Dr.-Ing. Friedrich-Wilhelm Hennecke
Curriculum vitae

- 1940 born
- 1960-1972 Studies and research
  - Mechanical and Chemical Engineering at Technical University of Hannover and University of Bristol
  - Research at Max-Planck-Institute of Fluid Dynamics and at Technical University of Karlsruhe
- 1972- 2002 BASF Works Engineering
  - Plant engineer Ammonia plants
  - Maintenance Manager of a refinery
  - Manager Engineering Pumps and Motors
- 2002 retired

Dr.-Ing. Friedrich-Wilhelm Hennecke
Memberships

- Speaker of BASF Pump Working Group
- Speaker of the Pump Working Group of German Chemical Industry
- Member of the German Pump Standardization Committee
- Co-Editor of Life-Cycle-Cost Guideline for Pumps of Hydraulic Institiute (USA) and Europump

Life Cycle Cost of the Hydra-Cell Pump

A comparison with other Pumps

Elements of Life Cycle Costs (LCC)

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

C_{ic}	=	initial cost
C_{in}	=	installation and commissioning cost
C_e	=	energy costs
C_o	=	operating cost
C_m	=	maintenance and repair costs
C_s	=	down time ans loss of production cost
C_{env}	=	environmental cost
C_d	=	decommissioning and disposal cost

Calculation of LCC

Discounting $$C_p = \frac{C_n}{[1+(i-p)]^n}$$

where

n	=	number of years
i	=	interest rate
P	=	annual inflation
i-p	=	real discount rate
C_n	=	cost paid after „n“ years
C_p	=	present value of a single cost element

Present Value $$PV = \sum C_{px}$$

LCC calculation factor C_p/C_n

Table 1: Factor C_p/C_n for a single cost element after *n* years													
	Real interest rate (nominal interest rate minus inflation rate)												
No. of years (n)	- 2	-1	0	1	2	3	4	5	6	7	8	9	10
1	1.02	1.01	1	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.91
2	1.04	1.02	1	0.98	0.96	0.94	0.92	0.91	0.89	0.87	0.85	0.84	0.82
3	1.06	1.03	1	0.97	0.94	0.92	0.89	0.86	0.84	0.81	0.79	0.77	0.74
4	1.08	1.04	1	0.96	0.93	0.89	0.86	0.82	0.79	0.76	0.73	0.70	0.68
5	1.10	1.05	1	0.95	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.65	0.61
6	1.12	1.06	1	0.94	0.89	0.84	0.79	0.75	0.71	0.67	0.63	0.59	0.56
7	1.15	1.07	1	0.94	0.87	0.82	0.76	0.71	0.67	0.62	0.58	0.54	0.51
8	1.17	1.08	1	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46
9	1.19	1.09	1	0.92	0.84	0.77	0.71	0.65	0.60	0.55	0.50	0.46	0.42
10	1.21	1.10	1	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47	0.42	0.39
15	1.32	1.15	1	0.87	0.76	0.66	0.57	0.50	0.43	0.38	0.33	0.28	0.25
20	1.44	1.20	1	0.83	0.69	0.58	0.48	0.40	0.34	0.28	0.23	0.19	0.16
25	1.56	1.25	1	0.80	0.64	0.51	0.41	0.33	0.26	0.21	0.17	0.13	0.11
30	1.69	1.30	1	0.77	0.59	0.46	0.35	0.27	0.21	0.16	0.12	0.09	0.07

LCC calculation discount factor

Table 2: Discount factor (df) for constant yearly expenditures													
	Real interest rate (nominal interest rate minus inflation rate)												
No. of years (n)	- 2	-1	0	1	2	3	4	5	6	7	8	9	10
1	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.93	0.92	0.91
2	2.06	2.03	2.00	1.97	1.94	1.91	1.89	1.86	1.83	1.81	1.78	1.76	1.74
3	3.12	3.06	3.00	2.94	2.88	2.83	2.78	2.72	2.67	2.62	2.58	2.53	2.49
4	4.21	4.10	4.00	3.90	3.81	3.72	3.63	3.55	3.47	3.39	3.31	3.24	3.17
5	5.31	5.15	5.00	4.85	4.71	4.58	4.45	4.33	4.21	4.10	3.99	3.89	3.79
6	6.44	6.22	6.00	5.80	5.60	5.42	5.24	5.08	4.92	4.77	4.62	4.49	4.36
7	7.60	7.29	7.00	6.73	6.47	6.23	6.00	5.79	5.58	5.39	5.21	5.03	4.87
8	8.77	8.37	8.00	7.65	7.33	7.02	6.73	6.46	6.21	5.97	5.75	5.53	5.33
9	9.97	9.47	9.00	8.57	8.16	7.79	7.44	7.11	6.80	6.52	6.25	6.00	5.76
10	11.19	10.57	10.00	9.47	8.98	8.53	8.11	7.72	7.36	7.02	6.71	6.42	6.14
15	17.20	16.27	15.00	13.87	12.85	11.94	11.12	10.38	9.71	9.11	8.56	8.06	7.61
20	24.89	22.26	20.00	18.05	16.35	14.88	13.59	12.46	11.47	10.59	9.82	9.13	8.51
25	32.85	28.56	25.00	22.02	19.52	17.41	15.62	14.09	12.78	11.65	10.67	9.82	9.08
30	41.66	35.19	30.00	25.81	22.40	19.60	17.29	15.37	13.79	12.41	11.26	10.27	9.43

The Hydra-Cell Pump

- Flowrate - 8,4 m3/h
- Head (Pressure) - 70 (170) bar
- Temperature - 70 ^{0}C
- Selfpriming - 2,5 m
- Viscosity - 4000 mPaS
- Solids-content - 50 %
- Solids-size - 0,8 mm
- Efficiency - 80 %

