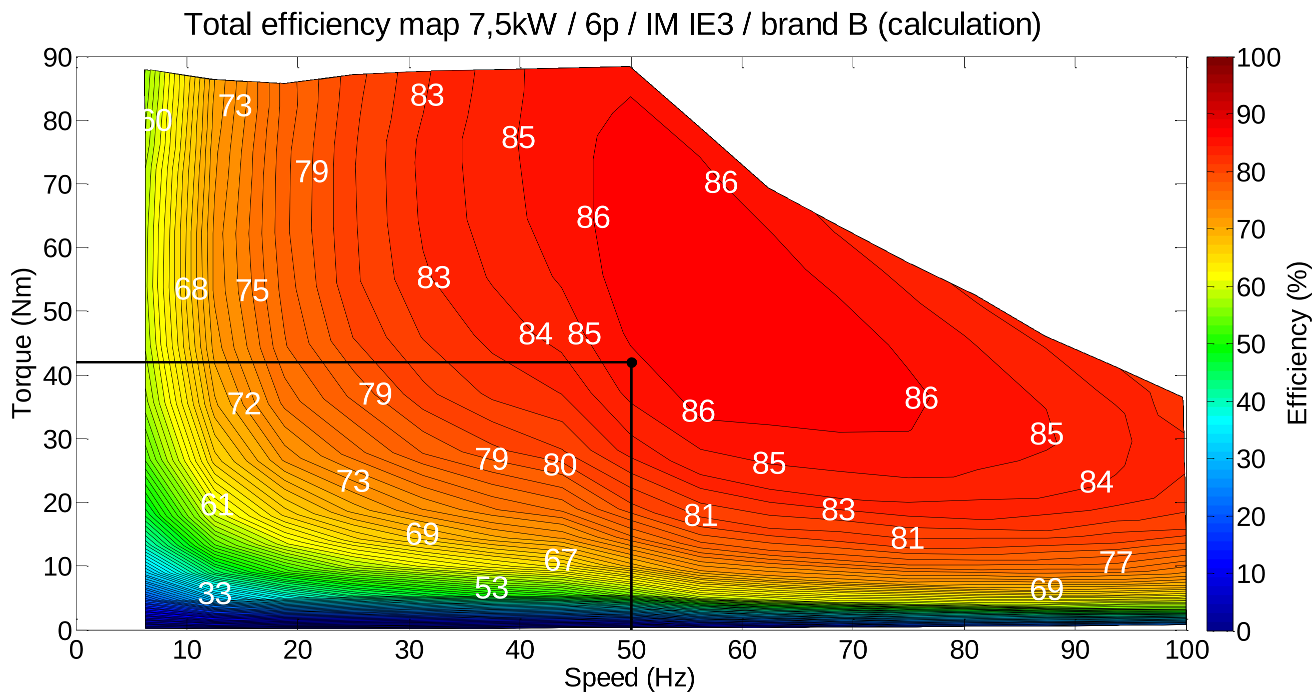
Case 3: Aveve Dust Extraction (Laborelec)

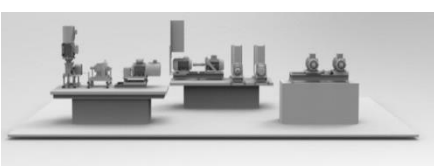


Step 3: analysis and optimization study

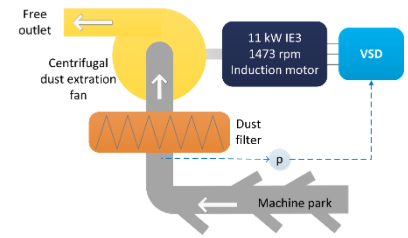
→7,5 kW versus 11 kW ?   Lower P-range: lower η

	11kW IE3 4p IM	7,5kW IE3 6p IM
Speed (rpm)	1465	975
Torque (Nm)	71,7	73,5
DOL motor η (%)	91,2	89,3
Total work point η (%)	**84,3**	**85,8**





Case 3: Aveve Dust Extraction (Laborelec)



