District Heating
the
Grundfos Way

"We are providing pumps and solutions which can move energy in an efficient way"

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GRUNDFOS®

District Heating the Grundfos Way

Energy Audit in

District Heating

Distribution

Distribution of energy in a efficient way and thereby saving energy and cost

Focus on reduced pump operation cost and improved system operation

Energy audit procedure:

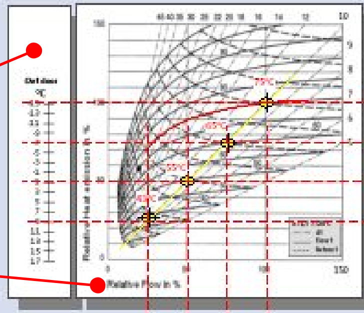
1. Evaluation of existing data
2. On site registration of system and pumps
3. Measuring to get exact figures at the present situation
   - Flow/Δp/temperatures/kW (data locking)
4. Evaluation of the measurements
5. Selection of new pump systems
6. Calculation of Life Cycle Cost and Pay-back time
7. Proposals for new strategies/system upgrading
8. Installation of new pump systems
9. Commissioning of the system
10. Instruction of the operation manager

Energy Audit in District Heating Distribution

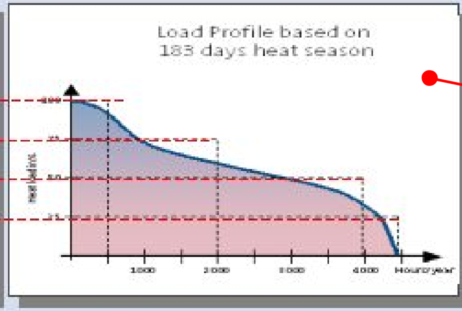
Energy saving concept calculation

Scale for out door temperature

Radiator emission curve



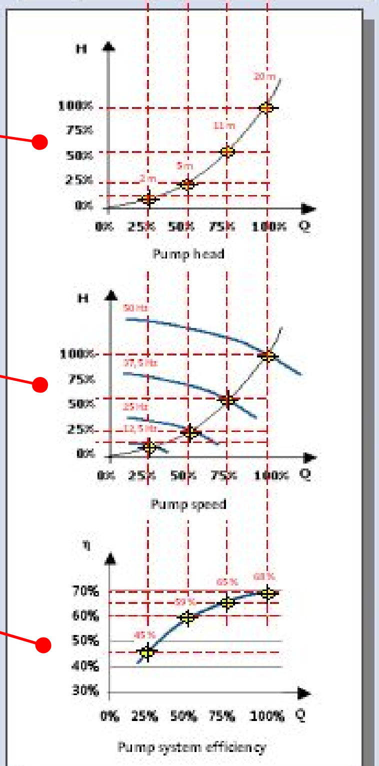
Load profile



System characteristic

Variable speed pump curve

Pump system efficiency



Flow based on m²

Energy calculation

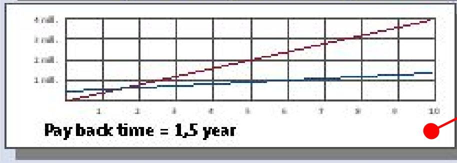
Duty point		1	2	3	4
Out door	t	-15	-7	0	7
Hours	h	500	1500	2000	440
Flow t	°C	75	65	55	43
Return t	°C	65	55	45	33
Delta t	°C	10	10	10	10
Flow	m³/h	880	660	440	220
Head	m	20	11	5	2
Speed	Hz	50	37,5	25	12,5
P4	kW	47,9	19,7	6	1,2
η	%	68	65	59	45
P1	kW	70,5	30,3	10	2,7
Energy	kWh	35.250	45.450	20.000	1.188
Energy Consumption kWh/year				101888	

Life Cycle Cost calculation

10 year Life Cycle Cost (0,8 RMB/kWh)

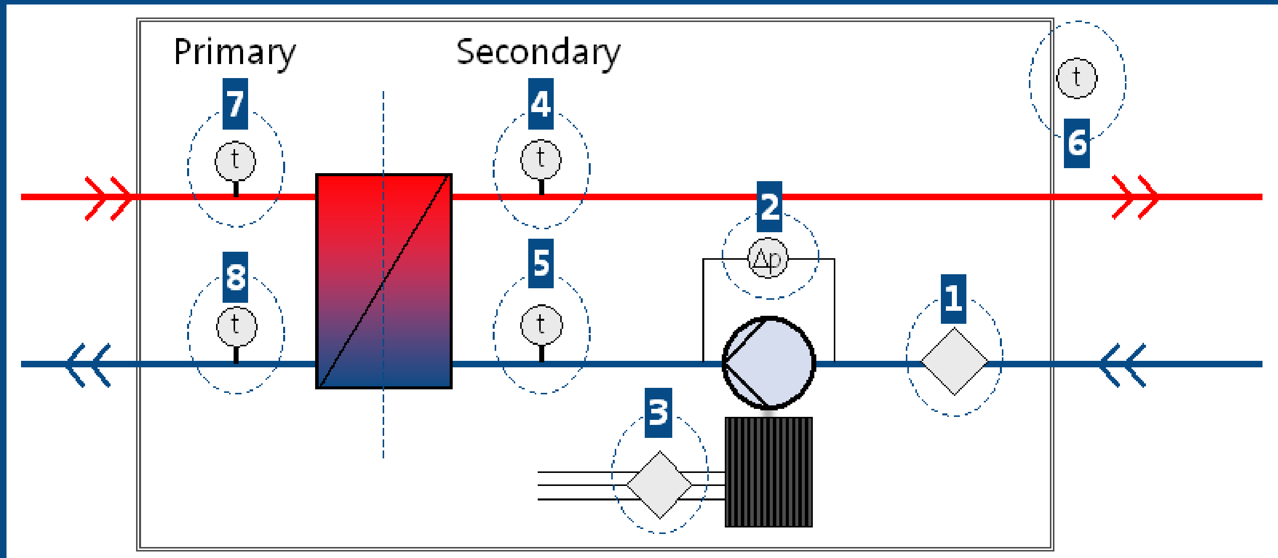
	Old system	New system	Saving
Initial cost	0	300.000	-300.000
Maintenance cost	30.000	5.000	25.000
Energy cost	3.977.600	815.104	3.162.496
	4.007.600	1.120.104	2.887.496

