Estimation of costs associated with CO_2 based EOR projects - revised report

Delivery D4.1.4

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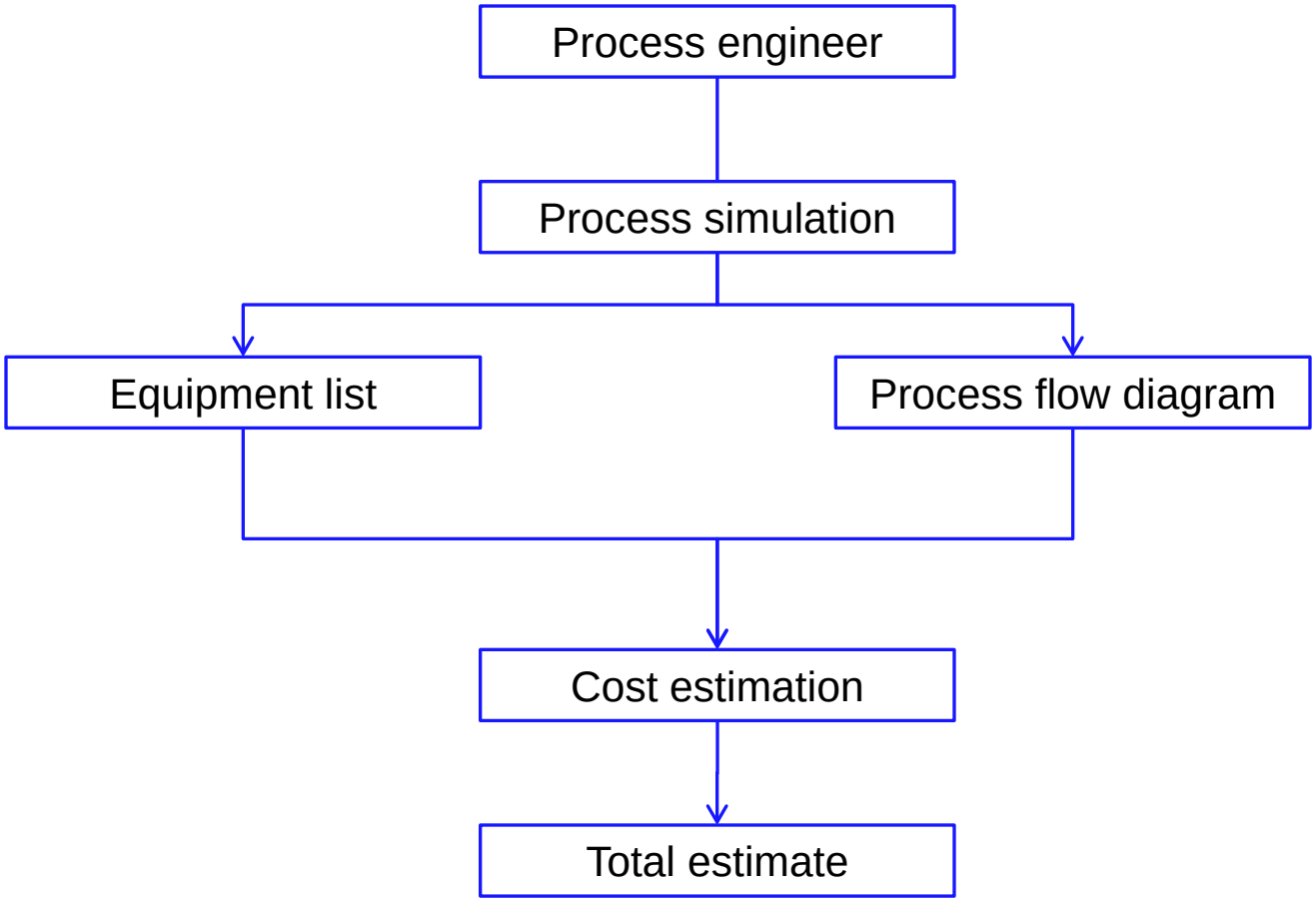
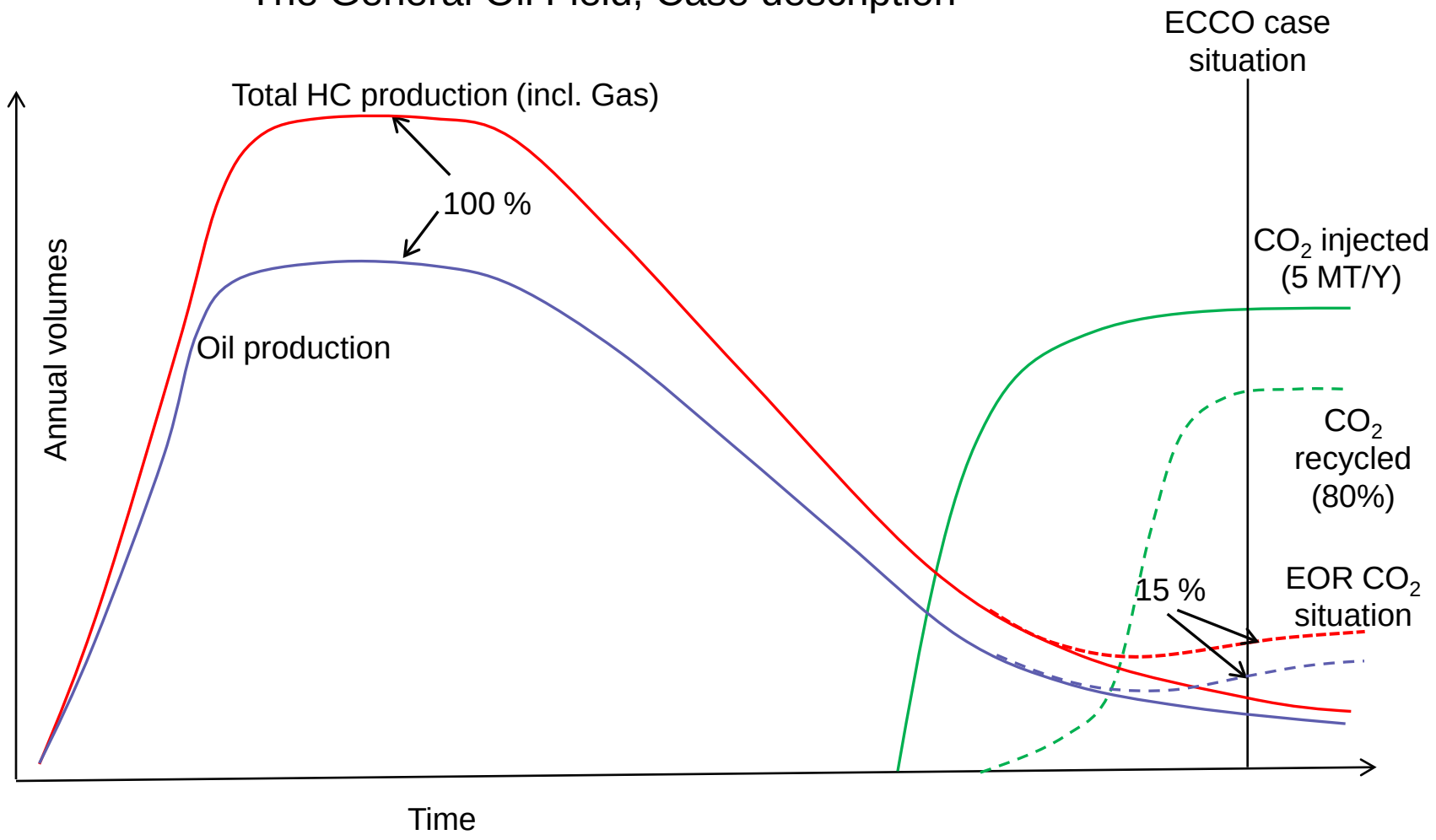
Estimation of costs - elements