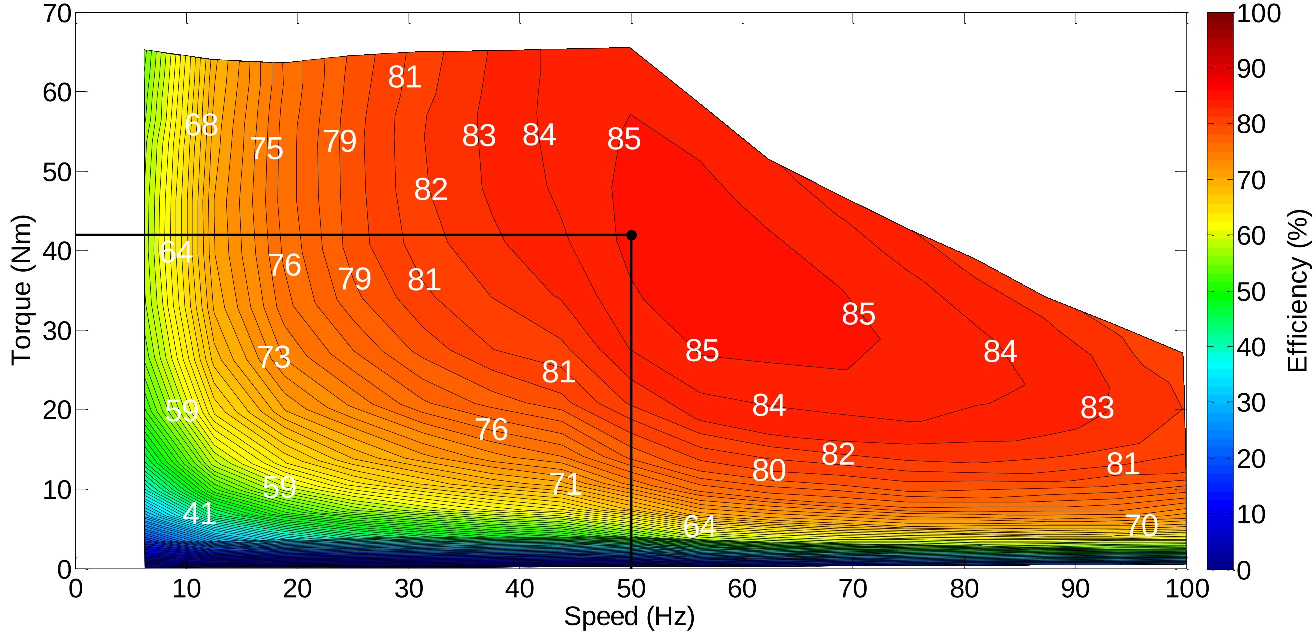
Step 3: analysis and optimization study

5,5 kW versus 11 kW ?

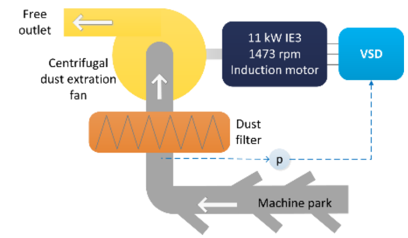
Δ +1,0%

Δ -0,5% vs. 7,5kW 6p IE3

	11kW IE3 4p IM	5,5kW IE3 6p IM
Speed (rpm)	1465	965
Torque (Nm)	71,7	54,5
DOL motor η (%)	91,2	88,0
Total work point η (%)	**84,3**	**85,3**



Case 3: Aveve Dust Extraction (Laborelec)