Scope of investigation

Flowrate	1,4		4,2		8,4	m^3/h
Pressure	5	10	50	75	100	bar

Hydra-Cell Pump

Centrifugal Pump

Sidechannel Pump

Peristaltic Pump

Membrane Piston Pump

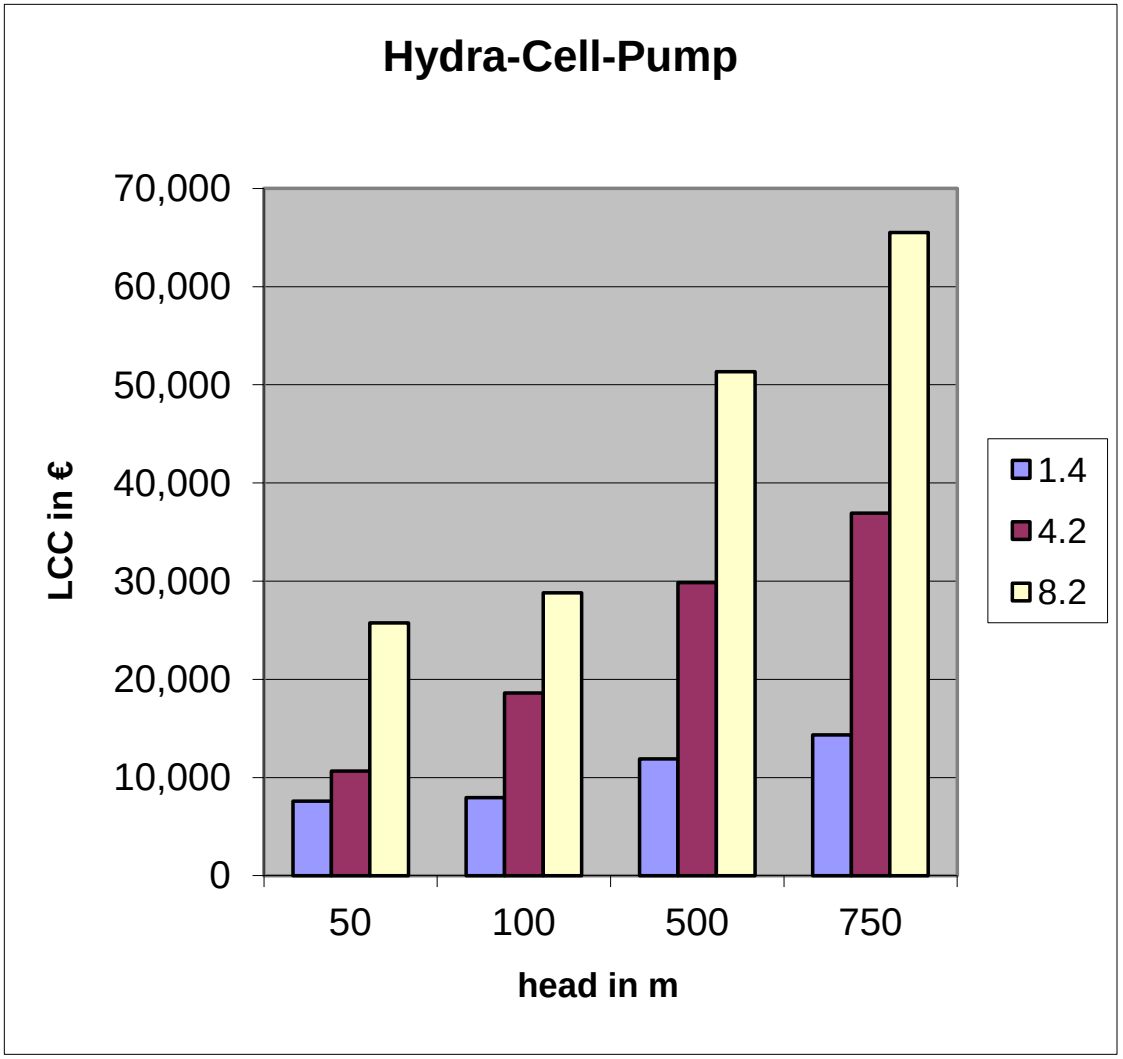
Input

Operating data													
flowrate	1	m^3/h	1,4	1,4	1,4	1,4	4,2	4,2	4,2	4,2	8,2	8,2	8,2	8,2
head	2	m	50	100	500	750	50	100	500	750	50	100	500	750
density	3	kg/dm^3	1	1	1	1	1	1	1	1	1	1	1	1
kinem.Viscosity	4	mm^2/s	1	1	1	1	1	1	1	1	1	1	1	1
energy price per kWh	5	€	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08
operating hours per Jahr	6	h	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
number of years	7	-	10	10	10	10	10	10	10	10	10	10	10	10
interest rate	8	%	9	9	9	9	9	9	9	9	9	9	9	9
inflation rate	9	%	0	0	0	0	0	0	0	0	0	0	0	0
Pump data														
Type			G10	G10	G10	G10	G25	G25	G25	G25	G35	G35	G35	G35
pump aggregate	10	€	3.300	3.400	3.600	3.700	3.590	8.198	8.198	8.198	13.900	14.150	14.800	15.200
add. Inverter etc	11	€	0	0	0	0	0	0	0	0	0	0	0	0
complete aggregate	12 10+11	€	3.300	3.400	3.600	3.700	6.800	6.900	7.500	8.000	13.900	14.150	14.800	15.200
installation a commissioning cost	13	€	0	0	0	0	0	0	0	0	0	0	0	0
power, hydraulic	14 1*2*3/367	kW	0,2	0,4	1,9	2,9	0,6	1,1	5,7	8,6	1,1	2,2	11,2	16,8
effiency	15	%	45	58	77	79	46	59	77	79	45	58	77	79
power, demanded	16	kW	0,4	0,7	2,5	3,6	1,3	1,9	7,4	10,9	2,5	3,9	14,5	21,2
energy cost per year	17 6*7*16	€	136	210	793	1.159	401	622	2.377	3.475	794	1.233	4.643	6.788
operating cost per year	18	€	0	0	0	0	0	0	0	0	0	0	0	0
routine maintenance cost per year	19	€	100	100	100	100	100	100	100	100	100	100	100	100
spare parts per repair	20	€	350	350	350	350	550	550	550	550	900	900	900	900
labour cost per repair	21	€	150	150	150	150	150	150	150	150	150	150	150	150
time between repairs	22	h	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
repair costs per 8000 operating hours	23 (20+21)/22*8000	€	1.000	1.000	1.000	1.000	1.400	1.400	1.400	1.400	2.100	2.100	2.100	2.100
repair costs per year	24 23/8000*6	€	500	500	500	500	700	700	700	700	1.050	1.050	1.050	1.050
maintenance costs per year	25	€	600	600	600	600	800	800	800	800	1.150	1.150	1.150	1.150
downtime costs per year	25	€	0	0	0	0	0	0	0	0	0	0	0	0
other costs per year	27	€	0	0	0	0	0	0	0	0	0	0	0	0
decommissioning costs	28	€	0	0	0	0	0	0	0	0	0	0	0	0