Pay back calculation



Energy Audit in District Heating Distribution

Energy Audit Measurement and calculations



Measurement

1: Flow Q [m^3/h]
2: Differential pressure H [m]
3: Power p 1 [kW]
4: Flow temperature t [^{o}C] (Secondary site)
5: Return temperature t [^{o}C] (Secondary site)
6: Outdoor temperature t [^{o}C]
7: Flow temperature t [^{o}C] (Primary site) option
8: Return temperature t [^{o}C] (Primary site) option

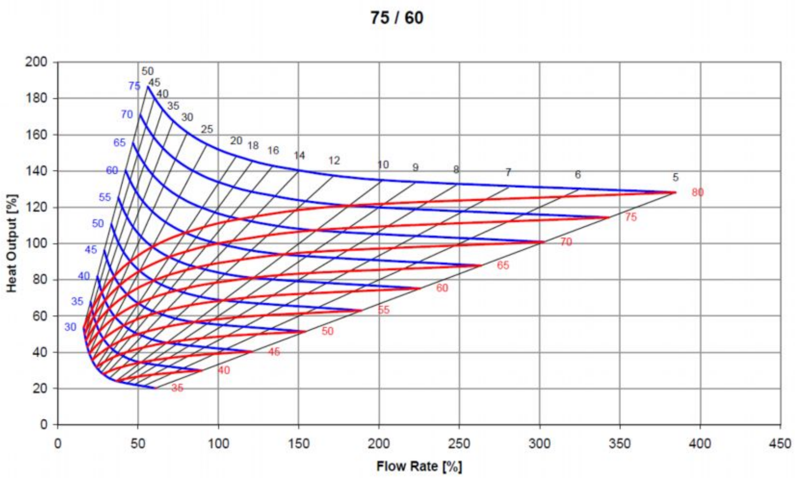
Calculated values based on measurements

4-5:	Differential temperature Δt [^{o}C] (Secondary site)
7-8:	Differential temperature Δt [^{o}C] (Primary site)
1x 2:	Hydraulic effect P 4 [kW]
(1x2)/3:	Pump and motor efficiency η [%]
1x (4-5):	Energy flow Φ [kW]

Energy Audit in District Heating Distribution

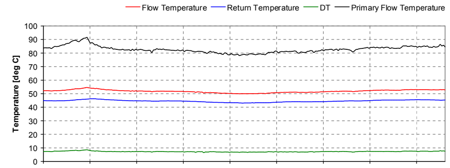
The graphic view of the measurements which is used for the analyze of the system.

Data available from customer:
Energy consumption per year 342.000 kWh
Cost of energy 0,7 RMB/kWh
Heating season 183 days (3350 hours)
3 pumps installed (incl. 1 standby)
Data on nameplate is :
800 m^3/h x 20 m, motor size 55 kW
CO2 emission 0,9 kg/kWh