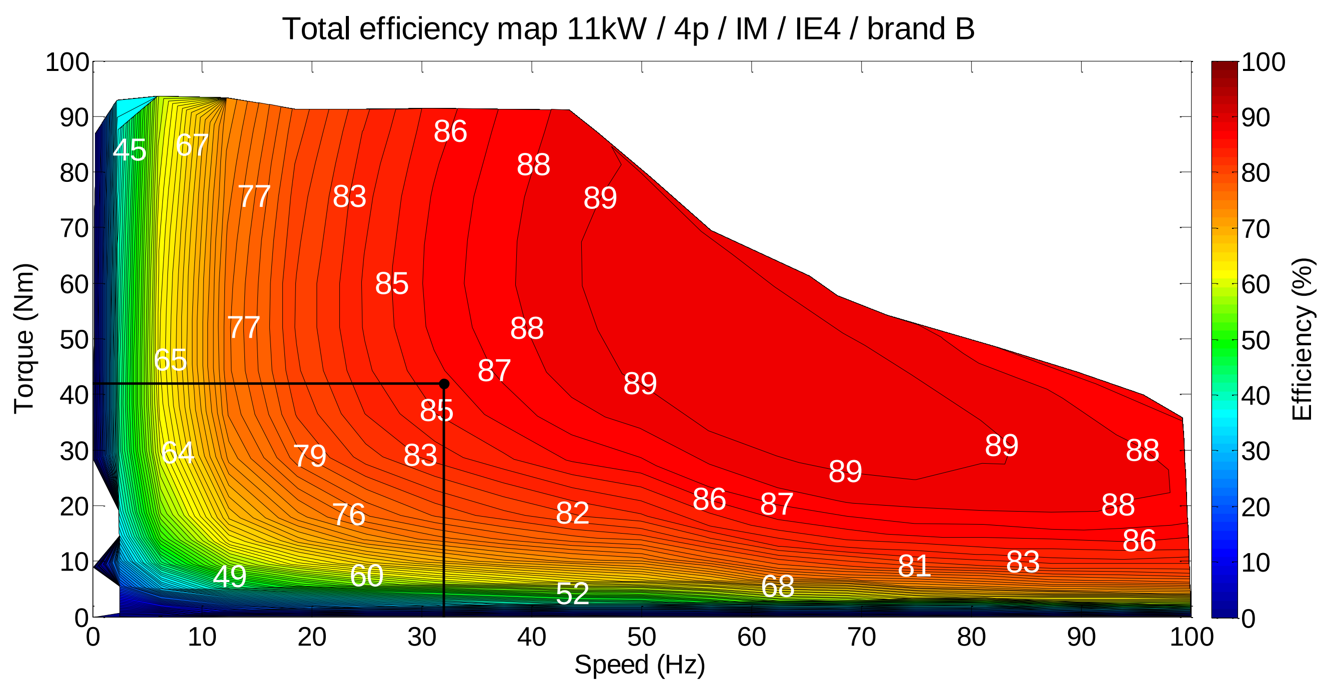


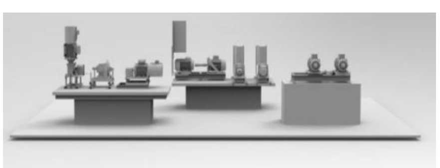
Step 3: analysis and optimization study

5,5 kW versus 11 kW ?

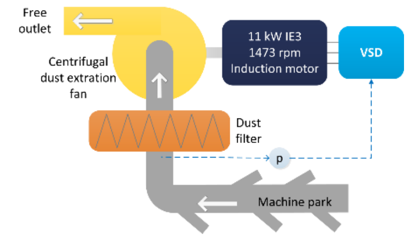
Δ +1,4% but low speed range and low torque range

	11kW IE3 4p IM	11kW IE4 4p IM
Speed (rpm)	1465	1475
Torque (Nm)	71,7	71,3
DOL motor η (%)	91,2	93,3
Total work point η (%)	**84,3**	**85,7**





Case 3: Aveve Dust Extraction (Laborelec)