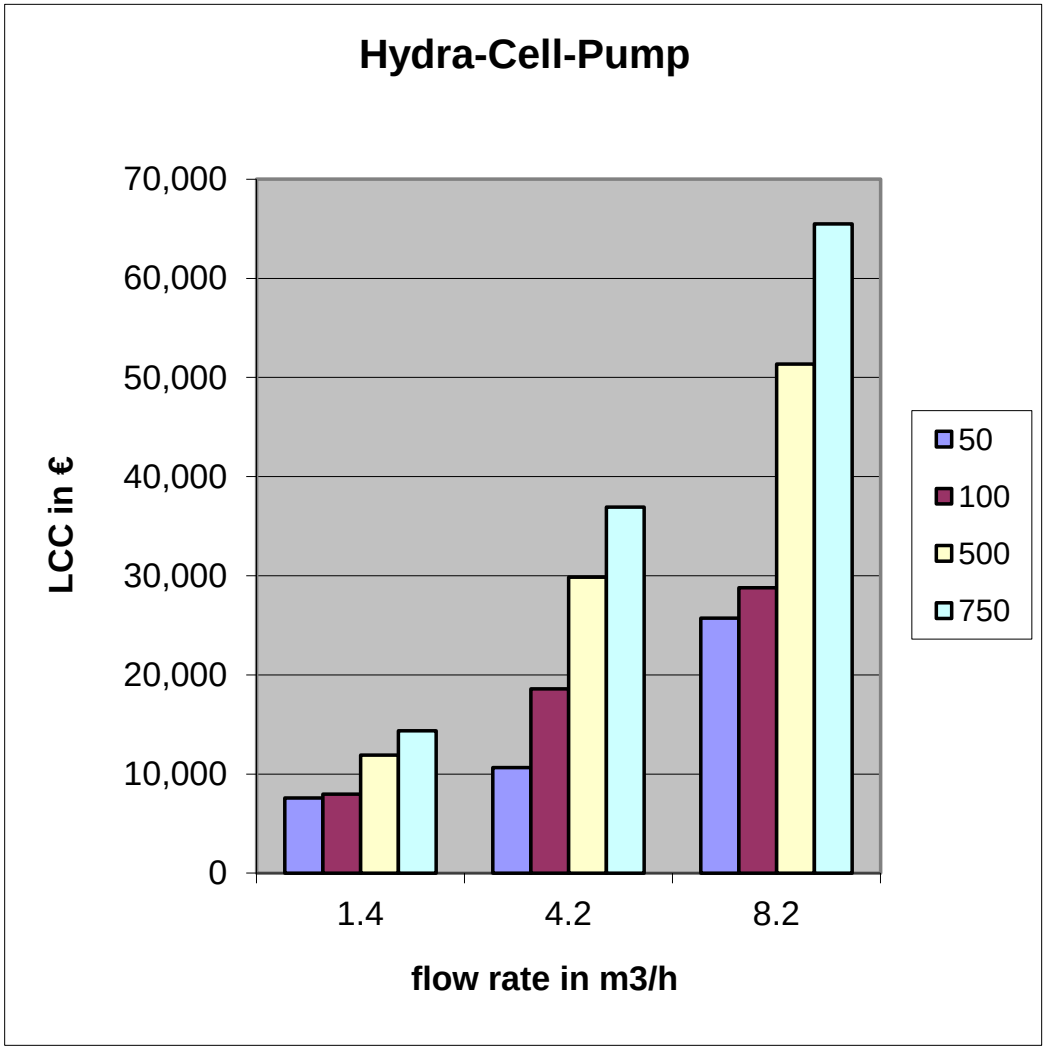
LCC calculation

Type				G10	G10	G10	G10	G25	G25	G25	G25	G35	G35	G35	G35
complete aggregate	1		€	3.300	3.400	3.600	3.700	6.800	6.900	7.500	8.000	13.900	14.150	14.800	15.200
installation and commissioning cost	2		€	0	0	0	0	0	0	0	0	0	0	0	0
Initial investment costs	3	1+2	€	3.300	3.400	3.600	3.700	6.800	6.900	7.500	8.000	13.900	14.150	14.800	15.200
energy costs per year	4		€	136	210	793	1.159	401	622	2.377	3.475	794	1.233	4.643	6.788
operating costs per year	5		€	0	0	0	0	0	0	0	0	0	0	0	0
maintenance costs per year	6		€	500	500	500	500	700	700	700	700	1.050	1.050	1.050	1.050
downtime costs per year	7		€	0	0	0	0	0	0	0	0	0	0	0	0
other costs per year	8		€	0	0	0	0	0	0	0	0	0	0	0	0
sum of yearly costs	9	3 to 8	€	636	710	1.293	1.659	1.101	1.322	3.077	4.175	1.844	2.283	5.693	7.838
discount factor df see table 2)=f(n,i-p)	10		-	6,42	6,42	6,42	6,42	6,42	6,42	6,42	6,42	6,42	6,42	6,42	6,42
present value of yearly costs	11	9*10	€	4.079	4.560	8.296	10.646	7.065	8.482	19.746	26.796	11.837	14.650	36.534	50.301
decommissioning costs	12		€	0	0	0	0	0	0	0	0	0	0	0	0
factor Cp / Cp (see table .1)=f(n,i-p)	13		-	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42	0,42
present value of decommissioning costs	14	12*13	€	0	0	0	0	0	0	0	0	0	0	0	0
Result															
Life Cycle Costs	15	3+11+14	€	7.379	7.960	11.896	14.346	13.865	15.382	27.246	34.796	25.737	28.800	51.334	65.501
- present value energy costs	16	4*11	€	870	1.351	5.087	7.437	2.573	3.990	15.253	22.304	5.098	7.911	29.796	43.562
- pesent value maintenance costs	17	6*11	€	3.209	3.209	3.209	3.209	4.492	4.492	4.492	4.492	6.739	6.739	6.739	6.739

Results (1)


Hydra-Cell-Pump
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
LCC in €
50
100
500
750
head in m
1.4
4.2
8.2

Results (2)


Hydra-Cell-Pump
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
LCC in €
1.4
4.2
8.2
flow rate in m3/h
50
100
500
750

Pump comparison (1) 1,4 m³/h 50 m

Type			Hydra Cell	Centri fugal	Side channel	Peris-taltic	Mem brane Piston
			G10	32-200	1204	VF25	LDB/3
flowrate	1	m^3/h	1,4	1,4	1,4	1,4	1,4
head	2	m	50	50	50	50	50
density	3	kg/dm^3	1	1	1	1	1
kinem.viscosity	4	mm^2/s	1	1	1	1	1
energy price per kWh	5	€	0,08	0,08	0,08	0,08	0,08
operating hours per year	6	h	4.000	4.000	4.000	4.000	4.000
number of years	7	-	10	10	10	10	10
interest rate	8	%	9	9	9	9	9
inflation rate	9	%	0	0	0	0	0

Pump comparison (2) 1,4 m³/h 50 m

Type				Hydra Cell	Centri fugal P.	Side channel P.	Peristal tic P.	Mem brane Piston P.
				G10	32-200	1204	VF25	LDB/3
pump aggregate	10		€	3.300	3.550	3.400	1.968	8.700
add. Inverter etc	11		€					500
complete aggregate	12	10+11	€	3.300	3.550	3.400	1.968	9.200
installation and commissioning cost	13		€					
power, hydraulic	14	1*2*3/367	kW	0,19	0,19	0,19	0,19	0,19
effiency	15		%	45	19	19	27	55
power, demanded	16		kW	0,4	1,0	1,0	0,7	0,3
energy cost per year	17	6*7*16	€	136	321	321	226	111