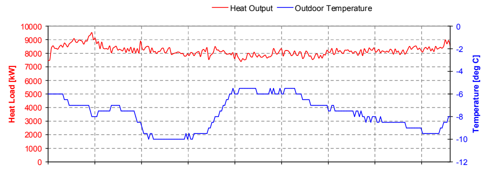


Heat emission curve

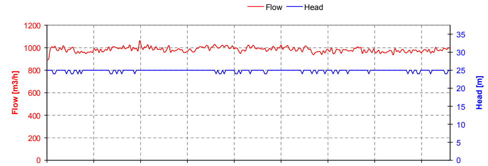
Medium temperature



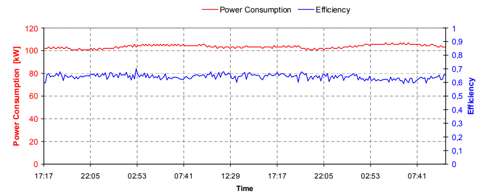
Heat load and
Out door temperature



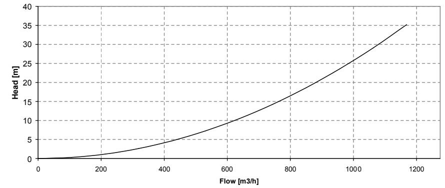
Flow and head



Power and efficiency



System characteristics

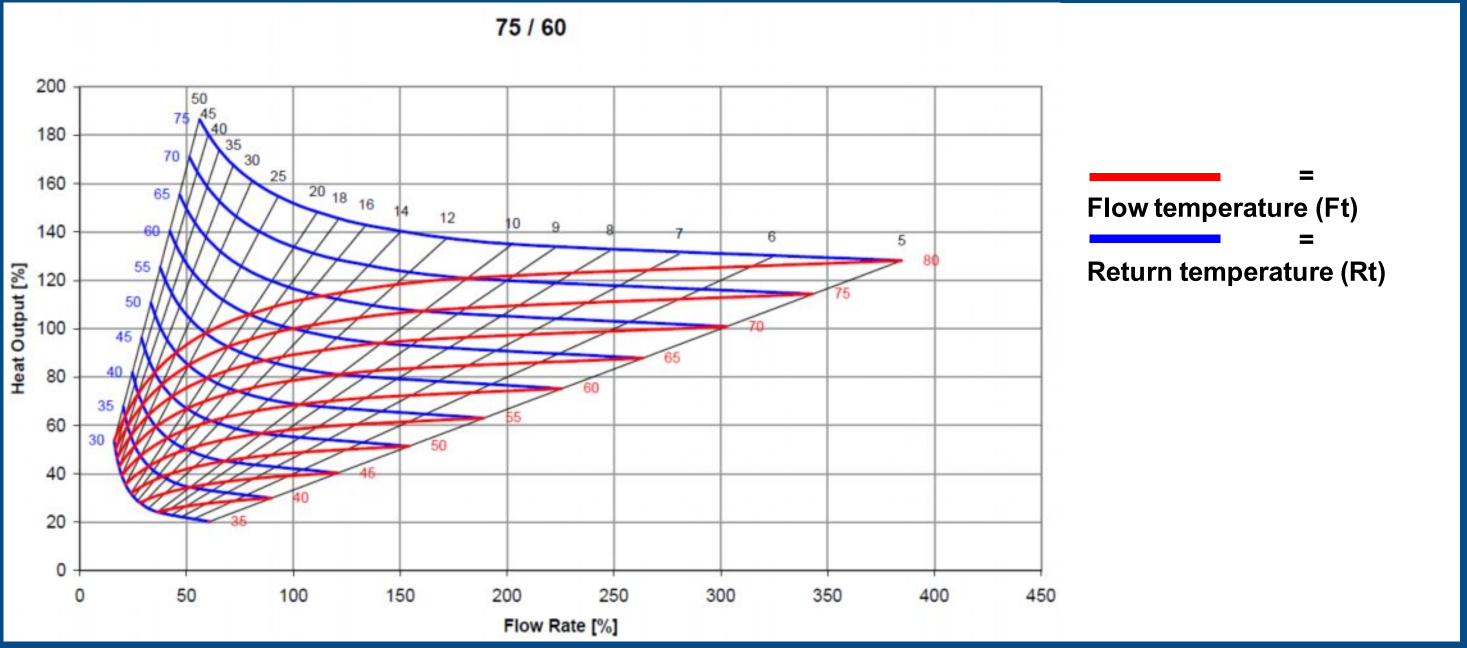


Energy Audit in District Heating Distribution

An important equation in an Audit:

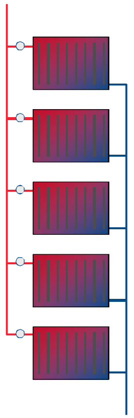
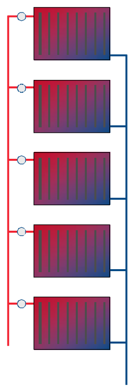
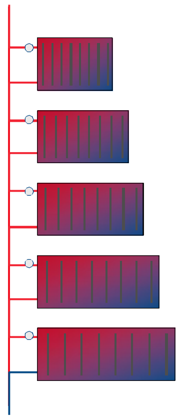
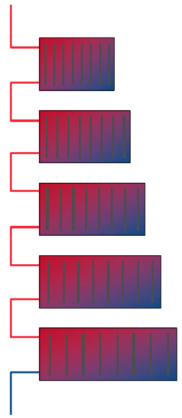
$$\Phi = Q \times \Delta t \quad \text{or} \quad \Phi/\Delta t = Q$$

And also the heat emission curve for a system showing the link between Φ Q Ft and Rt:



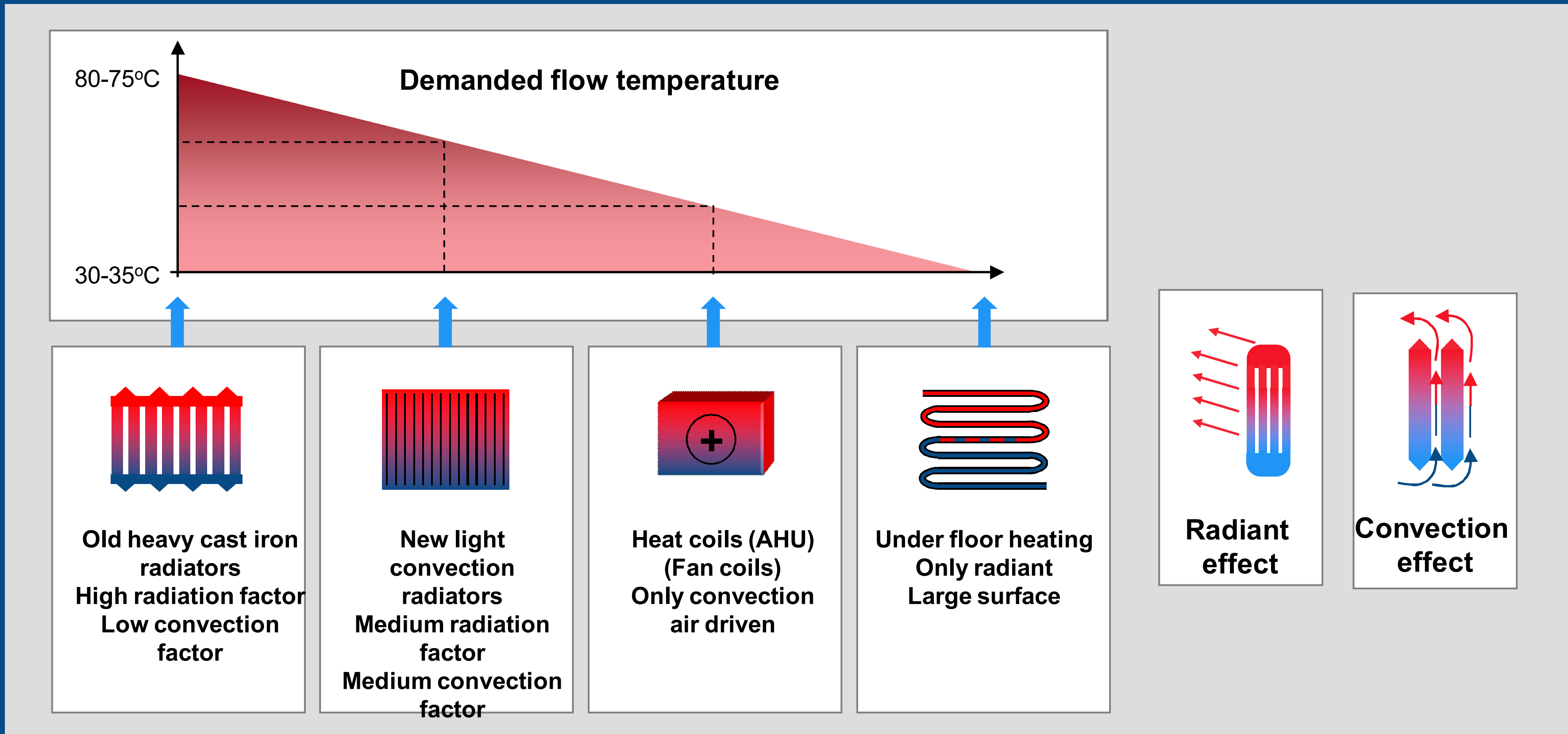
Energy Audit in District Heating Distribution

The temperatures will also have a large impact on the heat balance and out put in site the building depending on the design of the heating system and the radiators. Especially single pipe systems is a challenge when it come to radiator design.

