HUB

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14 06 2011

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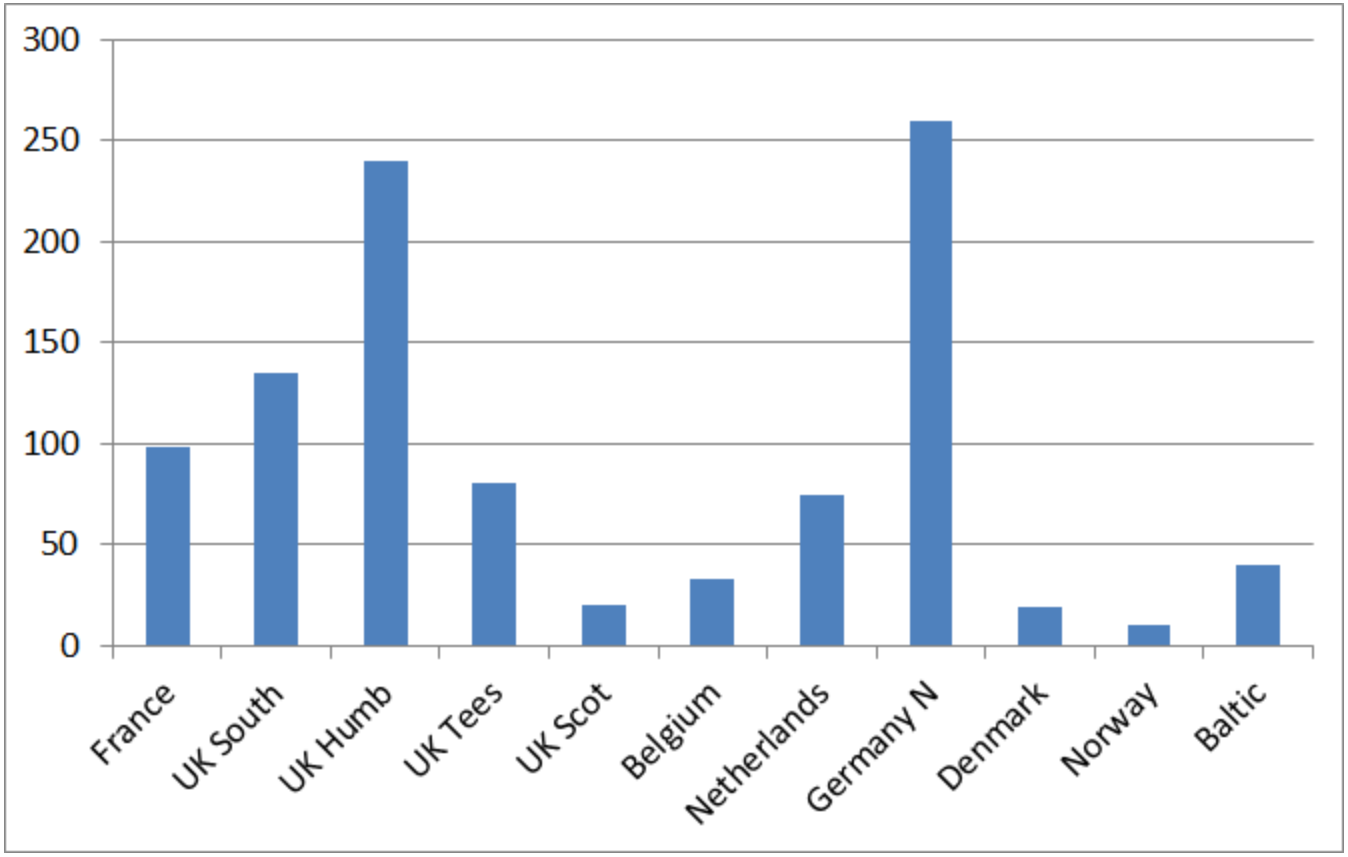
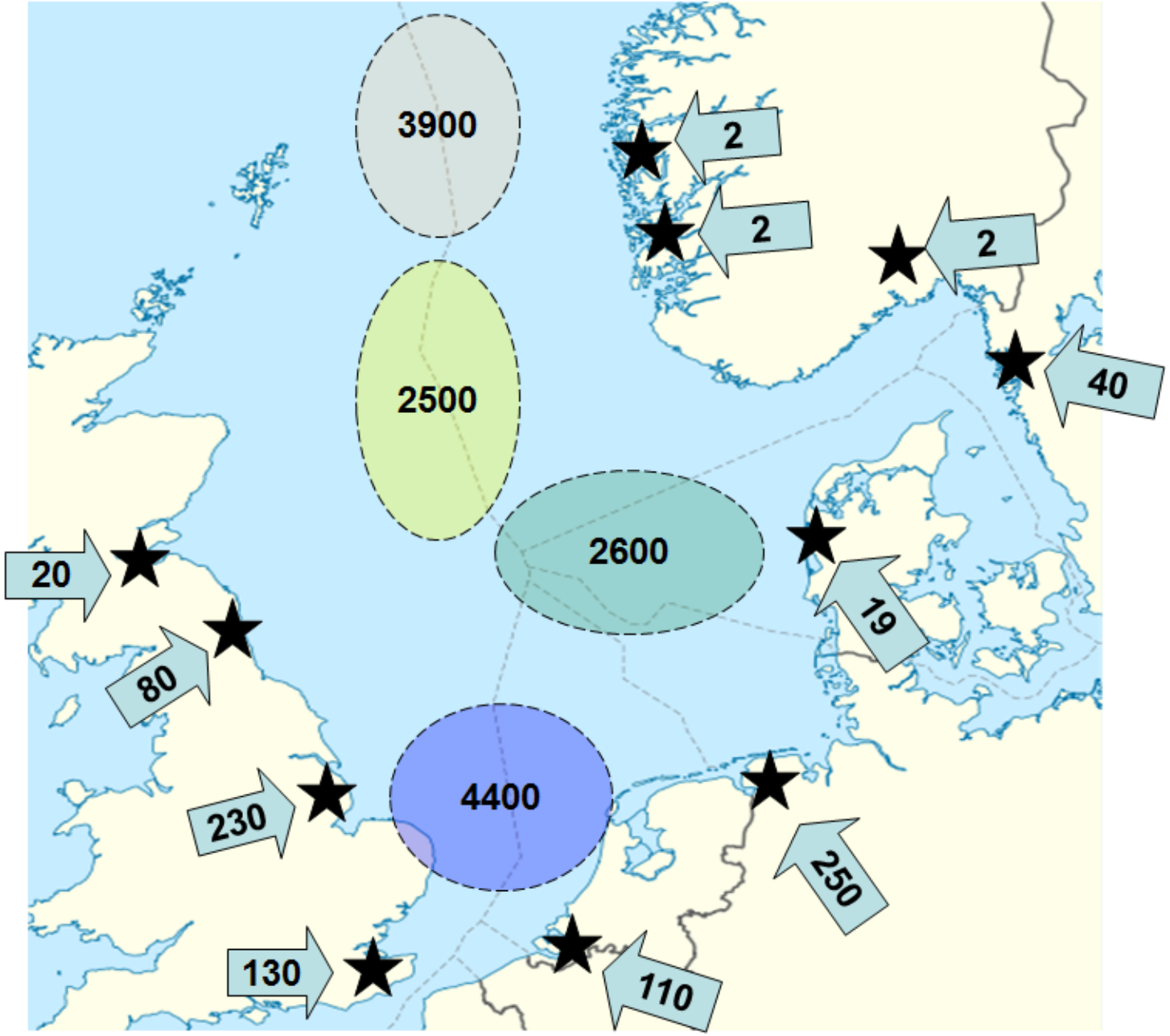