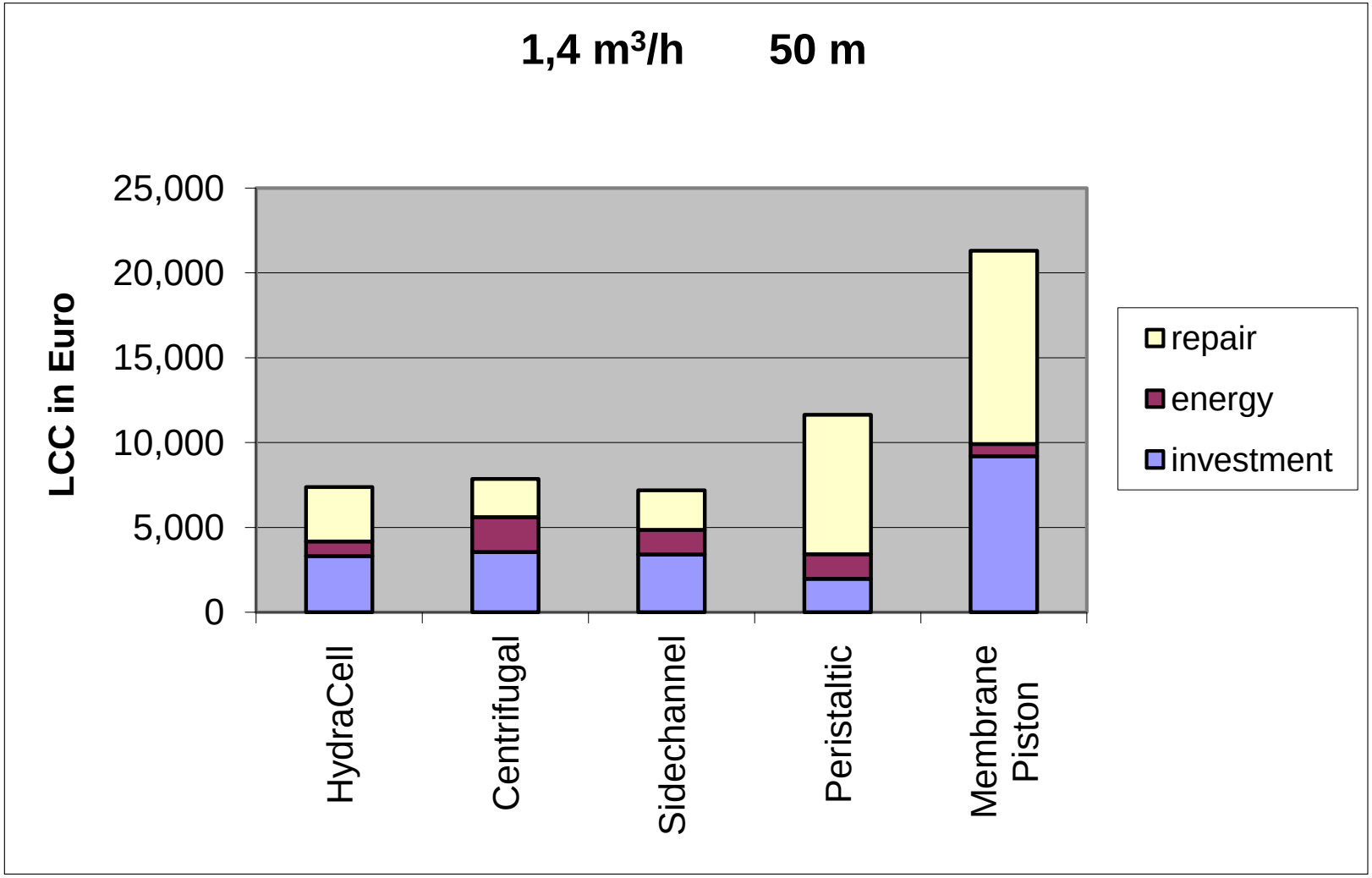
Pump comparison (3) 1,4 m³/h 50 m

Type				HydraCell	Centri-fugal	Side-channel	Peristaltic	Piston membrane
operating cost per year	18		€	0	0	0	0	0
routine maintenance cost per year	19		€	100	100	100	100	250
spare parts per repair	20		€	350	400	450	170	1.550
labour cost per repair	21		€	150	1.000	1.000	150	2.000
time between repairs	22		h	4.000	16.000	16.000	1.000	8.000
repair costs per 8000 operating hours	23	(20+21)/22*8000	€	1.000	700	725	2.560	3.550
repair costs per year	24	23/8000*6	€	500	350	363	1.280	1.775
maintenance costs per year	25		€	600	450	463	1.380	2.025
downtime costs per year	25		€	0	0	0	0	0
other costs per year	27		€	0	0	0	0	0
decommissioning costs	28		€	0	0	0	0	0