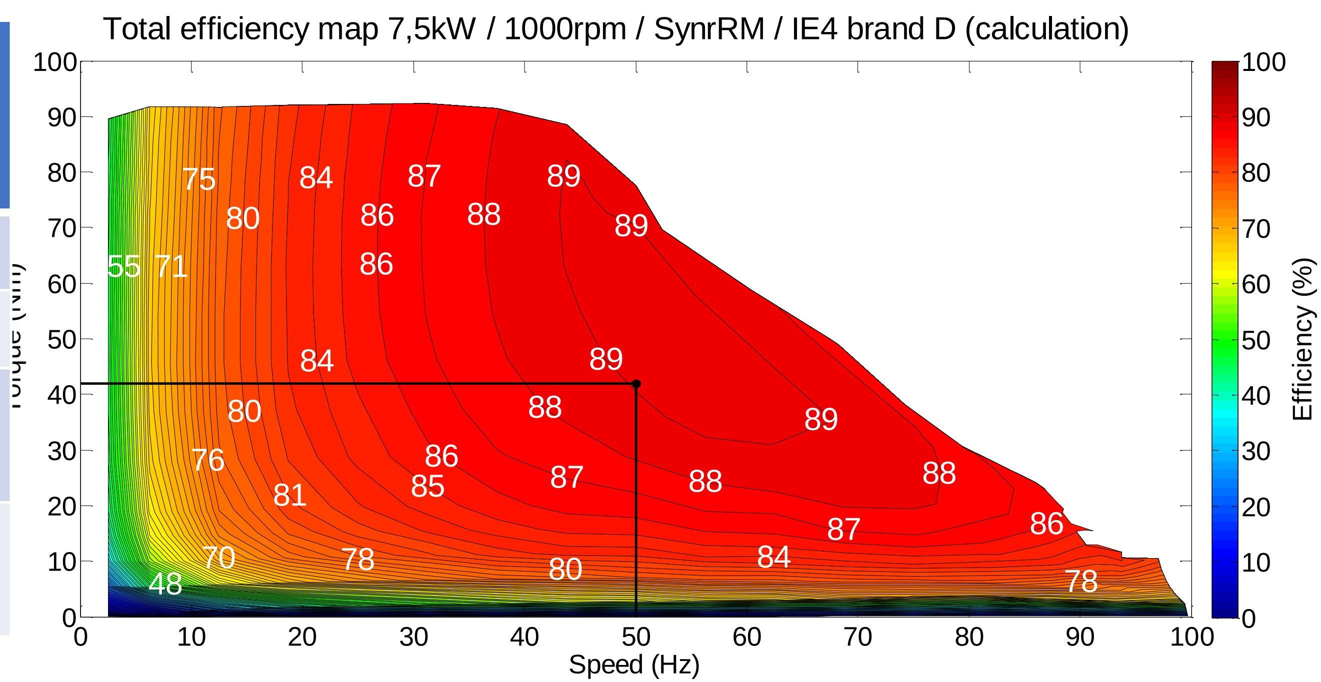


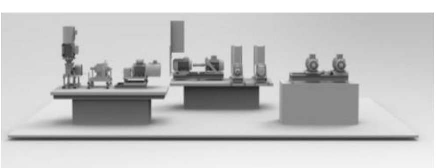
Step 3: analysis and optimization study

11 kW IM versus 7,5 kW SynRM ?

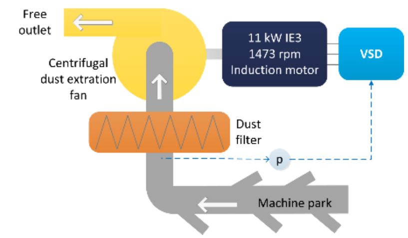
Δ +4,7%, speed range OK, medium torque range

	11kW IE3 4p IM	11kW IE4 4p SynRM
Speed (rpm)	1465	1500
Torque (Nm)	71,7	70,0
DOL motor η (%)	91,2	91,3 VSD
Total work point η (%)	**84,3**	**89,0**



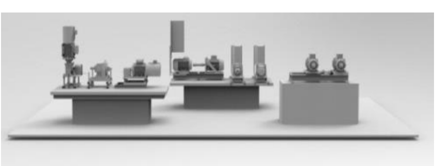


Case 3: Aveve Dust Extraction (Laborelec)

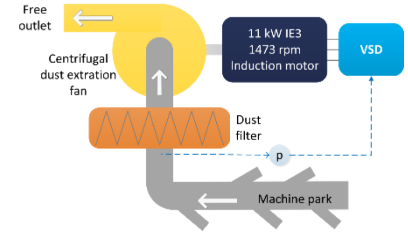


Step 3: analysis and optimization study

Motor	Speed (rpm)	Torque (Nm)	DOL motor η (%)	Total work point η (%)	Delta η (%)
11kW IE3 WEG 4p IM	1465	71,7	91,2	84,3	
11kW IE3 6p IM	975	108	90,5	84,8	0,5
7,5kW IE3 6p IM	975	73,5	89,3	85,8	1,5
5,5kW IE3 6p IM	965	54,5	88,0	85,3	1,0
11kW IE4 4p IM	1475	71,3	93,3	85,7	1,4
11kW IE4 6p IM	980	107	92,3	85,8	1,5
7,5kW IE4 6p IM	980	73,1	91,3	86,9	2,6
5,5kW IE4 6p IM	975	53,9	90,5	86,7	2,4
11kW IE4 4p SynRM	1500	70	93,3 (VSD supply)	88,8	4,5
7,5kW IE4 6p SynRM	1000	72	91,3 (VSD supply)	89,0	4,7



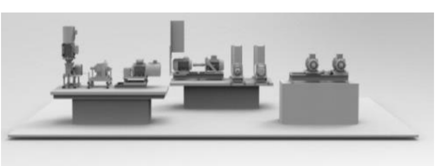
Case 3: Aveve Dust Extraction (Laborelec)