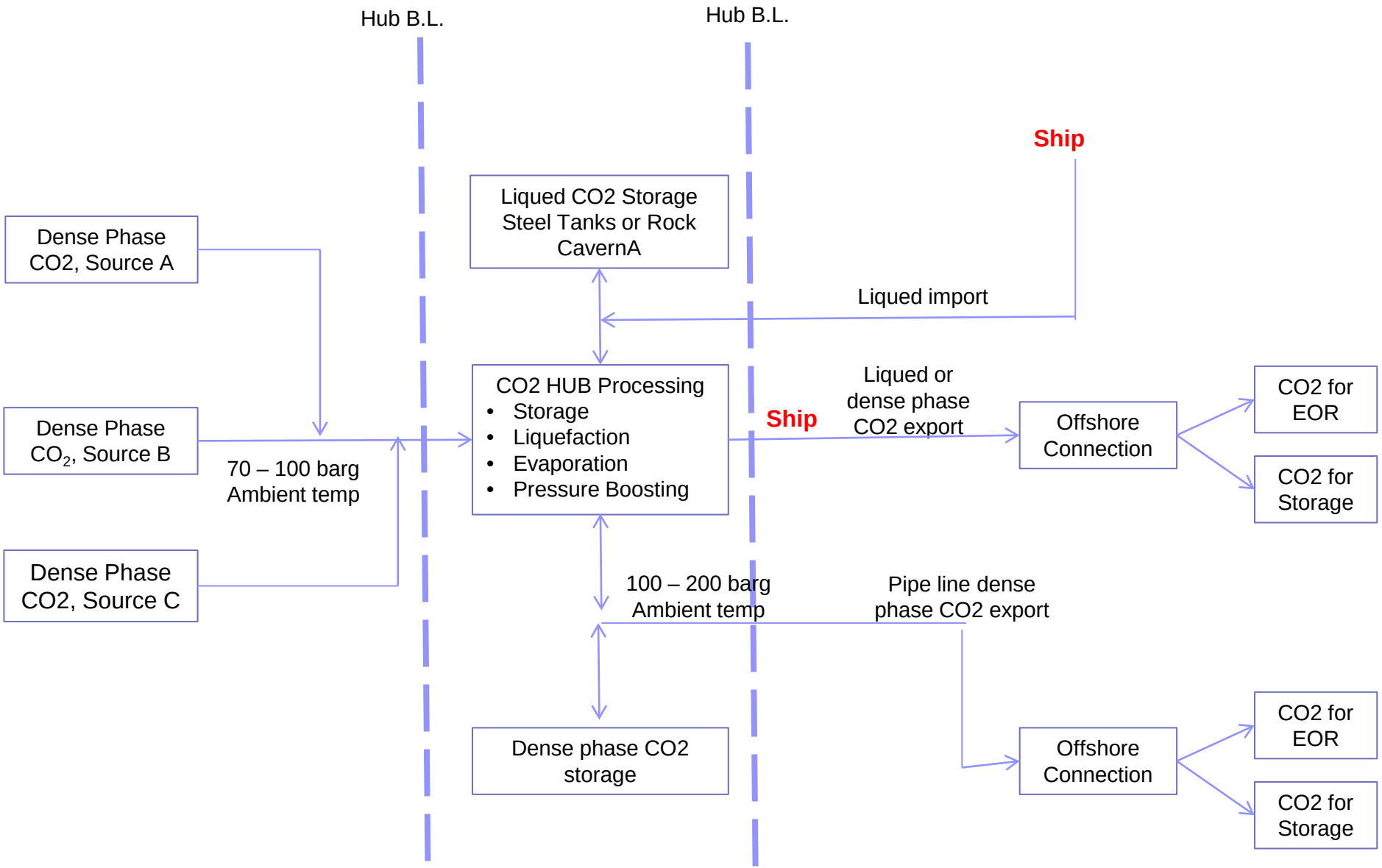
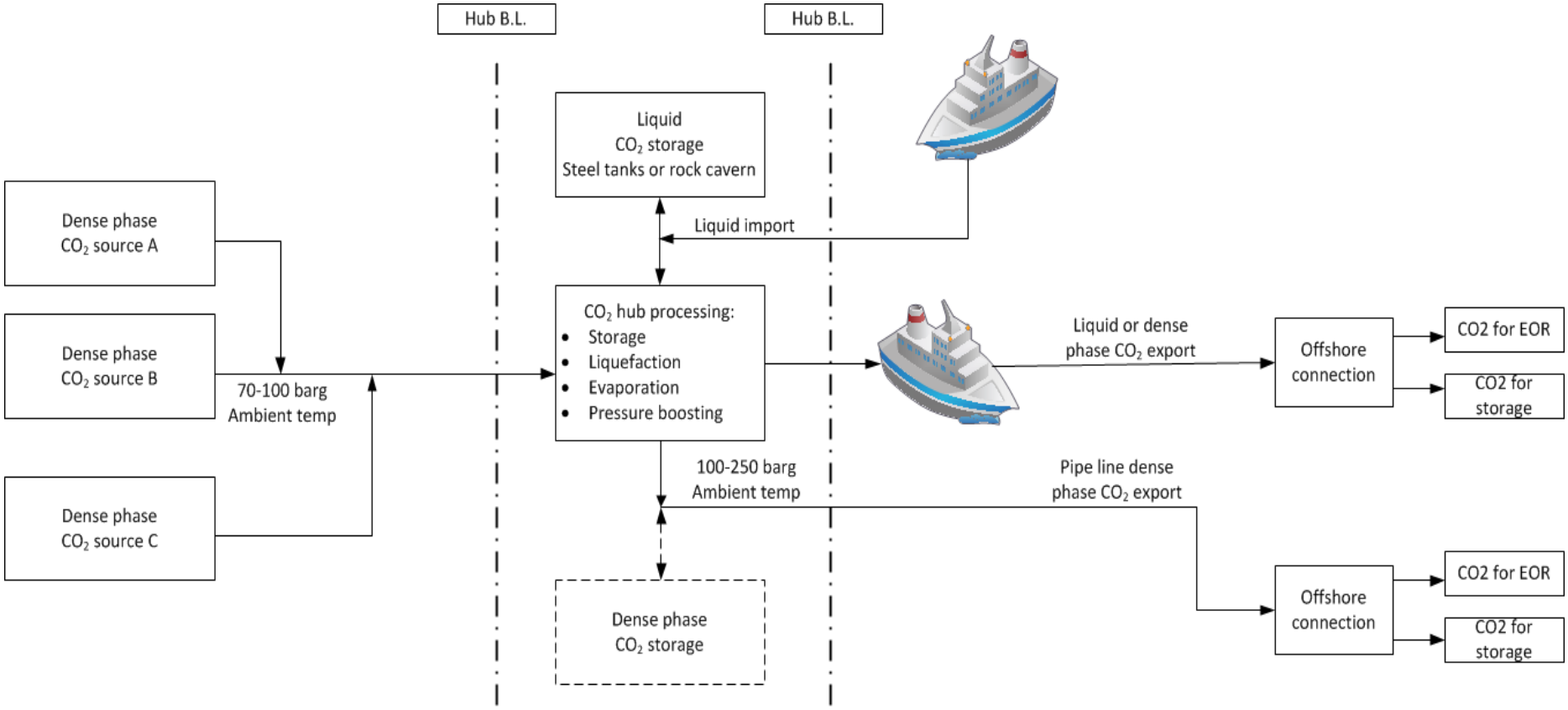
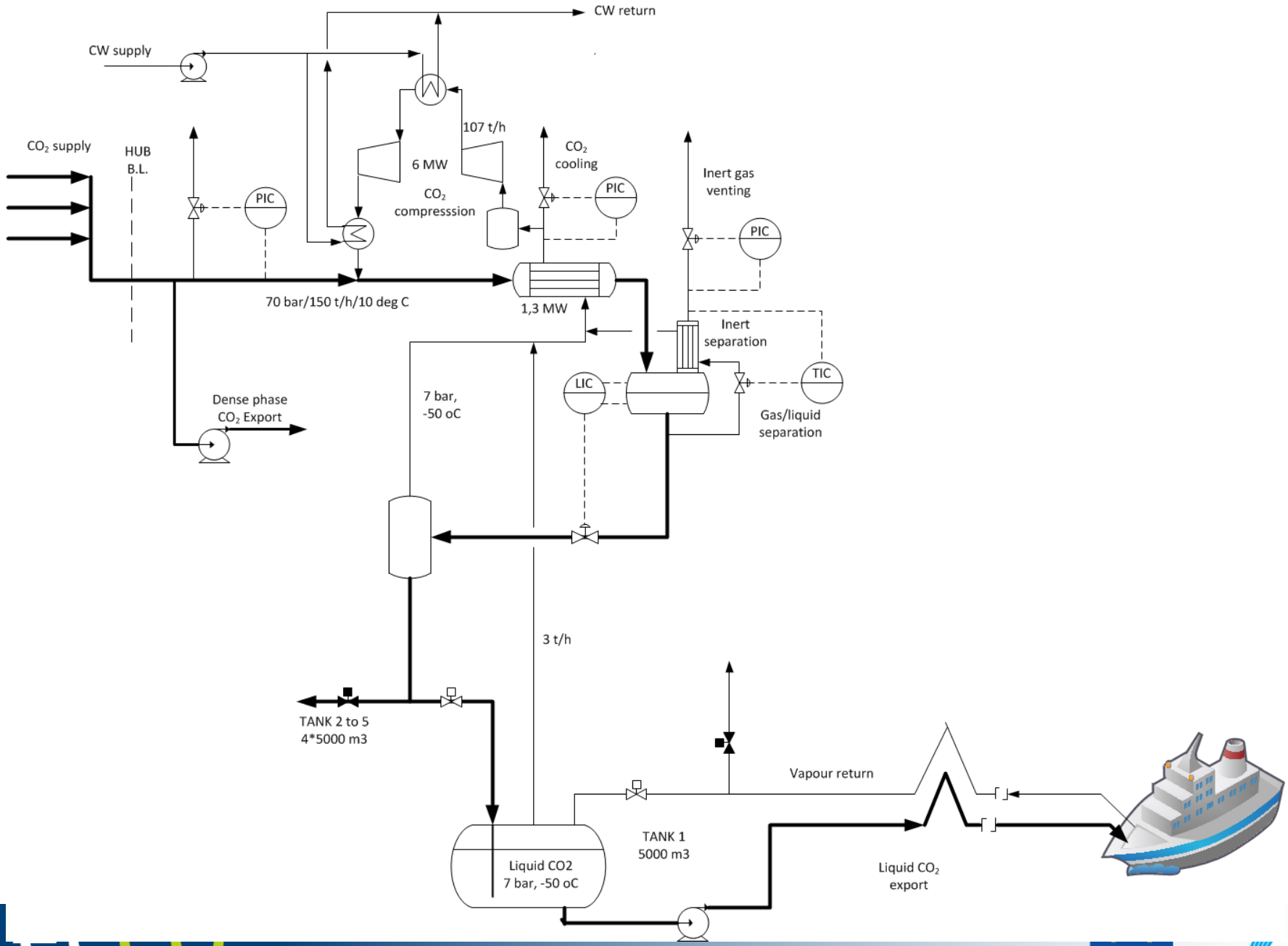