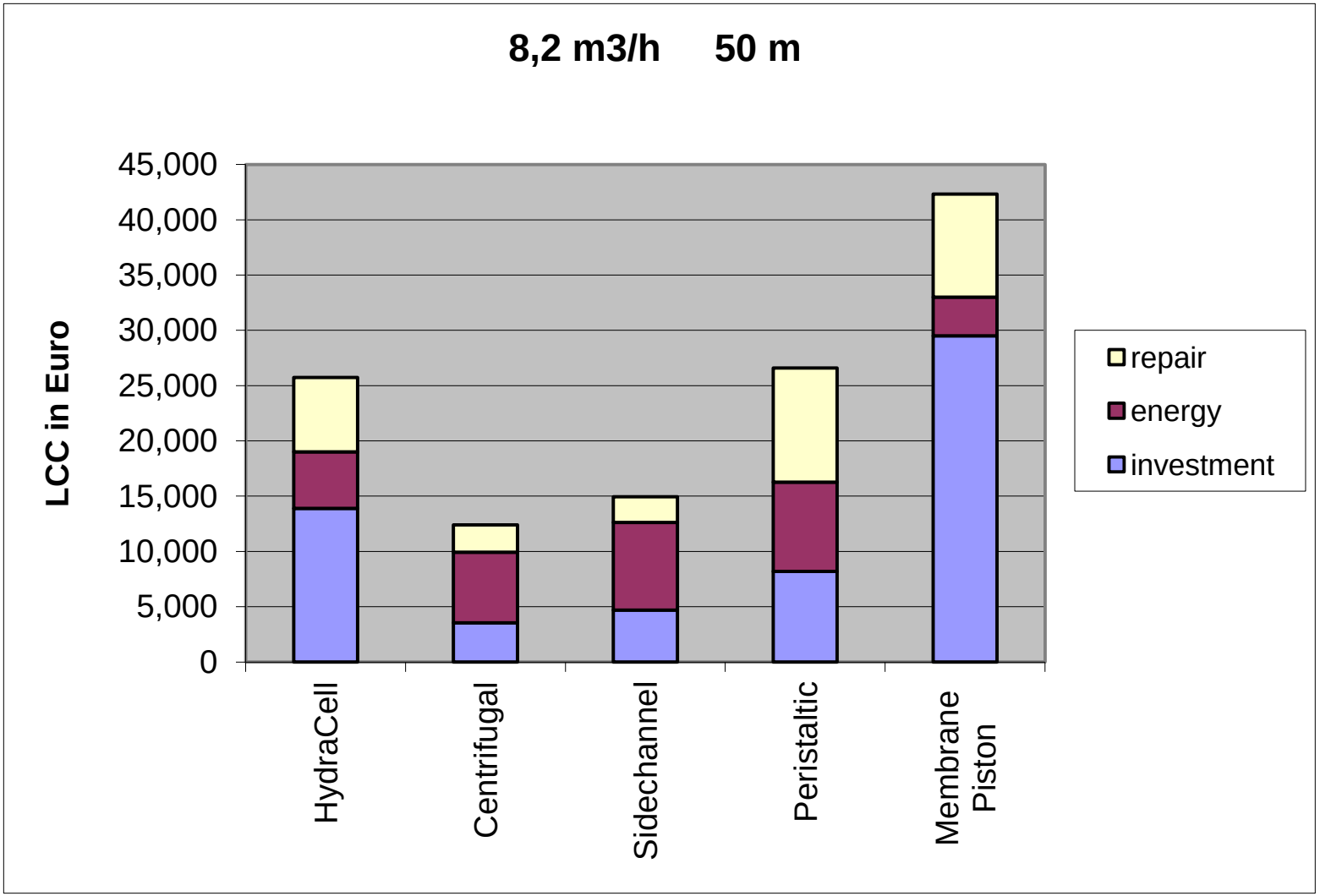
Pump comparison (4) 1,4 m³/h 50 m

Type				HydraCell	Centrifugal	Sidechannel	Peristaltic	Membrane Piston
complete aggregate	1		€	3300	3550	3400	1968	9200
installation and commissioning cost	2		€	0	0	0	0	0
Initial investment costs	3	1+2	€	3.300	3.550	3.400	1.968	9.200
energy costs per year	4		€	136	321	321	226	111
operating costs per year	5		€	0	0	0	0	0
maintenance costs per year	6		€	600	450	463	1.380	2.025
downtime costs per year	7		€	0	0	0	0	0
other costs per year	8		€	0	0	0	0	0
sum of yearly costs	9	3 to 8	€	736	771	784	1.606	2.136