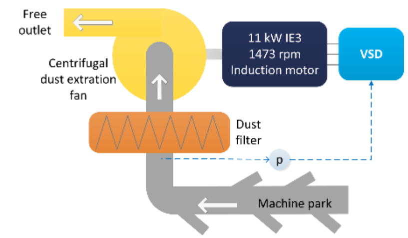
Step 3: analysis and optimization study

- Best (technical) choice: 7,5kW IE4 6p SynRM
- Economic analysis: 11 kW IE4 4p SynRM (€$_{elek}$: 0,1€/kWh; operating hours: 8000h)

Motor	Total work point η (%)	Delta η (%)	Price (%)	PB (year)	10 year profit (€)
11kW IE3 WEG 4p IM	84,3		100		
7,5kW IE3 6p IM	85,8	1,5	106	0,8	554
11kW IE4 4p IM	85,7	1,4	134	4,5	309
11kW IE4 6p IM	85,8	1,5	184	10,3	-19
7,5kW IE4 6p IM	86,9	2,6	150	3,5	675
11kW IE4 4p SynRM	88,8	4,5	142	1,7	1493
7,5kW IE4 6p SynRM	89,0	4,7	157	2,2	1459

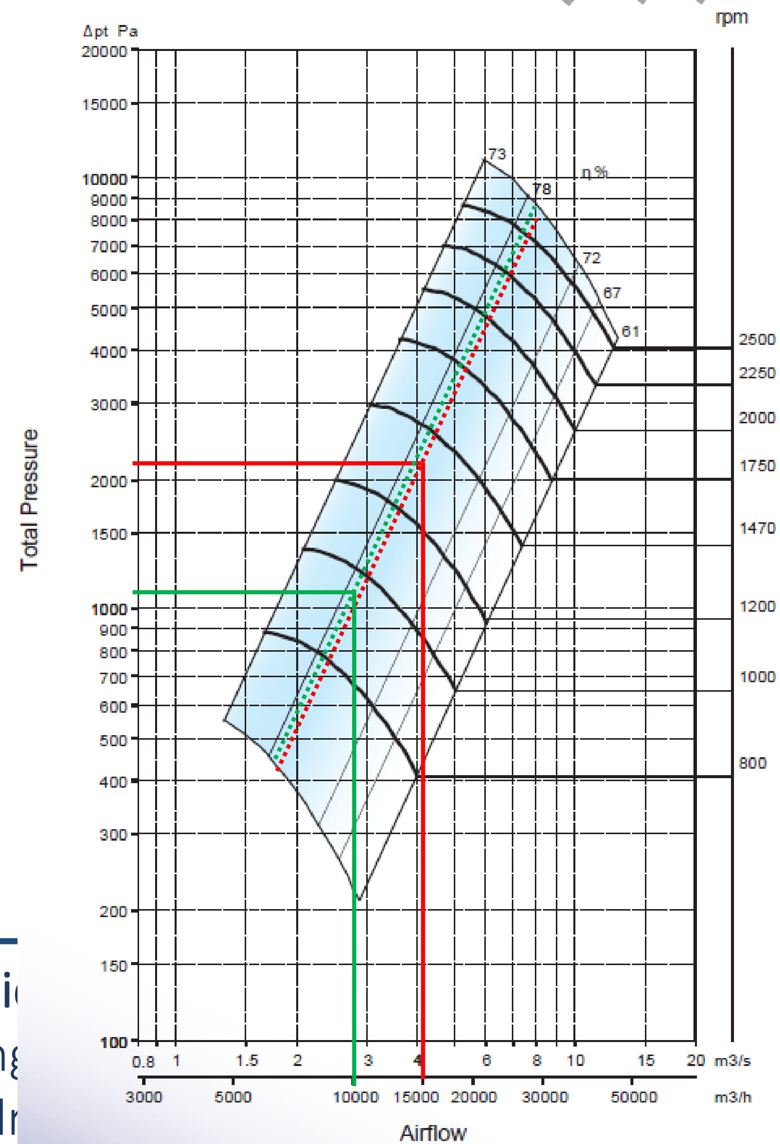


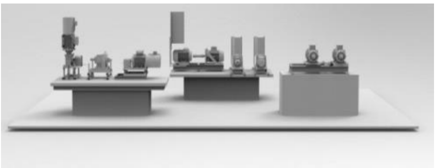
Case 3: Aveve Dust Extraction (Laborelec)



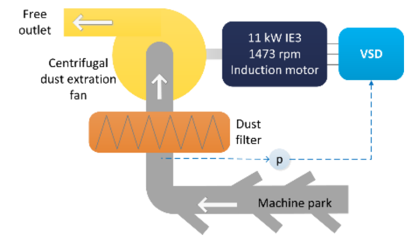
Step 3: analysis and optimization study

- Select a better fan ? Runs in part load @ 32 Hz
  - Current fan: GT550/56
    15000 m³/h
    2200 Pa
    Efficiency = 76%
    Fans speed = 1470 rpm
  - Current load:
    10000 m³/h
    1220 Pa
    Efficiency = 77%
    $P_{fan\ elec}$ = 4,4kW
    Fans speed = 1000 rpm





Case 3: Aveve Dust Extraction (Laborelec)



Step 3: analysis and optimization study

Select a better fan ?