300
250
200
150
100
50
0
France
UK South
UK Humb
UK Tees
UK Scot
Belgium
Netherlands
Germany N
Denmark
Norway
Baltic

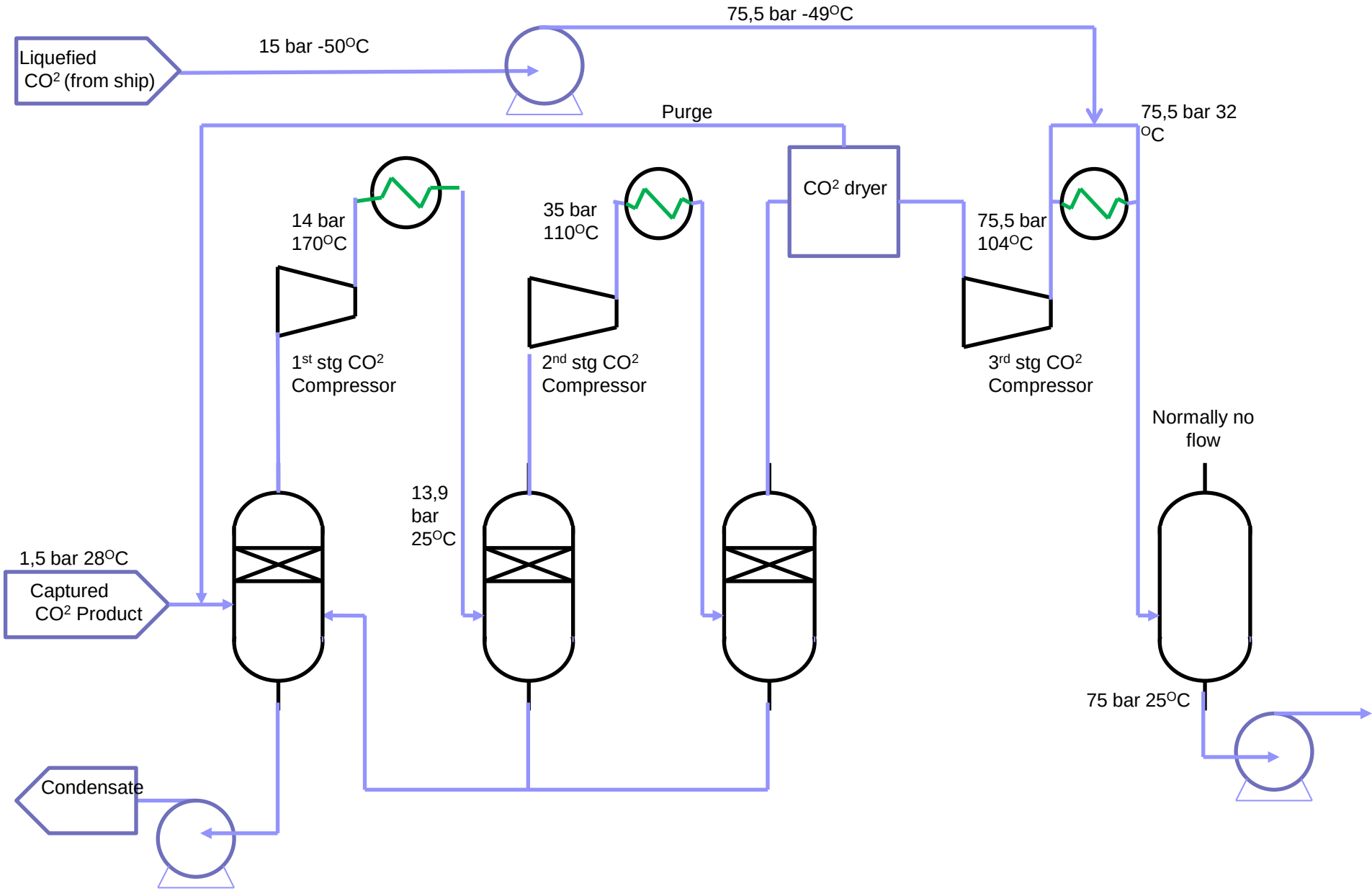

3900
2500
2600
4400
2
2
2
40
20
80
19
230
250
130
110


Hub B.L.
Hub B.L.
Ship
Liqued CO2 Storage
Steel Tanks or Rock
CavernA
Dense Phase
CO2, Source A
Liqued import
CO2 HUB Processing
• Storage
• Liquefaction
• Evaporation
• Pressure Boosting
Ship
Liqued or
dense phase
CO2 export
Offshore
Connection
CO2 for
EOR
CO2 for
Storage
Dense Phase
CO_2, Source B
70 – 100 barg
Ambient temp
Dense Phase
CO2, Source C
100 – 200 barg
Ambient temp
Pipe line dense
phase CO2 export
Dense phase CO2
storage
Offshore
Connection
CO2 for
EOR
CO2 for
Storage