discount factor df see table 2)=f(n,i-p)	10		-	6,42	6,42	6,42	6,42	6,42
present value of yearly costs	11	9*10	€	4.721	4.950	5.030	10.307	13.708
decommissioning costs	12		€	0	0	0	0	0
factor Cp / Cp (see table .1)=f(n,i-p)	13		-	0,42	0,42	0,42	0,42	0,42
present value of decommissioning costs	14	12*13	€	0	0	0	0	0
Result								
Life Cycle Costs	15	3+11+14	€	8.021	8.500	8.430	12.275	22.908
of which are energy costs	16	4*10	€	870	2.062	2.062	1.451	712
of which are maintenance costs	17	6*10	€	3.851	2.888	2.968	8.856	12.996

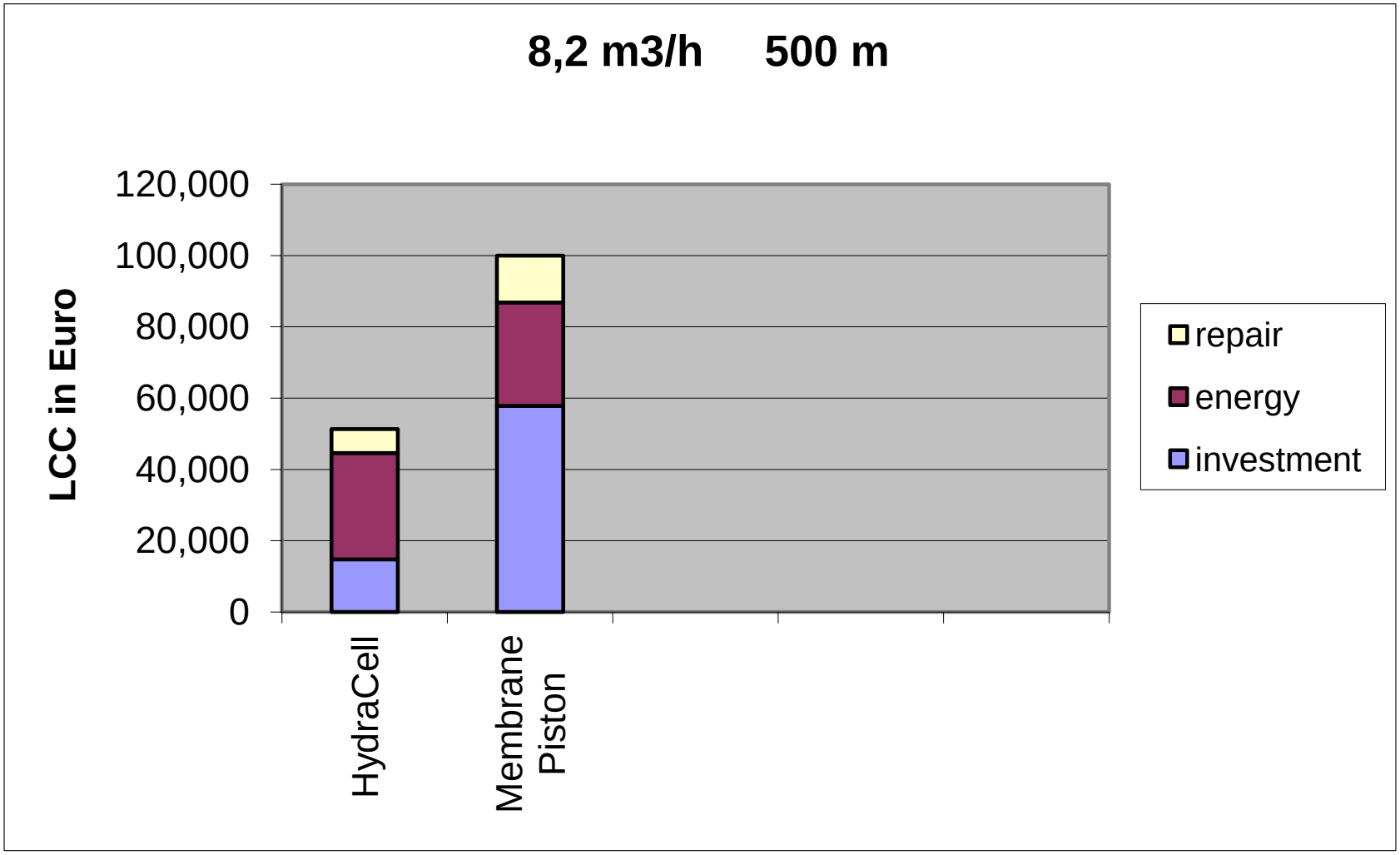
Pump comparison (5)