Two pipe system		Single pipe system	
Reverse return		With by-pass	Series connection
			
Very good balance Individual control Not sensitive to radiator size	Need balancing Individual control Not sensitive to radiator size	Need balancing Individual control Sensitive to radiator size	No need for balancing No individual control Very sensitive to radiator size

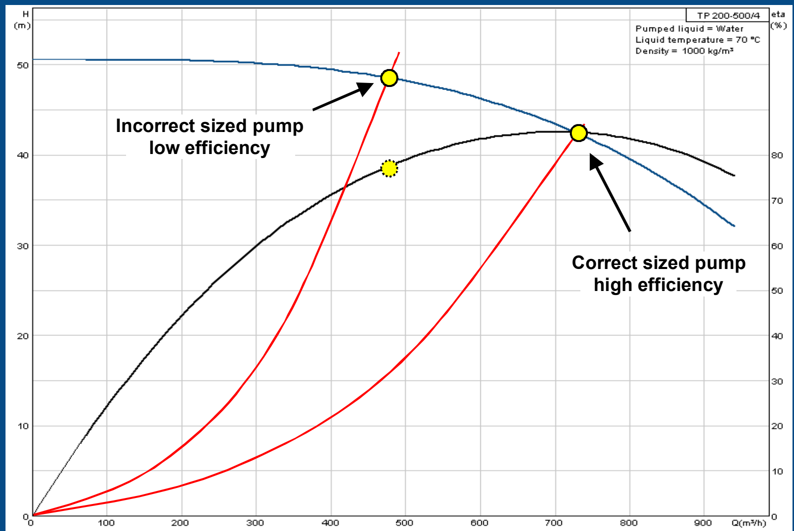
Energy Audit in District Heating Distribution

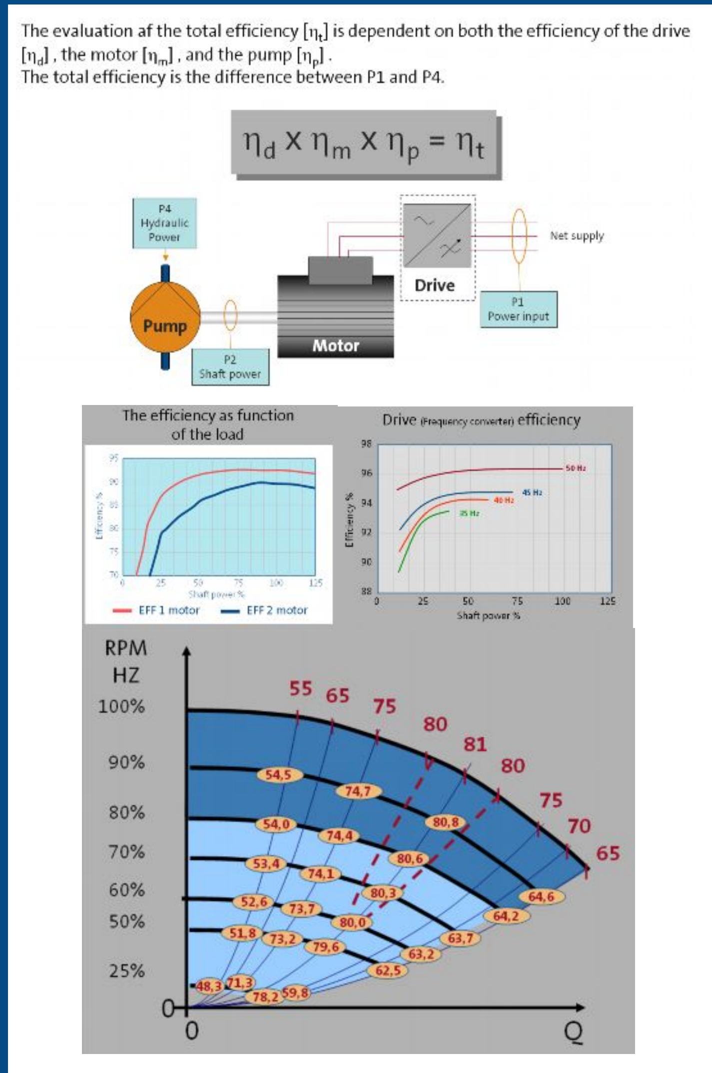
The temperatures will also have a large impact on the heat balance and out put in site the building depending on the design of the heating system and the radiators. Especially single pipe systems is a challenge when it come to radiator design.



Energy Audit in District Heating Distribution

The efficiency on the pump system is not linked to pump quality, but very often it a question of the right design of the pump system.





Energy Audit in District Heating Distribution

Evaluation of the analyze of the system.

Energy/cost calculation for 5 diff. situations

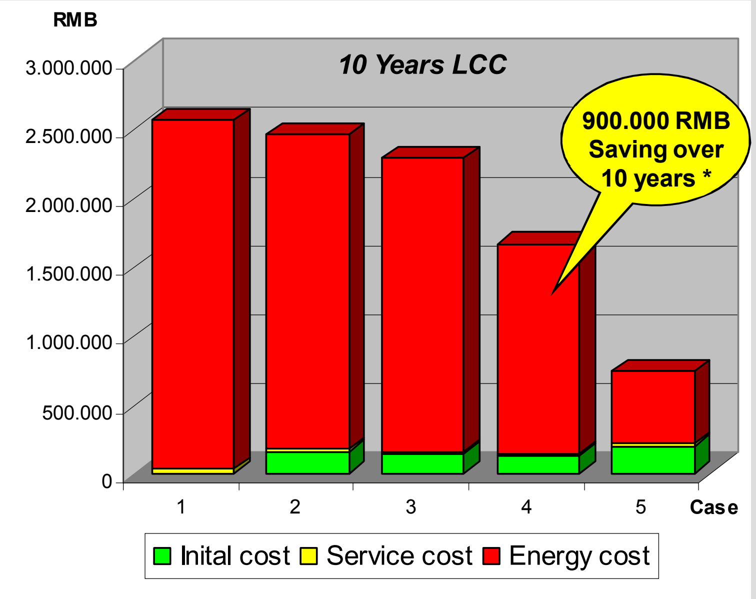
1.Energy consumption on existing pumps system.
2.Select new pumps based on nameplate on the old pump (no measurements).
3.Do a simple pump audit measuring Flow, Head and Power, and select pumps based on these data.
4.Make Energy Audit measuring Flow, Head, Power and Temperatures including analyze of system, and select constant speed pumps based on how the system operates most efficient.
5.Make Energy Audit measuring Flow, Head, Power and Temperatures, analyze of system, providing a load profile and operation strategy. Select variable speed pumps based on how the system operates most efficient.