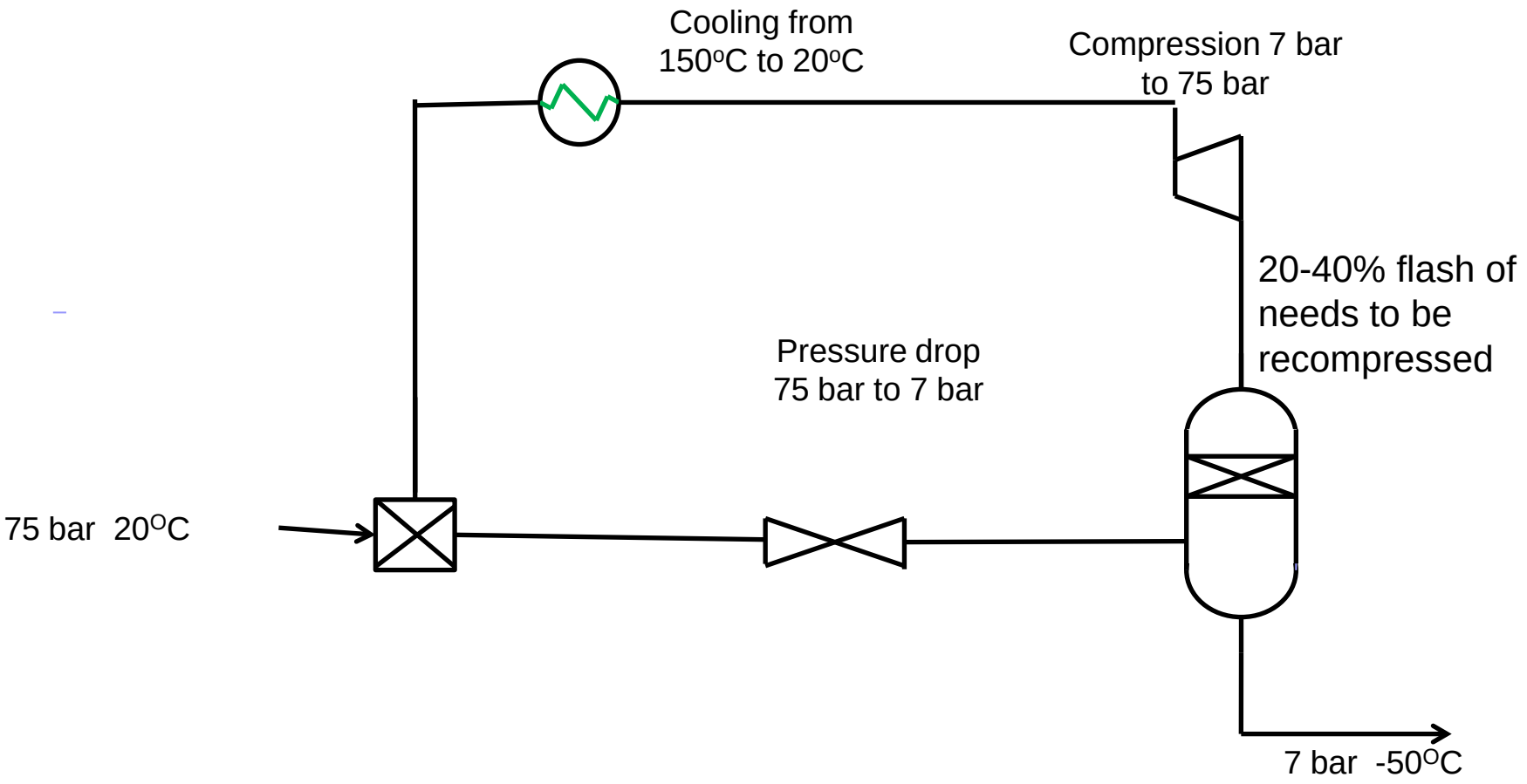

Hub B.L.
Hub B.L.
Liquid
CO_2 storage
Steel tanks or rock cavern
Liquid import
Dense phase
CO_2 source A
Dense phase
CO_2 source B
Dense phase
CO_2 source C
70-100 barg
Ambient temp
CO_2 hub processing:
Storage
Liquefaction
Evaporation
Pressure boosting
Liquid or dense
phase CO_2 export
Offshore
connection
CO2 for EOR
CO2 for
storage
100-250 barg
Ambient temp
Pipe line dense
phase CO_2 export
Dense phase
CO_2 storage
Offshore
connection
CO2 for EOR
CO2 for
storage

Export of	Typical capacity	Pump required	Pump condition	CO2 density	CO2 purity	H2O ppm v
Dense phase CO2 to aquifer	5 Mt/year supply capacity	Yes	100 - 200 bar outlet pump	900 kg/m3		<500
Dense phase CO2 for EOR	Reservoir dependant	Yes	100- 250 bar outlet pump	900 kg/m3	Statoil rec below	<50
Dense phase CO2 to ship	2 Mt/year	Yes	Max 70 bar outlet pump	900 kg/m3		<50* or <500**
Liqued CO2 to ship	Pump capacity max 1000 t/h	Yes	7 bara/ -50 degree C at pump section	1100 kg/m3	>99 vol%	<50




Liquefied
CO2 (from ship)
15 bar -50OC
75,5 bar -49OC
Purge
75,5 bar 32
OC
CO2 dryer
14 bar
170OC
35 bar
110OC
75,5 bar
104OC
1st stg CO2
Compressor
2nd stg CO2
Compressor
3rd stg CO2
Compressor
Normally no
flow
13,9
bar
25OC
1,5 bar 28OC
Captured
CO2 Product
75 bar 25OC
Condensate