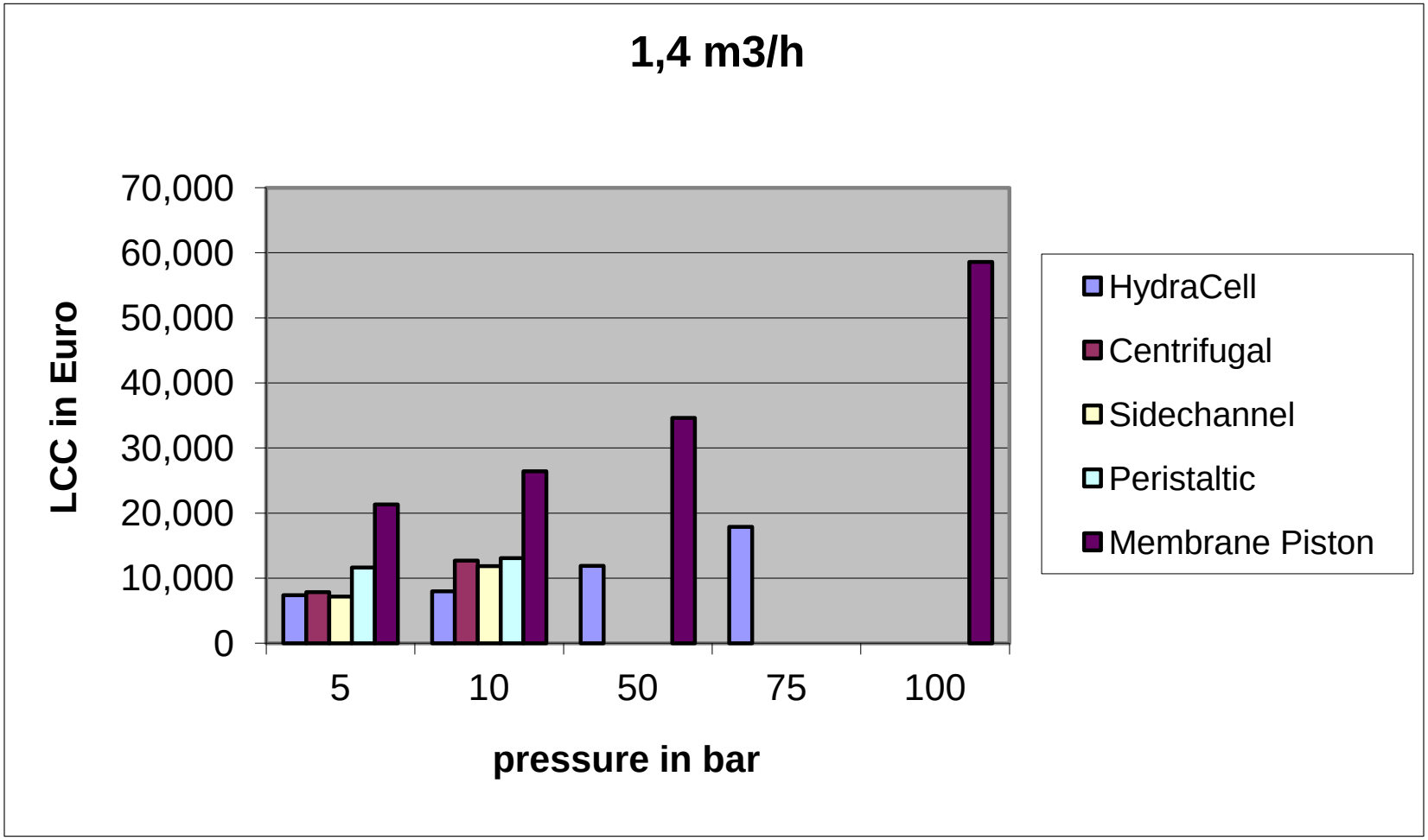
Pump comparison (6)



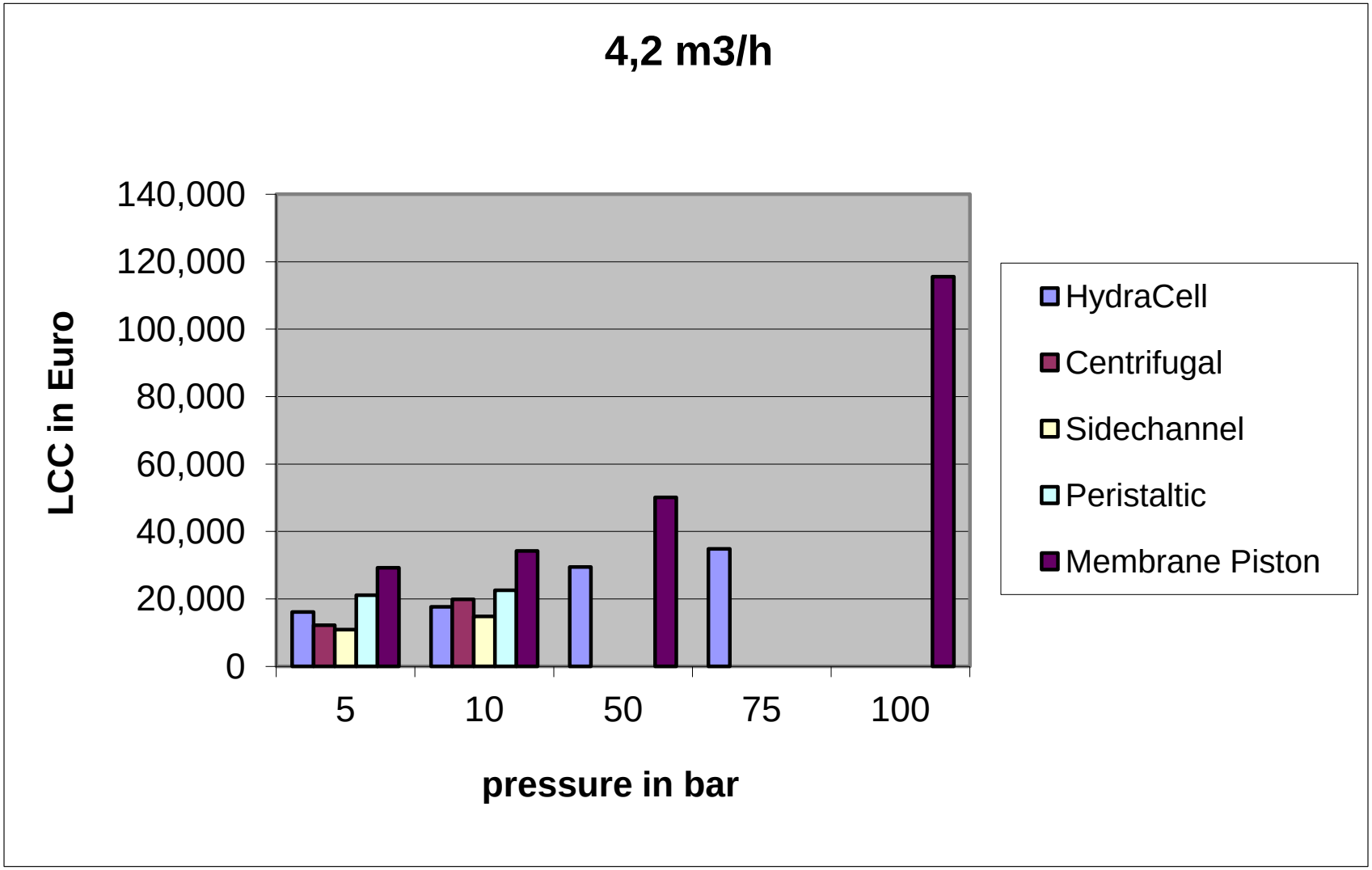
Pump comparison (7)