The General Oil Field, Case description



General Oil Field (GOF) - description

GOF input data	
Wellhead pressure after choking (bars)	85
Temperature (°C)	70
Oil and gas (% of plateau prod.)	15
Oil production (bbl/day)	37 500
Water quantity (% by wt of oil/water mix)	90
HC gas production (% by wt of oil/gas mix)	7.5
CO_2 gas injected (kton/year)	5 000
Recovery (80% of injected) (kton/year)	4 000
H_2S	Yes (high)

Membrane separation

- Known membranes give CO_2 as permeate at low pressure.
- No reference to more than 75 vol% CO_2 inlet.

Requirements:

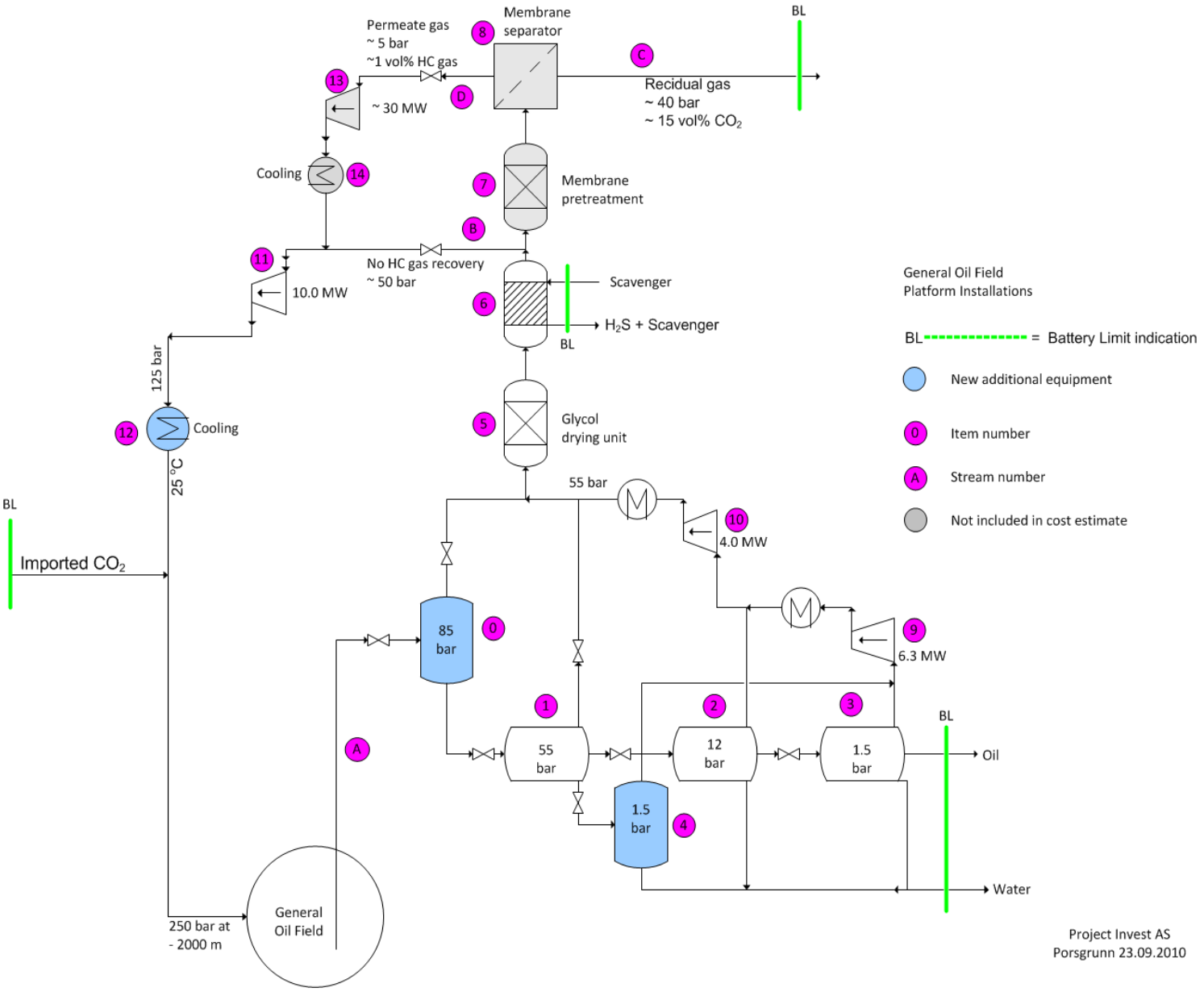
- ✓ Large membrane area
- ✓ Expensive recompression
- ✓ Development of better membranes?

Consequence:

- ✓ Fuel gas production at GOF is probably not realistic

Qualitative cost for fuel gas production

Item		Investment (Capex)	Operational cost (Opex)
7	Membrane pretreatment	Medium	Moderate
8	Membranes	Very large	Low
13	Permeate recompression	Large	Large
14	Permeate cooler	Large	Moderate


Permeate gas
~ 5 bar
~1 vol% HC gas
8
Membrane separator
BL
C
Recidual gas
~ 40 bar
~ 15 vol% CO_2
13
D
~ 30 MW
Cooling
14
7
Membrane pretreatment
B
11
No HC gas recovery
~ 50 bar
10.0 MW
Scavenger
6
H_2S + Scavenger
BL
125 bar
12
Cooling
25 °C
5
Glycol drying unit
55 bar
BL
Imported CO_2
10
4.0 MW
85 bar
0
9
6.3 MW
1
2
3
BL
55 bar
12 bar
1.5 bar
Oil
A
1.5 bar
4
Water
250 bar at
- 2000 m
General Oil Field
General Oil Field
Platform Installations
BL = Battery Limit indication
New additional equipment
0 Item number
A Stream number
Not included in cost estimate
Project Invest AS
Porsgrunn 23.09.2010

Offshore cost,
man-hour compared to base cost from contractor.