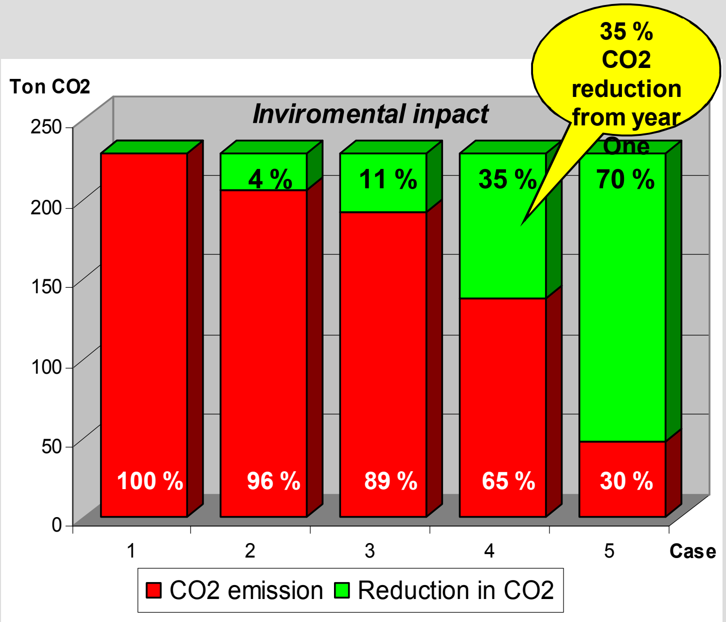
		Flow	Head	P4	Total η	P1	Hours	kWh	Energy cost	Early energy	Saving	Inital cost	Audit	Total	Pay-back
	Design duty point	m3/h	m	kW		kW			RMB / kWh	RMB	RMB	RMB	RMB	RMB	Years
1	1600 m3/h x 20 m	1000	25	68,0	0,63	107,9	3350	361587	0,7	253111	0	0	0	0	
2	1600 m3/h x 20 m	1000	25	68,0	0,7	97,1	3350	325429	0,7	227800	25311	160000	0	160000	6,32
3	1000 m3/h x 25 m	1000	25	68,0	0,75	90,7	3350	303733	0,7	212613	40498	144000	20000	164000	4,05
4	880 m3/h x 20 m	880	20	47,9	0,74	64,7	3350	216718	0,7	151702	101409	130000	38000	168000	1,66
5	880 m3/h x 20 m	880	20	47,9	0,74	64,7	3350	75000	0,7	52500	200611	200000	38000	238000	1,19

Energy Audit in District Heating Distribution

Evaluation of the analyze of the system.

Energy/cost calculation for 5 diff. situations





•A solution which only need implementation at the substation.

Results of the Energy Audit in Jinzhou

Substation Hua Xin 56.000 m²						
	Flow	Head	Motor size	Pumps in operation	Year energy consumption	Saving year
	m^3/h	m	kW	No.	kWh/year	kWh/year
Before	320	32	45	2	**158.580**	**94.620 (59%)**
After	91,2	28,8	11	2	**63.960**	
	93	15,4	5,5	2		

Substation Tian Xing 143.000 m²						
	Flow	Head	Motor size	Pumps in operation	Year energy consumption	Saving year
	m^3/h	m	kW	No.	kWh/year	kWh/year
Before	320	32	45	3	**307.040**	**141.320 (46%)**
After	250	17	15	3	**165.720**	

Substation Tian Xing Low 40.000 m² High 22.000 m²							
		Flow	Head	Motor size	Pumps in operation	Year energy consumption	Saving year
		m^3/h	m	kW	No.	kWh/year	kWh/year
Before	Low	400	32	55	2	**134.686**	**53.720 (39%)***
	High	46,7	44	11	2		
After	Low	125,4	10,6	5.5x2	1	**80.960**	
	High	78,5	22,4	7.5	1		

* The saving is based on 3 month operation with new pumps

Total 161.000 m² gives a saving at 289.660 kWh/year =

1,8 kWh/year/m²

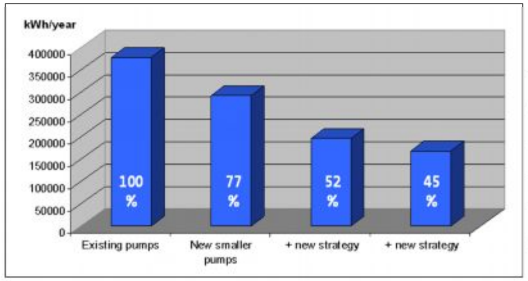
Energy Audit in District Heating Distribution

Haapsalu District Heating Company Estonia
Operated by Dalkia
One test Energy Audit on Boiler house with 196 building connected.
The audit was made in cooperation with CEREG and the Baltic Countries

Total savings potential

By installing new pumps and adding some new strategies there is a large saving as it can be seen on below. The saving is based on the calculation profile and the biggest saving will at part load where the number of operations hours is highest.

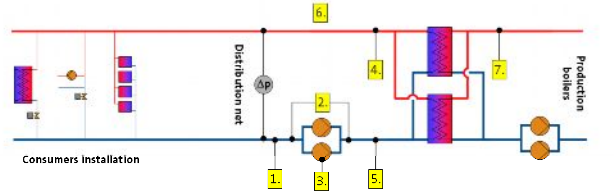
Yearly energy consumption	
Existing pump system and strategy	378.329 kWh/year
New pump system + Pressure/temp. strategy	169.092 kWh/year
Saving	209.237 kWh/year



Key figures on saving in kW per MW supplied heat

Load	Power	Power	Diff.
MW	kW	kW	%
15,0	110	83	25
9,75	70	34	50
7,5	55	21	62
5,25	19	8	58

Haapsalu District Heating Energy Audit



Measurement

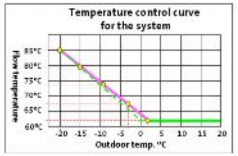
1: Flow Q [m³/h]
2: Differential pressure H [m]
3: Power p 1 [kW]
4: Flow temperature t [°C] (Secondary site)
5: Return temperature t [°C] (Secondary site)
6: Outdoor temperature t [°C]
7: Flow temperature t [°C] (Primary site) option

Calculated values based on measurements

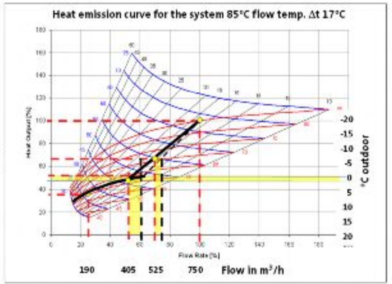
4-5: Differential temperature Δt [°C] (Secondary site)
1x 2: Hydraulic effect P 4 [kW]
(1x2)/3: Pump and motor efficiency η [%]
1x (4-5): Energy flow Φ [kW]

3.Changing flow temperature control strategy.