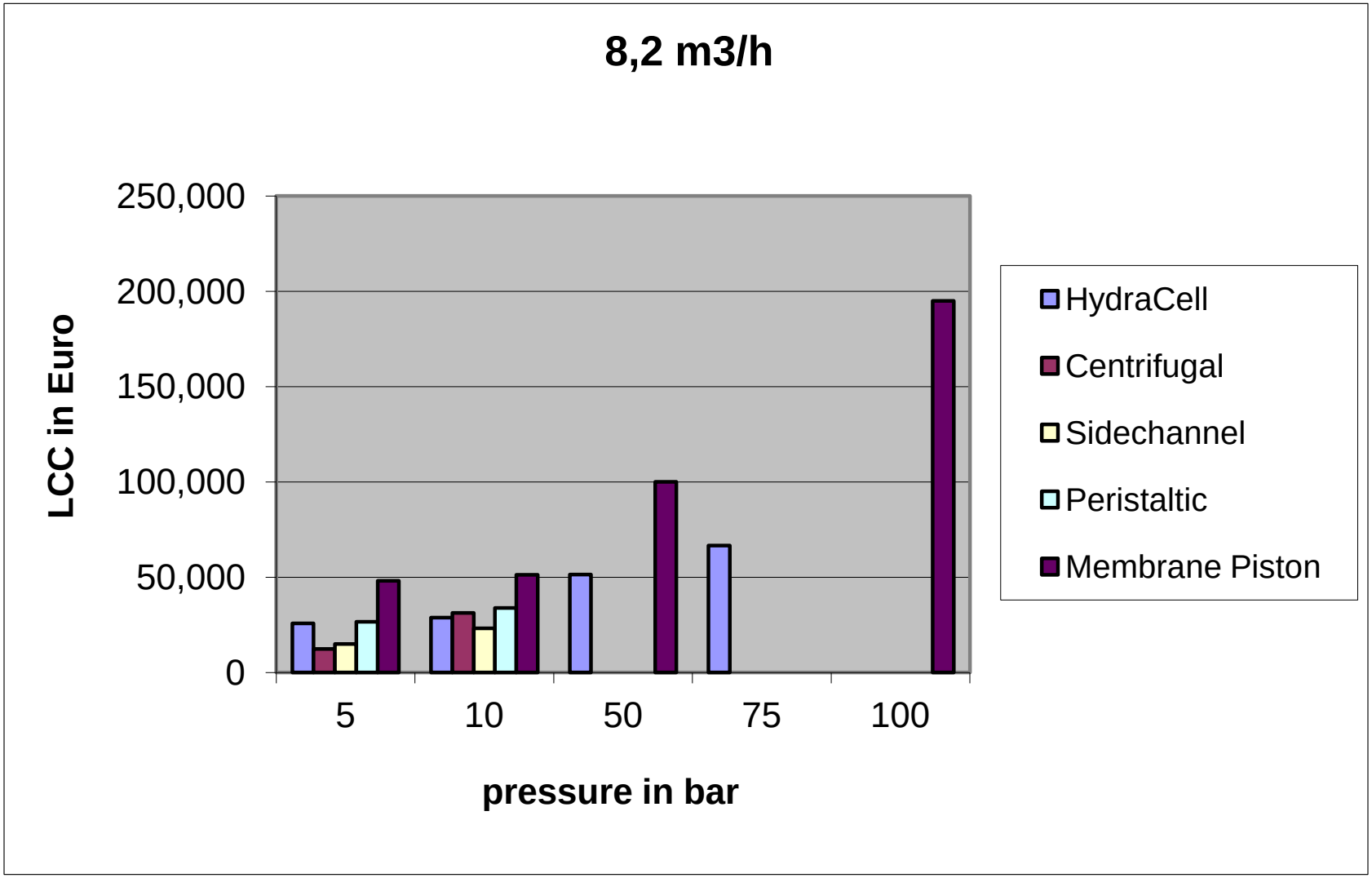
LCC comparison survey (1)



LCC comparison survey (2)



LCC comparison survey (3)



Results

- **Hydra-Cell** is the most economic pump in the considered range.

- The **Sidechannel** pump is similar, but can only handle clean fluids.
- **Centrifugal** pumps are for low pressure and high flowrates.
- **Peristaltic** pumps have high demand of tubes

- The Sidechannel pump, the centrifugal and the peristaltic pump are limited up to 10 bar. Above 10 bar only the HydraCell and the membrane piston pump are applicable.

- **Membrane Piston Pumps** have the best effiency. The investment cost and the cost for spare parts and labour changing the membranes are extremely high. Therefore the LCC exceed the HydraCell up to factor 3.