Cost element	**Base**	**Offshore (EUR/hour)**
Base cost from contractor	100 EUR/hour	100 EUR/hour
Travel and accomodation	250 EUR/day	33 EUR/hour
Efficiency	50 %	133 EUR/hour
Temporary facilities	0 %	0
Adjusted man-hour rate		**267 EUR/hour**

Estimation alternatives

Item no	Equipment	Max CAPEX Alt. 1	Min CAPEX & New rotors Alt. 2	Min CAPEX Alt. 3
0	Pre separator	New	New	New
1	Inlet separator	New	Existing	Existing
2	Middle separator	New	Existing	Existing
3	Outlet separator	New	Existing	Existing
4	CO_2 separator	New	New	New
5	Glycol drying unit	Existing	Existing	Existing
6	H2S scavenger	Existing	Existing	Existing
7	Membrane pretreatment [Fuel gas]	New	New	New
8	Membrane separator [Fuel gas]	New	New	New
9	Low pressure compressor	New	New rotor	Existing
10	Medium pressure compressor	New	New rotor	Existing
11	High pressure compressor	New	New rotor	Existing
12	Gas cooler	New	New	New
13	Permeate compressor [Fuel gas]	New	New	New
14	Permeate cooler [Fuel gas]	New	New	New

Equipment list General Oil Field

Tag no	Equipment description	Size	Unit	Pressure [bar]	Temp in C	Temp out C	Material
0	Pre-separator	37	m3	85			SS316
1	Inlet separator	Existing					
2	Middle separator	Existing					
3	Outlet separator	Existing					
4	CO2 water separator	150	m3	1,5			SS316
5	Glycol drying unit	Existing					
6	H2S scavenger	Existing					
7	Membrane pre treatment	Not included in the cost estimate					
8	Membrane separator	Not included in the cost estimate					
9	LP Compressor, internals only	6300	kW	12	66	300	
10	MP Compressor, internals only	4000	kW	55	45	134	
11	HP Compressor, internals only	10000	kW	125	44	114	
12	Gas cooler CO2 side	40	MW	125	114	25	SS316
12	Gas cooler sea water side	950	m2	3	5	30	Titanium
13	Permeate compressor	Not included in the cost estimate					
14	Permeate cooler	Not included in the cost estimate					

Cost estimate			
	Max CAPEX	Min CAPEX & New rotors	MIN CAPEX
	kEUR	kEUR	kEUR
Equipment costs	13 428	5 622	2 068
Erection cost	3 851	4 775	746
Piping incl. Erection	13 121	4 358	2 636
Electro (equip & erection)	7 589	2 112	1 267
Instrument (equip. & erection)	8 741	2 582	1 659
Ground work	3 239	906	547
Steel & concrete	7 651	2 150	1 306
Insulation	1 125	339	222
Direct costs	**58 744**	**22 844**	**10 452**
Engineering process	597	432	102
Engineering mechanical	249	114	49
Engineering piping	1 066	484	202
Engineering el.	594	265	100
Engineering instr.	717	326	137
Engineering ground	120	53	21
Engineering steel & concrete	358	160	62
Engineering insulation	54	25	11
Engineering	**3 756**	**1 858**	**684**
Procurement	124	83	41
Project control	207	149	38
Site management	6 845	3 025	1 084
Project management	5 618	2 484	894
Administration	**12 793**	**5 741**	**2 057**
Commissioning	2 199	1 346	427
Identified costs	**77 493**	**31 789**	**13 620**
Contingency	**15 499**	**6 358**	**2 724**
Total costs 2009	**92 992**	**38 147**	**16 344**

Conclusions (1)

1. Difficulties

- CO_2 breakthrough in the associated gas is unavoidable (after lag time).
- A major part of the CO_2 injected will break through and end up in the associated gas.
- CO_2 and water in carbon steel equipment will cause unacceptable corrosion.
- Modifications of an offshore platform are cumbersome and costly.
- Loss of oil production due to shutdowns to carry out platform modifications will have large economical implications.
  - Shut down time (loss of income) critical to overall project economy
- The supply of CO_2 to an offshore oil field will be costly.

Conclusions (2)

2. Advantages

- Postponed field close down - effects on close down costs
- Prolonged field lifetime – increased overall oil yield
- Part of the CO_2 quantity will be stored permanently

- Detailed engineering to be done for a concrete field
  - HES modifications, OPEX etc..

