Extra scenario with three versus four E-ferries for the total ferry service of Aeroe

Content:

1 Purpose of extra scenario

The purpose of this extra scenario is to evaluate the expected cost and income difference between operation with four small E-ferries versus operation with three bigger E-ferries investment costs included.

1.1 Methodology

An alternative with three large E-ferries will affect almost every operational and economic parameter of the case study. Therefore calculations in this annex are subject to higher uncertainties than for the three base scenarios made in the main analysis as many assumptions have to be made, e.g. when it comes to energy consumption of the larger ferry size for which no CFD calculations have been prepared.

New building prices are also subject to uncertainties as no indication price exists for the larger ferry design. Estimates are based on roughly made corrections to steel weights and requirements for extra equipment etc.

For changes to energy efficiency and operating cost these issues are discussed in brief analyses describing most important assumptions and impacts in the following chapters.

The same goes for the impacts to transport qualities affecting demand. For example will the total number of departures with three E-ferries only be marginally higher than now wherefore extra demand scenarios must be adjusted down.

Finally the found impacts to investment cost, operating cost and revenues will be summarised in order to evaluate the overall pros and cons and indicate if there is an economies of scale effect of choosing larger E-ferries for the total ferry service of Aeroe at present technological stage.

2 Energy efficiency and capacity

Energy efficiency of a longer vessel is better measured as deadweight to energy needed ratio. Capacity utilisation however will change. The flexibility of tonnage is less with three than with four ferries. Cuts have to be made in the departure plan.

In peak season average load factor of only three ferries will become higher but in off season it will be dramatically lower if a sufficient number of departures should be still obtained during the working day.

Thus average load factor and energy efficiency ratio per transported unit is expected to be reduced some in total due to a higher number of "half empty" departures in the total sailing schedule.

Energy consumption per trip is estimated to increase around 15 % due to the higher weight of ship and cargo despite a better deadweight to energy needed ratio. This is also caused by an expected increase in frequency of delays due to the higher number of cars per port call that entering and leaving the ferry. Two minutes shorter time for transit will increase energy consumption per trip around 25 %.

Initial capacity analysis for a three E-ferry scenario based on routes similar to case study's scenario 1 and 2 indicates a need to extent the E-ferry base design with around 12 meters allowing for 6 extra PCU on each but also allowing larger passenger numbers.

The extended design could be added suspended car decks with little impact to energy consumption at service speed but the suspended car decks are problematic if hourly service should be obtained for scenario 1 and 2 where time in port becomes critical short and delays will be expensive. Therefore a PCU capacity of only 31 vehicles has been used in the following calculations.

3-hour peak capacity		Three E-ferries		
	Today	Scenario 1	Scenario 2	Scenario 3
Ærøskøbing-Svendborg	168			149
Ærøskøbing-Rantzausminde	-	186		
Marstal-Rudkøbing	-		186	
Søby-Fynshav	32	46.5	46.5	46.5
Søby-Fåborg	38	46.5	46.5	46.5
PCU capacity	238	279	279	242
	Change:	17%	17%	1%

3-hour peak capacity		Four E-ferries		
	Today	Scenrio 1	Scenario 2	Scenario 3
Ærøskøbing-Svendborg	168			134
Ærøskøbing-Rantzausminde	-	168		
Marstal-Rudkøbing	-		168	
Søby-Fynshav	32	84	84	84
Søby-Fåborg	38	84	84	84
PCU capacity	238	336	336	302
	Change:	41%	41%	27%

Table 2.1 Peak capacity comparison of case study with three and four E-ferries. In base scenarios a capacity of 2x25 PCU and 2x28 PCU was chosen. For the extra scenario a capacity of 3x31 PCU is chosen.

Although total annual PCU capacity is increased by the three larger E-ferries, peak capacity with four smaller E-ferries is still better. Also departure flexibility (frequency) is higher with four E-ferries of course. Even if some capacity is out in the winter season – annual number of departures is higher with four E-ferries.

Annual Trips total			
	Today	4xE-Ferries	3xE-Ferries
Ærøsk.-Fyn	3602	4630	4630
Søby-Fynshav	1000	1882	1400
Søby-Fåborg	913	1671	1132
	5515	8183	7162
		48%	30%

Table 2.2 Total number of roundtrips according to the case scenarios analysed.

Using only three E-ferries of 31 PCU does not provide sufficient extra capacity for scenario 3 thus suspended car decks are needed. This can be managed if E-ferries are charged in Svendborg also. This is already suggested in the base scenario for the Svendborg route.