- Alternative fan: GT500/56

  10000 m³/h

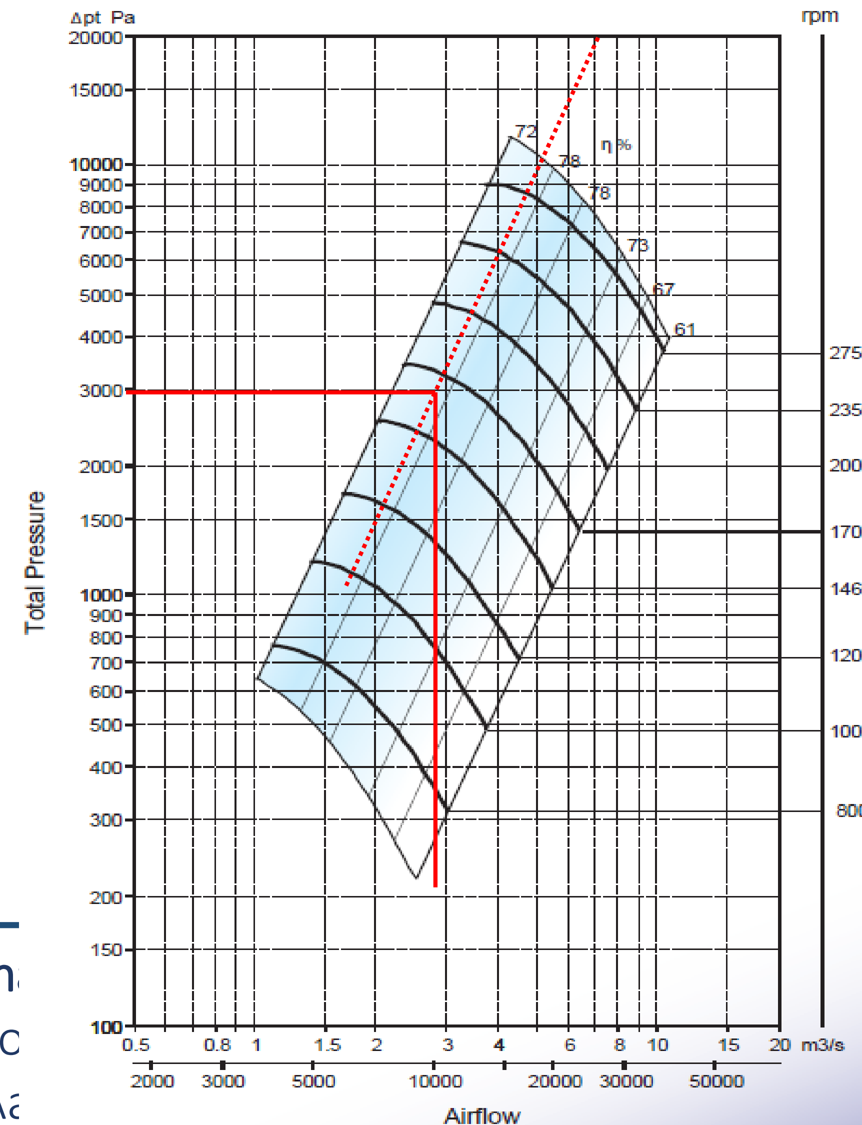
  1220 Pa

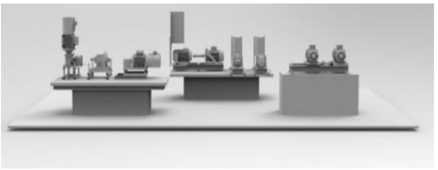
  Efficiency = 77% → equal

  $P_{fan\ elec}$ = 4,4kW

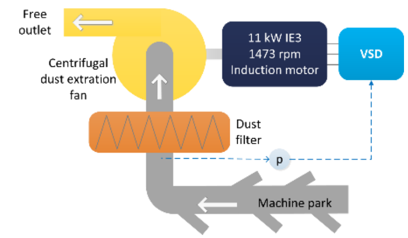
  Fans speed = 1200 rpm (versus 1000 rpm)