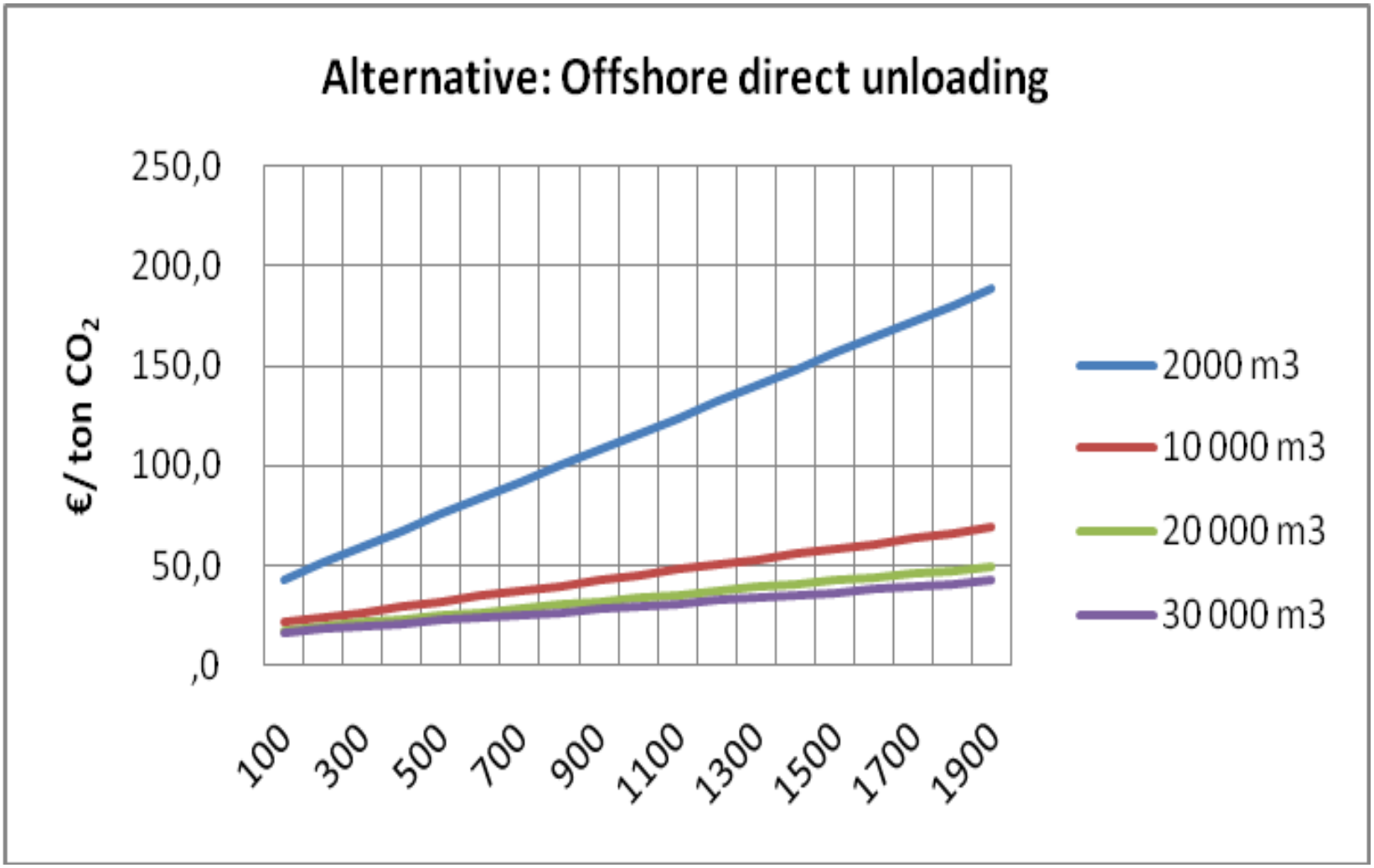
Liquefaction

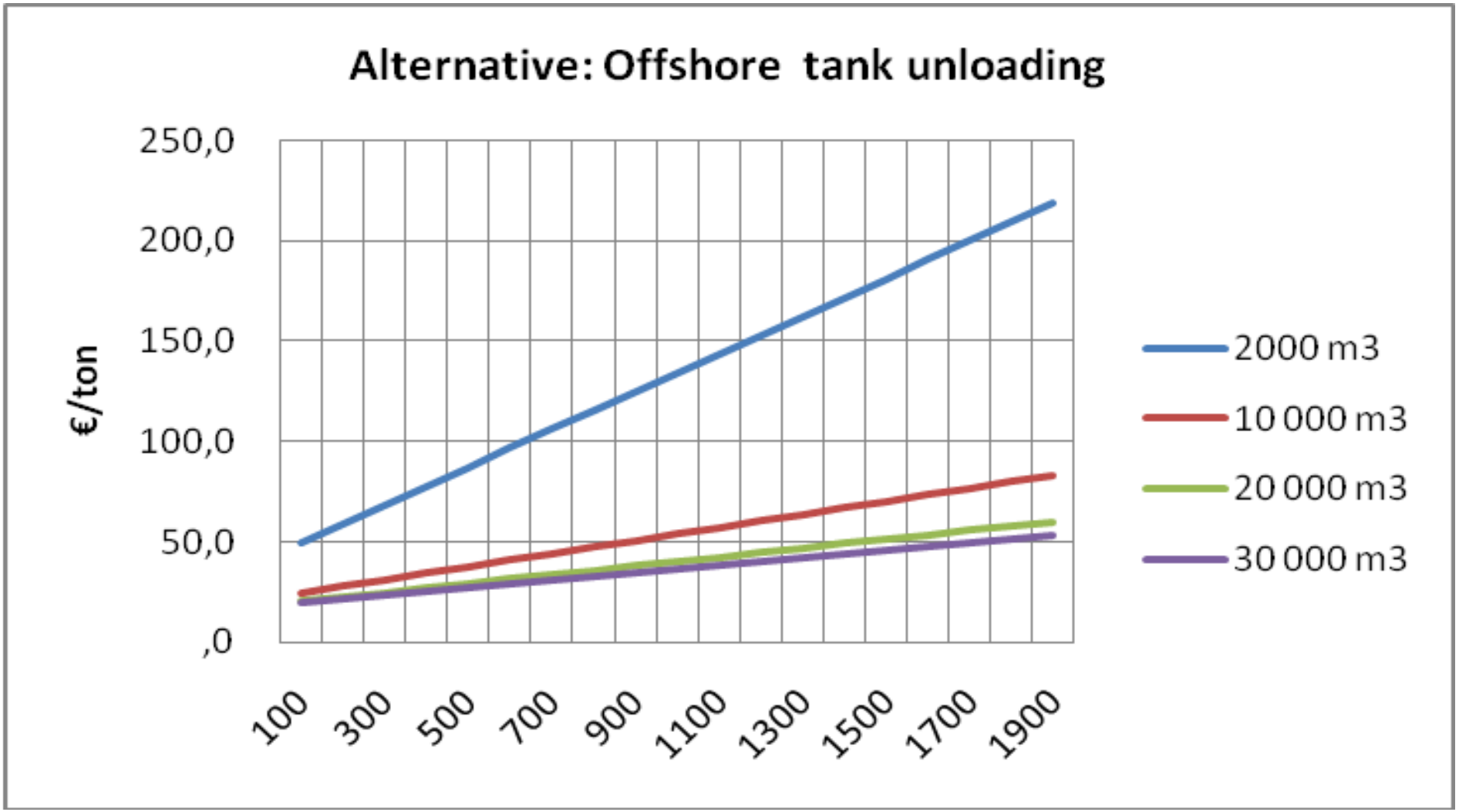


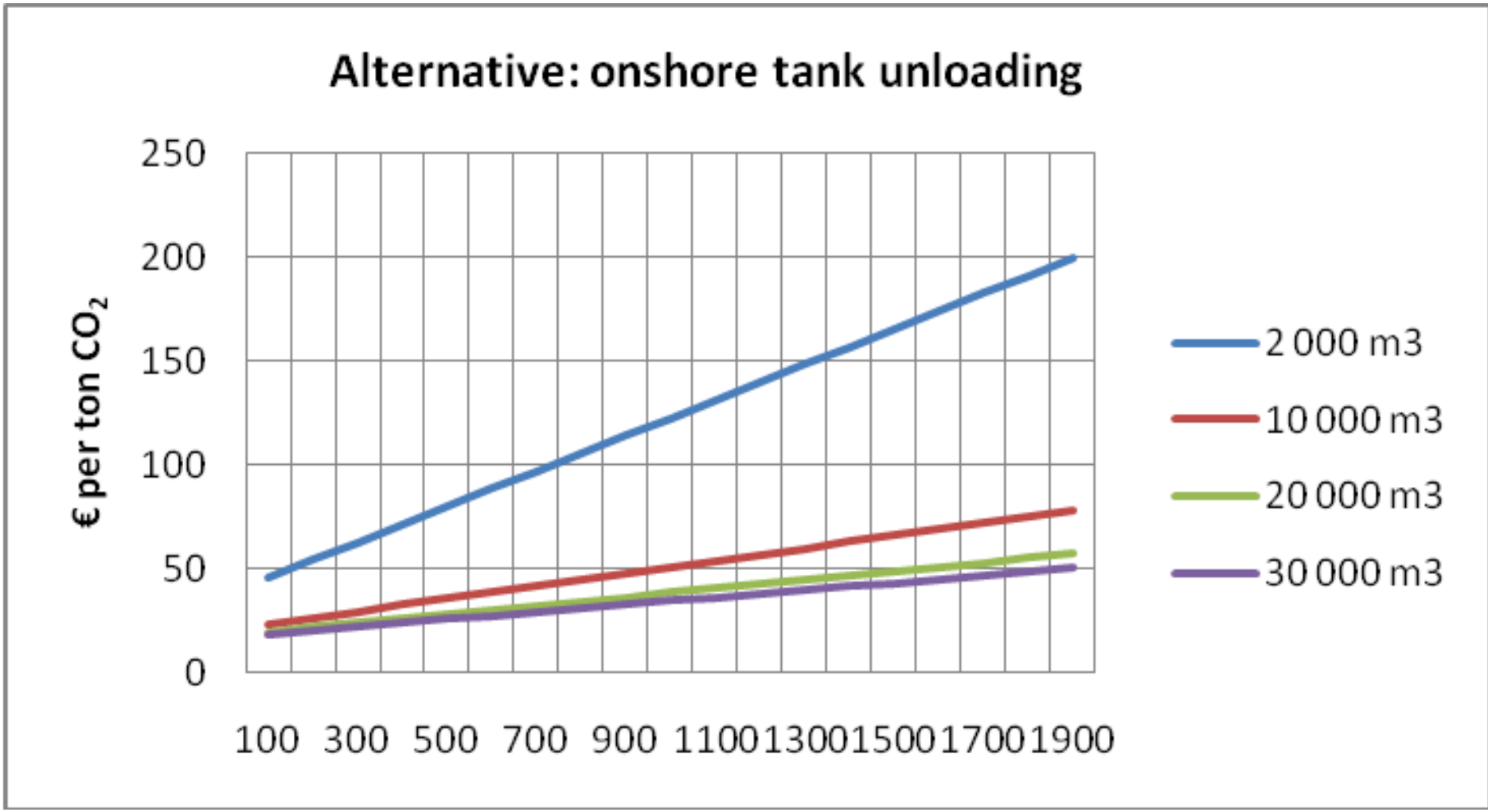
Transport to hub and liquefaction					
Transport method	*Ship*	*Barges*	*Ship*	*Barges*	Pipe line
CO_2 condition	Refrigerated liquid CO_2	Refrigerated liquid CO_2	Dense phase	Dense phase	Dense phase
Drying requirement, ppm vol% (mol%) H_2O	50	50	<50 or <500	<50 or <500	<50 or <500
Liquefaction installation	R	R	NR	NR	NR
Purge gas treatment	R	R	NR	NR	NR
Flash gas recompression	Compressor	Compressor	NR	NR	NR
On shore intermediate storage tanks	1,5 * ship or lower	NR Storage in barge	1,5 * ship or lower	NR Storage in barge	NR
Loading equipment	High capacity pumps	Pumps	High capacity pumps	NR	Booster pump
Equipment for transport connection	Loading arm / Hose conn.	Loading arm / Hose conn.	Loading arm / Hose conn.	Loading arm / Hose conn.	NR
Transport from hub to discharge spot					
Unloading connection	Loading arm / Hose conn.	Loading arm / Hose conn.	Loading arm / Hose conn.	Loading arm / Hose conn.	NR
Unloading equipment	High capacity pumps	Low capacity Pumps	High capacity pumps	NR	NR
On shore intermediate storage tanks	1.5*ship or lower	NR Storage in barge	1.5 * ship or lower	NR Storage in barge	NR
Heating installation	For prod. rate	For prod. rate	NR	NR	NR
Injection equipment permanent storage	High pressure pumps	High pressure Pumps	High pressure pumps	High pressure Pumps	NR
R = Required					
NR = Not Required					