Conclusions (3)

The required and preferred oil field / platform conditions are:

- The equipment and piping are made of non corroding steel, to withstand corrosion caused by sulphur components and CO_2.
- The selected field should have a low gas oil ratio (GOR) when starting the EOR
- The field should be at the end of its lifetime and operating with low associated gas quantity to secure capacity for handling the break through CO_2 with least possible platform modifications.
- Previously drilled wells for WAG injection may be used for CO_2 injection. Costs for injection well modifications have hence not been estimated in this study.
- The platform should have an alternative energy supply not requiring fuel gas production from the associated gas. The untreated associated gas therefore can be reinjected after breakthrough of CO_2.
  Fuel gas production from the GOF associated gas, > 90 vol% CO_2, may not be feasible or economical
- A secure and sufficient external CO_2 supply must be available at a reasonable cost. The required quantity for CO_2 will drop considerably at CO_2 break through.

Alt. 1:
New equipment and renewing the Separation and Compressor train

	IBL Equipment	IBL Bulk materiel	IBL Hour Cost	Sum
	kEUR	kEUR	kEUR	kEUR
Equipment costs	13 428	0	0	**13 428**
Erection cost		0	3 851	**3 851**
Piping incl. Erection		3 272	9 849	**13 121**
Electro (equip & erection)		1 070	6 519	**7 589**
Instrument (equip. & erection)		862	7 879	**8 741**
Ground work		213	3 027	**3 239**
Steel & concrete		1 078	6 572	**7 651**
Insulation		159	966	**1 125**
Direct costs	**13 428**	**6 653**	**38 664**	**58 744**
Engineering process			597	**597**
Engineering mechanical			249	**249**
Engineering piping			1 066	**1 066**
Engineering el.			594	**594**
Engineering instr.			717	**717**
Engineering ground			120	**120**
Engineering steel & concrete			358	**358**
Engineering insulation			54	**54**
Engineering			**3 756**	**3 756**
Procurement			124	**124**
Project control			207	**207**
Site management			6 845	**6 845**
Project management			5 618	**5 618**
Administration			**12 793**	**12 793**
Commissioning			**2 199**	**2 199**
Identified costs				**77 493**
Contingency				**15 499**
Total costs 2009	13 428	6 653	57 412	**92 992**

Alt. 2:
New equipment and renewing the Separation and new rotors in the Compressors

Cost estimate				
	IBL Equipment	IBL Bulk materiel	IBL Hour Cost	Sum
	kEUR	kEUR	kEUR	kEUR
Equipment costs	5 622	0	0	**5 622**
Erection cost		0	4 775	**4 775**
Piping incl. Erection		953	3 405	**4 358**
Electro (equip & erection)		298	1 814	**2 112**
Instrument (equip. & erection)		255	2 328	**2 582**
Ground work		60	847	**906**
Steel & concrete		303	1 847	**2 150**
Insulation		48	291	**339**
Direct costs	**5 622**	**1 916**	**15 307**	**22 844**
Engineering process			432	**432**
Engineering mechanical			114	**114**
Engineering piping			484	**484**
Engineering el.			265	**265**
Engineering instr.			326	**326**
Engineering ground			53	**53**
Engineering steel & concrete			160	**160**
Engineering insulation			25	**25**
Engineering			**1 858**	**1 858**
Procurement			83	**83**
Project control			149	**149**
Site management			3 025	**3 025**
Project management			2 484	**2 484**
Administration			**5 741**	**5 741**
Commissioning			**1 346**	**1 346**
Identified costs				**31 789**
Contingency				**6 358**
Total costs 2009	5 622	1 916	24 252	**38 147**

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Alt. 3:
New equipment

	IBL Equipment	IBL Bulk materiel	IBL Hour Cost	Sum
	kEUR	kEUR	kEUR	kEUR
Equipment costs	2 068	0	0	**2 068**
Erection cost		0	746	**746**
Piping incl. Erection		767	1 869	**2 636**
Electro (equip & erection)		179	1 089	**1 267**
Instrument (equip. & erection)		164	1 495	**1 659**
Ground work		36	511	**547**
Steel & concrete		184	1 122	**1 306**
Insulation		31	191	**222**
Direct costs	**2 068**	**1 360**	**7 023**	**10 452**
Engineering process			102	**102**
Engineering mechanical			49	**49**
Engineering piping			202	**202**
Engineering el.			100	**100**
Engineering instr.			137	**137**
Engineering ground			21	**21**
Engineering steel & concrete			62	**62**
Engineering insulation			11	**11**
Engineering			**684**	**684**
Procurement			41	**41**
Project control			38	**38**
Site management			1 084	**1 084**
Project management			894	**894**
Administration			**2 057**	**2 057**
Commissioning			**427**	**427**
Identified costs				**13 620**
Contingency				**2 724**
Total costs 2009	2 068	1 360	10 192	**16 344**