The heat emission curve is showing a a critical point around 50% where there is a relative high flow vs energy flow and also indicating potential for saving even it is in the small scale.



Values for calculation profile				
Load MW	15	9,75	7,5	5,25
Load %	100	65	50	35
Flow m³/h	750	525	405	190
Flow %	100	70	54	25
Hours/year	300	1500	3000	3960



Energy Audit in District Heating Distribution

Jaroslavl District Heating Company Russia
One test Energy Audit on Domestic Hot Water production and distribution.
The audit was made in cooperation with CEREG and GMO

Yaroslavl DHW Energy calculation for pumps

Main booster and re-circulation pump

Energy consumption existing pump with high recirculation flow.

24 hours load/calculation profile			
	Flow in %		
Hours	Re-circulation	DHW consumption	Total
3	40	60	100
5	40	45	85
9	40	35	75
7	40	20	60

Energy calculation						
Hours	Flow m3/h	Head m	P4 kW	Total η	P1 kW	Energy kWh
3	205	65	36,2	0,58	62,5	187,5
5	174	65	30,8	0,53	58,0	290,2
9	154	65	27,2	0,50	54,5	490,1
7	123	65	21,7	0,48	45,3	317,1
		Total energy per day (kWh)				1.284
		Total energy per year (kWh)				468.993

Cost kWh	2,5
Total yearly cost RUB	1.172.482
Saving RUB	0
Saving %	0

Energy consumption new pump with high recirculation flow.

24 hours load/calculation profile			
	Flow in %		
Hours	Re-circulation	DHW consumption	Total
3	40	60	100
5	40	45	85
9	40	35	75
7	40	20	60

Energy calculation						
Hours	Flow m3/h	Head m	P4 kW	Total η	P1 kW	Energy kWh
3	205	65	36,2	0,65	55,8	167,3
5	174	65	30,8	0,62	49,6	248,1
9	154	65	27,2	0,60	45,4	408,4
7	123	65	21,7	0,57	38,2	267,1
		Total energy per day (kWh)				1090,8
		Total energy per year (kWh)				398.156

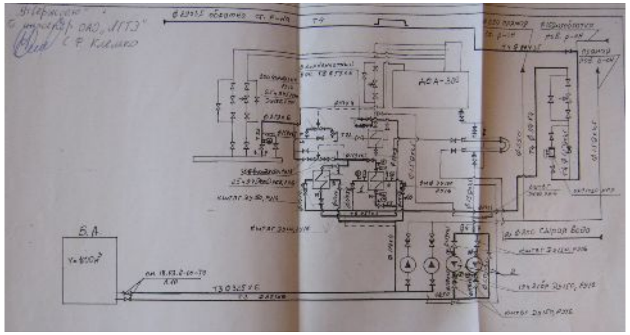
Cost kWh	2,5
Total yearly cost RUB	995.390
Saving RUB	177.092
Saving %	15

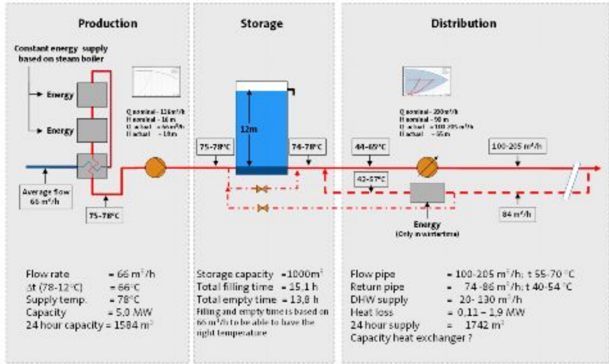
Energy consumption new pump with low recirculation flow.

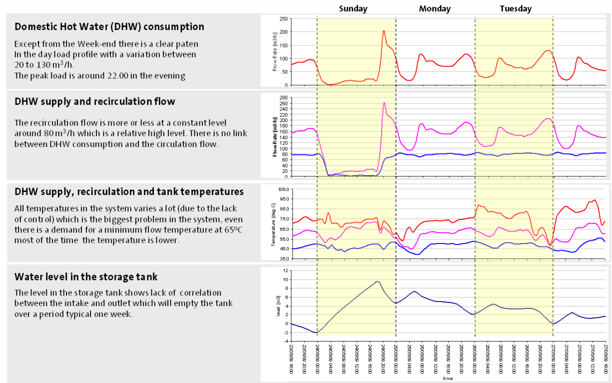
24 hours load/calculation profile			
	Flow in %		
Hours	Re-circulation	DHW consumption	Total
2	32	68	100
4	32	58	90
12	32	38	70
6	32	18	50

Energy calculation						
Hours	Flow m3/h	Head m	P4 kW	Total η	P1 kW	Energy kWh
2	165	65	29,2	0,65	44,9	134,6
4	148	65	26,2	0,62	42,4	211,0
12	116	65	20,5	0,60	34,2	307,6
6	83	65	20,5	0,57	36	180,2
		Total energy per day (kWh)				833
		Total energy per year (kWh)				304.229