European value chain for CO_2
CO-FUNDED BY THE EUROPEAN UNION
SEVENTH FRAMEWORK PROGRAMME

CO_2 liquefaction (ton/h) (m^3)	115 (100)	230 (200)	345 (300)	460 (400)	575 (500)	690 (600)
Plant investments (mill €)	55,7	81,5	101,8	119,3	134,9	149,1
Maintenance (mill €/y)	2,2	3,3	4,1	4,8	5,4	6,0
El power (mill €/y)	4,9	9,7	14,6	19,4	24,3	29,1
Operators (mill €/y)	2,5	2,5	2,5	2,5	2,5	2,5
OPEX (mill €/y)	**9,6**	**15,5**	**21,1**	**26,7**	**32,2**	**37,6**


Alternative: Offshore direct unloading
€/ ton CO2
250,0
200,0
150,0
100,0
50,0
,0
100
300
500
700
900
1100
1300
1500
1700
1900
2000 m3
10 000 m3
20 000 m3
30 000 m3


Alternative: Offshore tank unloading
€/ton
250,0
200,0
150,0
100,0
50,0
,0
100
300
500
700
900
1100
1300
1500
1700
1900
2000 m3
10 000 m3
20 000 m3
30 000 m3

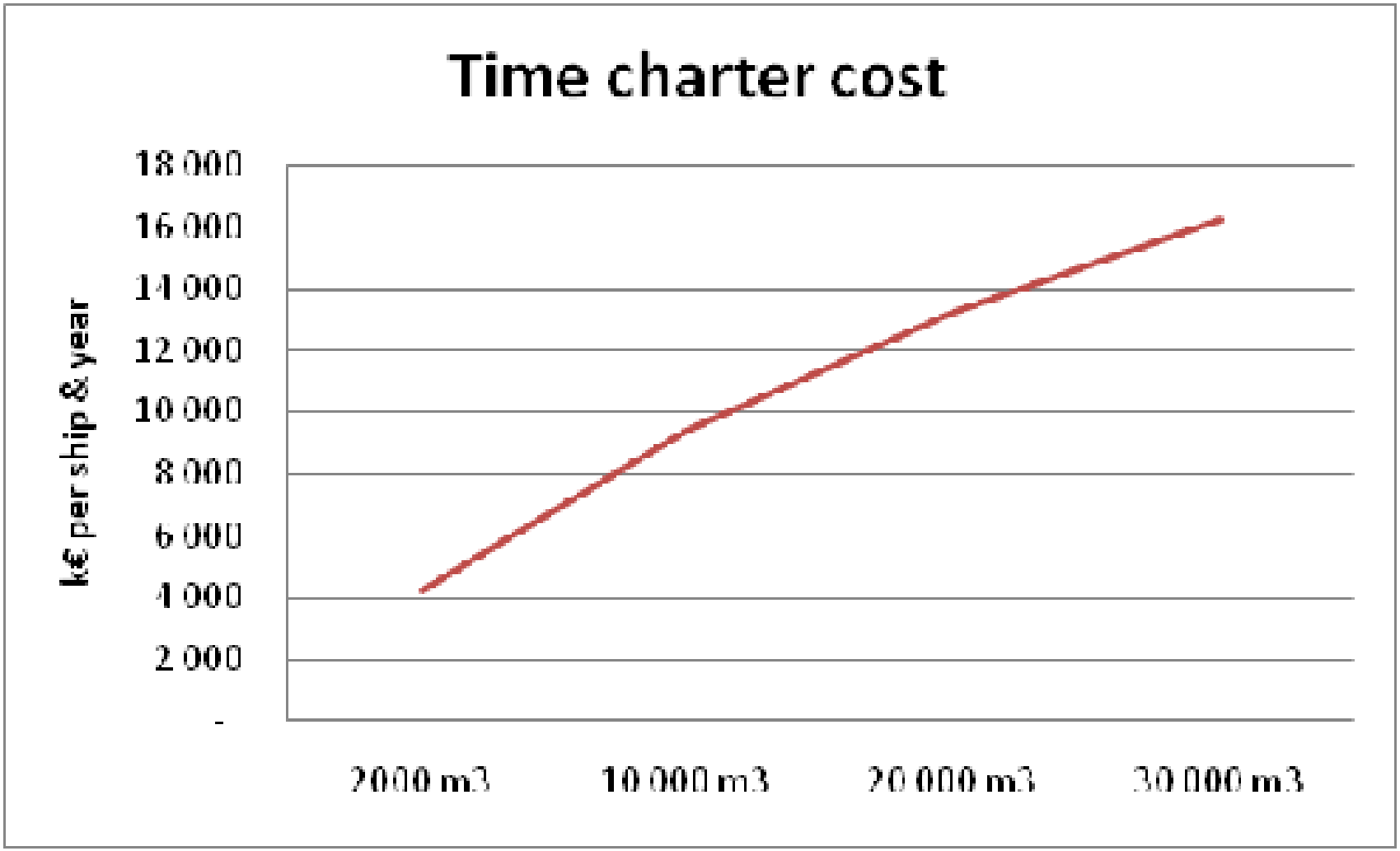

Alternative: onshore tank unloading
€ per ton CO_2
250
200
150
100
50
0
100 300 500 700 900 1100 1300 1500 1700 1900
2 000 m3
10 000 m3
20 000 m3
30 000 m3

Transport capacity per ship per year (kt CO_2)

Ship size (m^3)	2 000	10 000	20 000	30 000
Distance (km)				
100	472	2 402	4 879	7 419
200	383	1 974	4 050	6 216
300	323	1 675	3 462	5 349
400	279	1 455	3 024	4 694
500	245	1 286	2 683	4 182
600	219	1 152	2 412	3 771
700	198	1 044	2 191	3 433
800	180	954	2 006	3 151
900	166	878	1 851	2 912
1000	153	814	1 717	2 706
1100	143	758	1 602	2 528
1200	133	709	1 501	2 371
1300	125	667	1 412	2 233
1400	118	629	1 333	2 110
1500	112	595	1 263	2 000
1600	106	565	1 199	1 901
1700	101	537	1 142	1 811
1800	96	512	1 090	1 729
1900	92	490	1 042	1 655

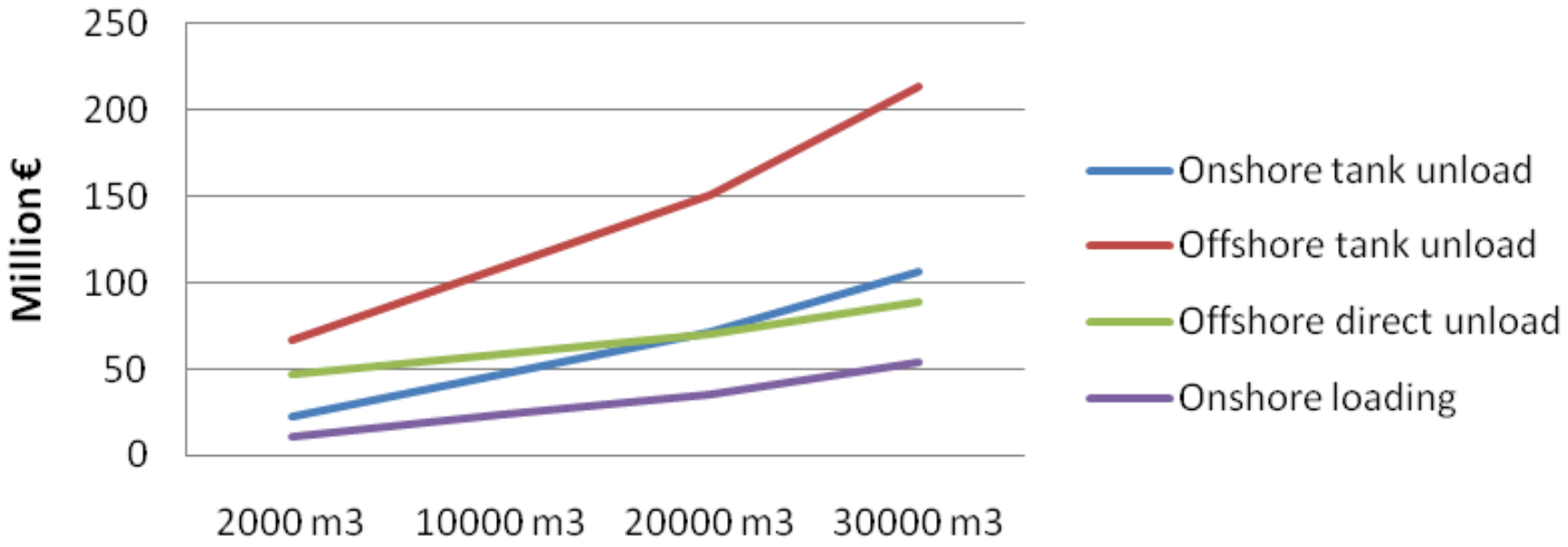
Ship transport input data.

Ship size (m^3)	2 000	10 000	20 000	30 000
Timecharter ship (k€/an)	**4 196**	**9 382**	**13 268**	**16 249**
Speed knots	12	13	14	15
Speed km/hr	22	24	26	28
In-Port time (hours)	***30***	***30***	***30***	***30***
Port maneuvering, loading (hrs)	5	5	5	5
Loading, duration (hrs)	10	10	10	10
Maneuvering, unloading (hrs)	5	5	5	5
Unloading, duration (hrs)	10	10	10	10


Time charter cost
k€ per ship & year
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2 000
-
2000 m3
10 000 m3
20 000 m3
30 000 m3

Investment alternatives

loading and unloading



CONCLUSIONS

- The CO_2 emitted from the countries around the North Sea may supply the need for EOR if captured.
- The transport of these quantities, several hundred million tonnes per year, will require major installations and a large number of hubs with tailor-made specifications.
- The information on CO_2 sources given in chapter 2, specifically figure 2.2, show a great span both in quantities and distances, making it obvious that hubs must be tailor made.
- The complexity of a hub itself, and also its costs, will increase drastically if ship transport of liquid CO_2 is introduced, since then both liquefaction plant and storage volumes, steel pressure tanks or rock cavern, will be required.

CONCLUSIONS

- A hub for handling of dense phase CO_2 in pipelines only will be relatively simple and cheap. The transport cost will then mainly be linked to pipeline installations.
- A hub requiring ship transport for import and/ or export of CO_2 is significantly more complex and will require installations for liquefaction, intermediate storage capacities and loading/ unloading facilities.

- Some unit sizes based on proven technology are limited requiring parallel units, see chapter 5.

Estimation of costs - elements