- **What is the impact on the motor efficiency?**





Case 3: Aveve Dust Extraction (Laborelec)

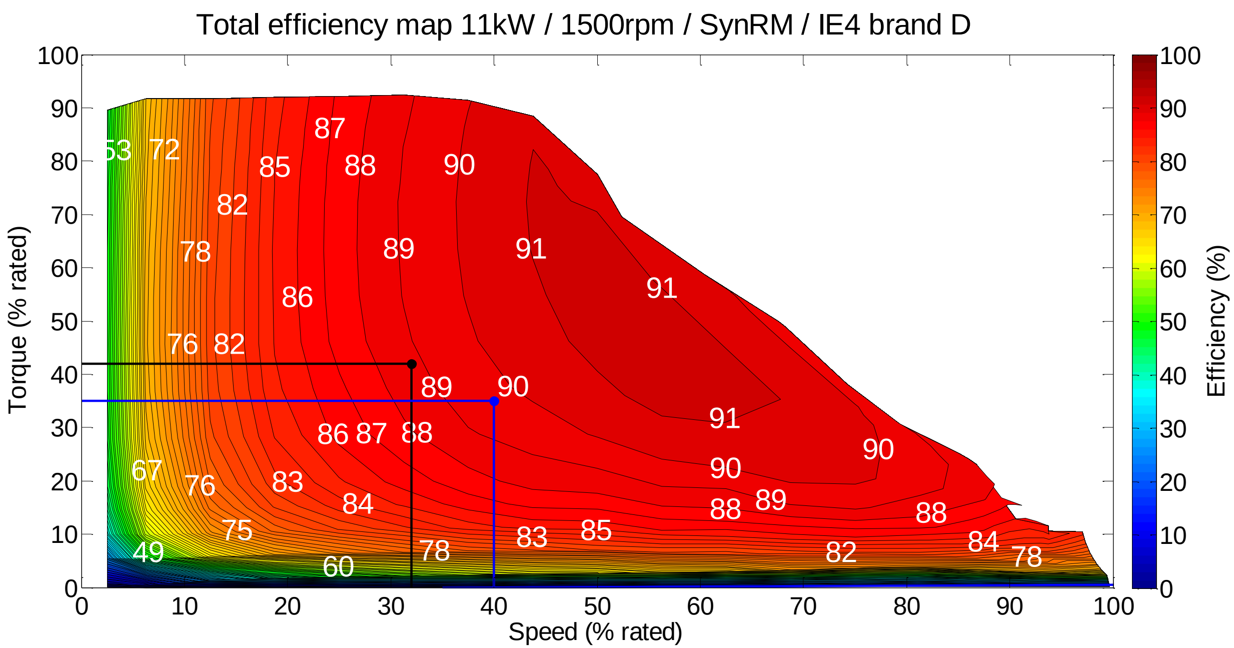


Step 3: analysis and optimization study

Select a better fan ?

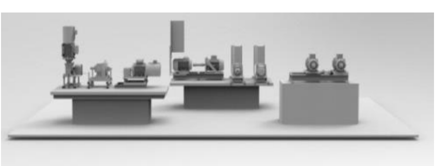
- Alternative fan GT500/56 impact on motor efficiency?

Fans speed = 1200 rpm

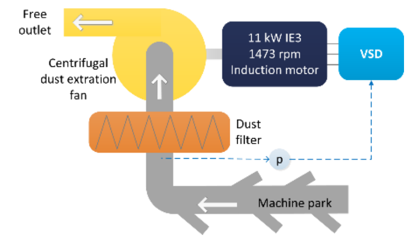


	GT 550	GT 500
	11kW IE4 4p SynRM	
Total work point η (%)	88,8	89,6

Efficiency gain: Δ +0,8%



Case 3: Aveve Dust Extraction (Laborelec)