Cost kWh	2,5
Total yearly cost RUB	762.380
Saving RUB	410.102
Saving %	35







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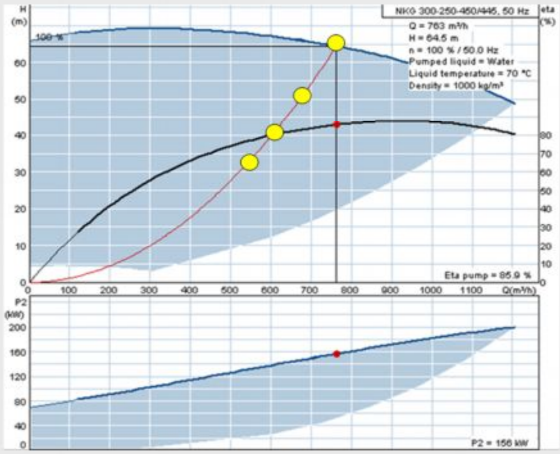
Energy Audit in District Heating Distribution

Jaroslavl District Heating Company Russia
One test Energy Audit on heating distribution production and distribution.
The audit was made in cooperation with CEREG and GMO

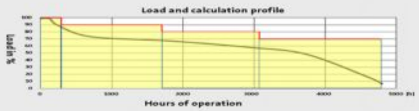
Pump performance old (20 years) and a new Grundfos variable speed pump

By the flow variable based on the load and calculation profile, it is possible to obtain a considerable energy saving even the flow is only lowered to maximum 70%.

Pump curve with the new duty points



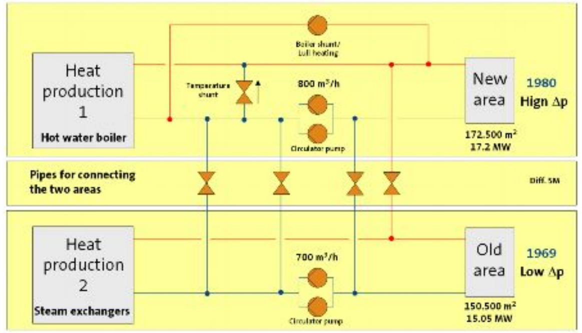
Energy calculation

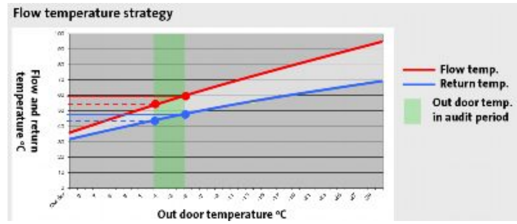


Old D630/90 split case pump				
Flow	Head	Time	P1	Energy
m3/h	m	h	kWh	kWh/year
760	65	4800	284	1.363.200
			Total	1.363.200

New Grundfos NKG Variable speed pump				
Flow	Head	Time	P1	Energy
m3/h	m	h	kWh	kWh/year
760	65	240	164	39327
684	53	1440	121	174141
608	42	1440	86	123834
532	32	1680	58	98010
			Total	435312

Saving kWh/year	927.888
Saving %	68

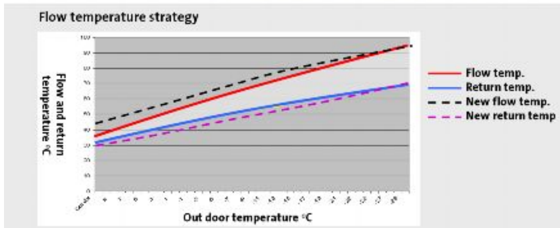




Chancing control strategy

Example on how the strategy can look

Out door temp.°C		Flow temp.°C		RPM	Hz
-31	-23	95	88	1450	50
-22	-10	85	68	1305	45
-9	1	67	53	1100	40
2	10	52	38	1015	35



Potential saving :
68% with new pump and new control strategy

District Heating the Grundfos Way

"For us, district heating means calculations transformed into **saving in energy!**"

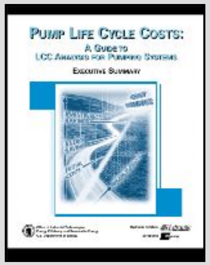
District Heating the Grundfos Way

Life Cycle Cost

A Guide to LCC Analysis for Pumping Systems is the result of a collaboration between:

- **Hydraulic Institute**
- **Europump**
- **US Department of Energy's Office of industrial Technologies**

The life cycle cost of any piece of equipment is the total "lifetime" cost to purchase, install, operate, maintain and dispose of that equipment. Determining LCC involves following a methodology to identify and quantify all of the components of the LCC equation.



$$LCC = C_{ic} + C_{in} + C_e + C_o + C_m + C_s + C_{env} + C_d$$

LCC = life cycle cost

C_{ic} = inital costs, purchase price

C_{in} = installation and commissioning cost

C_e = energy costs

C_o = operation cost (labour cost)

C_m = maintenance and repair costs

C_s = down time costs (loss of production)

C_{env} = environmental costs

C_d = decommissioning/disposal costs

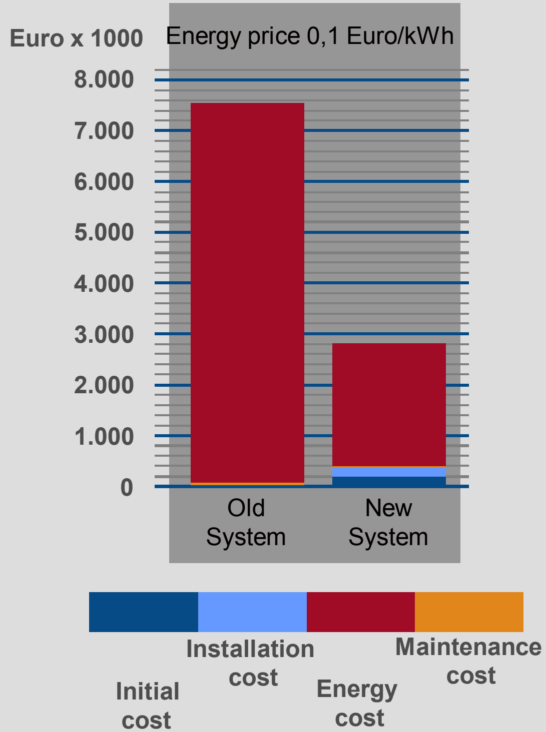
District Heating the Grundfos Way

Calculations transformed into **saving in energy!**

Ulaanbaatar Heat Efficiency Project
Booster pump station 3
Maximum capacity
Flow: 2500 m3/h
Head: 60 m

By replacing 3 circulator pump in a booster station , with new speed controlled pumps, a yearly energy saving at 65% can be obtained.
The pay-back of the new system is less than 2 years

Life Cycle Cost
– 20 years operation



District Heating the Grundfos Way

Calculations transformed into **saving in energy!**

A housing society with 20 apartment blocks consider to replace all radiator val-ves to thermostatic valves, and at the same time they will replace the 9 years old pumps.

What is energy saving and life cycle cost?

Existing pump installation:

> 20 Grundfos UPC 40-120
> Flow: 12.7 m^3/h
> Head: 5.0 m
> Operation days/year: 365 days
> Energy consumption: **4,554 kWh/year/pump**

Life Cycle Cost will be based on 2 new alternatives.

> System 1: Constant speed pump UPS 40-120
> System 2: Speed controlled pump MAGNA 40-120

District Heating the Grundfos Way

Calculations transformed into **saving in energy!**

Transforming life cycle cost into saving in energy and cost saving

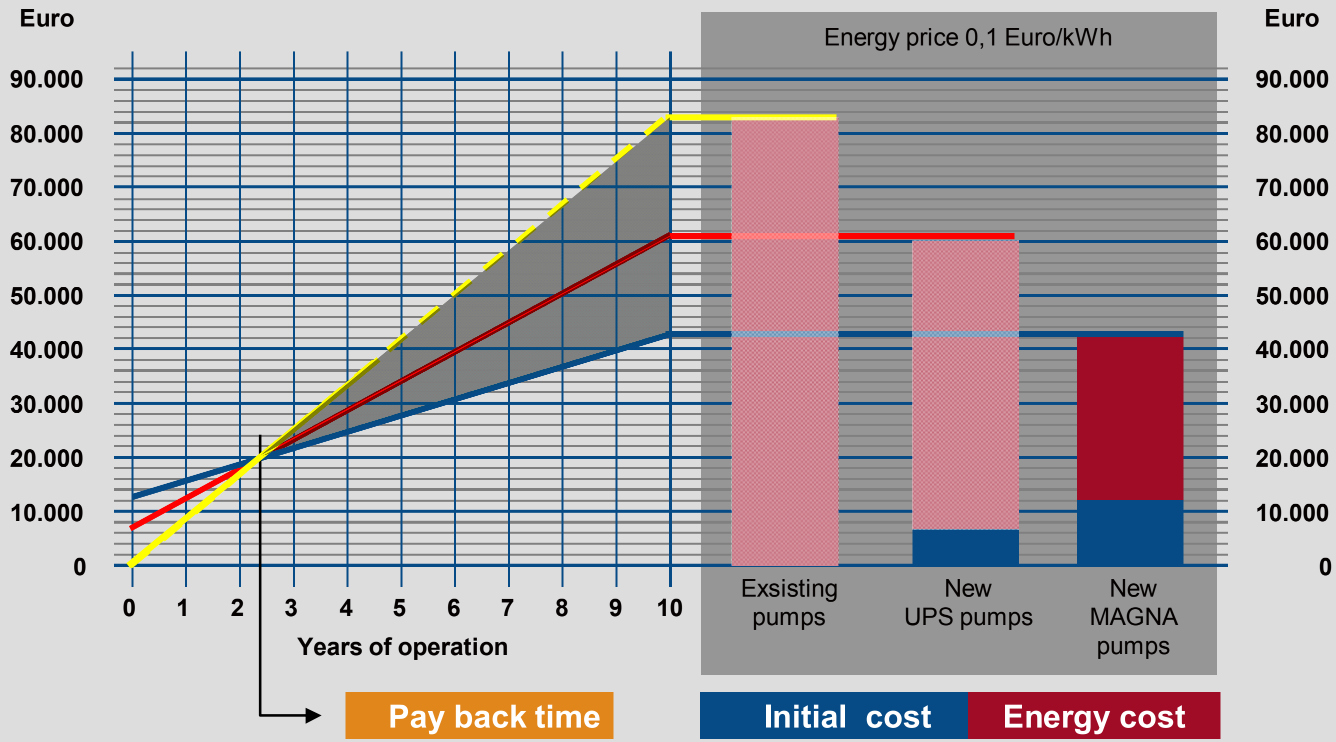
	10 years operation time						
	System 1 Euro	% LCC	System 2 Euro	% LCC	Savings Euro	Saving %	Remarks
C_{ic}	6.400	9,1%	12.000	28,5%	-5.600	-88%	End user price
C_{in}	1.000	1,4%	1.000	2,4%	0	0%	Commissioning
C_e	62.100	88,7%	28.640	68%	33.460	54%	Energy price 0,1 Euro/kWh
C_m	0	0%	0	0%	0	0%	
C_d	500	0,1%	500	0,1%	0	0%	
LCC	**70.001**	**100%**	**42.141**	**100%**	**27.860**	**40%**	

Saving for compared to existing system : 49.440 EURO

District Heating the Grundfos Way

Calculations transformed into **saving in energy!**

10 years Life Cycle Cost for 20 Circulator pumps



District Heating the Grundfos Way

Calculations transformed into **saving in energy!**

Transforming life cycle cost into saving in energy and cost saving

A 20 year old substation needs renovation, and at the same time the District Heating Company wants more focus on low operation costs.

- > Total heated area: 80,000 m^2
- > Total heat demand: 6,000 kW
- > The flow is calculated to : 129 m^3/h
- > The head is calculated to: 18 m

Existing pump installation (20 years old):

- > 1 constant speed pump in operation and 1 standby pump. (alternation between the 2 pumps)

Life Cycle Cost will be based on 2 new alternatives.

- > System 1: 1 constant speed pump
- > System 2: 2 speed controlled pumps

District Heating the Grundfos Way

Calculations transformed into **saving in energy!**

Transforming life cycle cost into saving in energy and cost saving

	20 years operation time						
	System 1 Euro	% LCC	System 2 Euro	% LCC	Savings Euro	Saving %	Remarks
C_{ic}	5.200	4,6%	7,300	11,7%	-2.100	-88%	End user price
C_{in}	500	0,4%	600	1%	-100	-20%	Commissioning
C_e	105.642	93,6%	53.032	84,9%	33.460	50%	Energy price 0,1 Euro/kWh
C_m	1.500	1,3%	1.500	2,4%	0	0%	
LCC	**112.842**	**100%**	**62.432**	**100%**	**27.860**	**45%**	

Total saving : 50.410 EURO

District Heating the Grundfos Way

Calculations transformed into **saving in energy!**