Step 3: analysis and optimization study

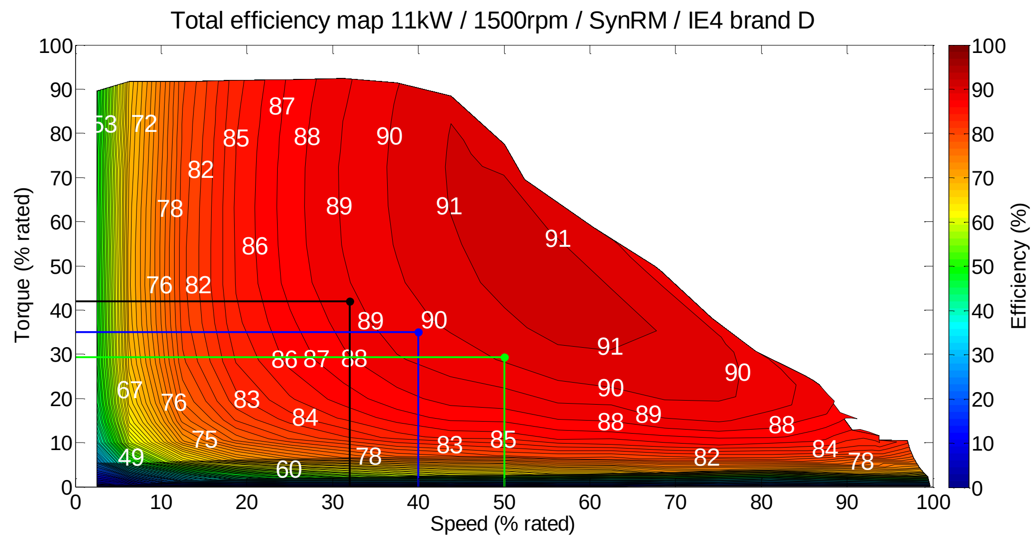
The best solution:

Best motor type choice: 11kW 4p SynRM

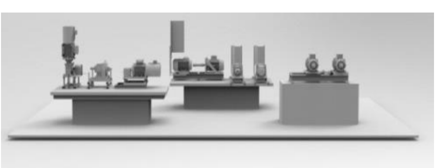
Optimum fan choice: GT450

Total efficiency optimization: +6%

Economics: PB ?



Motor	Total work point η (%)	Delta η (%)	Price (%)	PB (year)	10 year profit (€)
11kW IE3 WEG 4p IM	84,3		100		
11kW IE4 4p SynRM + GT550	88,8	4,5	142	1,7	1493
11kW IE4 4p SynRM + GT450	90,2	5,9	157	1,3	2053



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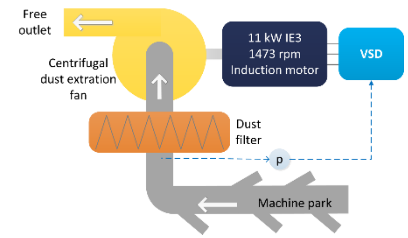
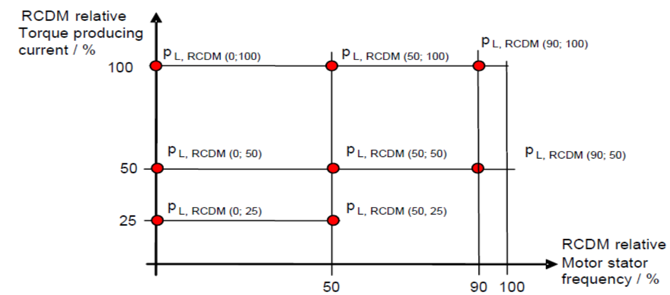


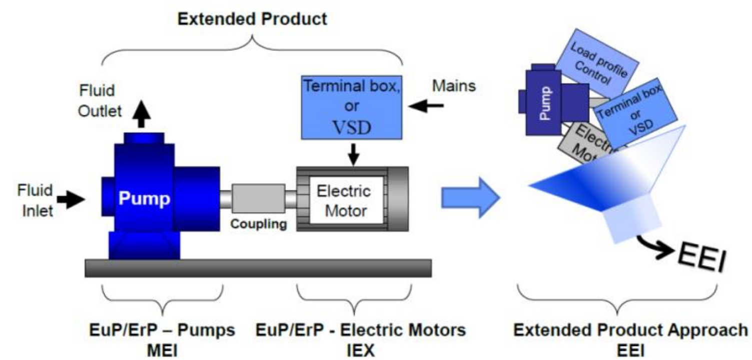
Lessons learned ?

- Motor optimization (based on contour maps): +4,5%
- Optimized fan selection: +1,5%



- Try to operate as close as possible to the high efficiency region of the motor system!

- **Total System Approach leads to additional 6% savings**
  → PB = 1,3 year



- VSD settings can result in extra savings potential of € 120/year (Flux optimization)