Added capacity from a three E-ferry setup with 31 PCU in scenario 1 and 2 could be sufficient if demand does not increase significantly in coming years. The extra peak capacity of 17 %, compared to now according to *Table 2.1*, will most likely be enough to absorb present lack of supply in summer season. But if improvement in transit time and hourly service on the central routes results in demand increases there is no possibility of adding extra capacity to the scenarios with three E-ferries.

The principle time-tables used for the extra scenario with three E-ferries can be found in chapter 4.

3 Time-tables for three E-ferry service

3.1 Scenario 1 and 2 with three E-ferries

Schedule of principle Scenario 1 & 2
Peak Season (13 weeks) Monday to Friday

Ferry A	Sailing time approx. 50 minutes							
Dep. Aeroe	0530	0730	0930	1230	1430	1630	1930	
Arr. Fyn	0620	0820	1020	1320	1520	1720	2020	
Dep. Fyn	0625	0825	1025	1325	1525	1725	2025	
Arr. Aeroe	0715	0915	1115	1415	1615	1815	2115	

Short crew watch

Crew

Crew

Ferry B	Sailing time approx. 50 minutes							
Dep. Aeroe	0630	0830	1030	1330	1530	1730	2130	
Arr. Fyn	0720	0920	1120	1420	1620	1820	2220	
Dep. Fyn	0725	0925	1125	1425	1625	1825	2225	
Arr. Aeroe	0815	1015	1215	1515	1715	1915	2315	

Ferry C	Sailing time approx. 50 minutes							
Dep. Soeby		0700		1115	1530		1730	
Arr. Als		0750		1205	1620		1820	
Dep. Als		0755		1210	1625		1825	
Arr. Soeby		0845		1300	1715		1915	

Ferry C	Sailing time approx. 50 minutes							
Dep. Soeby	0500	0900		1315			2030	
Arr. Faaborg	0550	0950		1405			2120	
Dep. Als	0555	0955		1410			2125	
Arr. Soeby	0645	1045		1500			2215	

Schedule of principle Scenario 1 & 2
Peak Season (13 weeks) Saturday and Sunday

Ferry A	Sailing time approx. 50 minutes							
Dep. Aeroe		0730	0930	1230	1430	1630	1930	
Arr. Fyn		0820	1020	1320	1520	1720	2020	
Dep. Fyn		0825	1025	1325	1525	1725	2025	
Arr. Aeroe		0915	1115	1415	1615	1815	2115	
		Short crew watch		Crew			Crew	
Ferry B	Sailing time approx. 50 minutes							
Dep. Aeroe	0630	0830	1030	1330	1530	1730		2130
Arr. Fyn	0720	0920	1120	1420	1620	1820		2220
Dep. Fyn	0725	0925	1125	1425	1625	1825		2225
Arr. Aeroe	0815	1015	1215	1515	1715	1915		2315

Ferry C	Sailing time approx. 50 minutes							
Dep. Soeby		0700		1115		1530	1730	
Arr. Als		0750		1205		1620	1820	
Dep. Als		0755		1210		1625	1825	
Arr. Soeby		0845		1300		1715	1915	

Ferry C	Sailing time approx. 50 minutes							
Dep. Soeby			0900		1315			2030
Arr. Faaborg			0950		1405			2120
Dep. Als			0955		1410			2125
Arr. Soeby			1045		1500			2215

Schedule of principle Scenario 1 & 2
Shoulder Season (13 weeks) Monday to Friday

Ferry A	Sailing time approx. 50 minutes							
Dep. Aeroe	0530	0730	0930	1230	1430	1630	1930	
Arr. Fyn	0620	0820	1020	1320	1520	1720	2020	
Dep. Fyn	0625	0825	1025	1325	1525	1725	2025	
Arr. Aeroe	0715	0915	1115	1415	1615	1815	2115	

Short crew watch

Crew

Crew

Ferry B	Sailing time approx. 50 minutes						
Dep. Aeroe	0630	0830	1030	1330	1530	1730	2130
Arr. Fyn	0720	0920	1120	1420	1620	1820	2220
Dep. Fyn	0725	0925	1125	1425	1625	1825	2225
Arr. Aeroe	0815	1015	1215	1515	1715	1915	2315

Ferry C	Sailing time approx. 50 minutes				
Dep. Soeby	0700	1115	1530	1730	
Arr. Als	0750	1205	1620	1820	
Dep. Als	0755	1210	1625	1825	
Arr. Soeby	0845	1300	1715	1915	

Ferry C	Sailing time approx. 50 minutes			
Dep. Soeby	0500	0900	1315	2030
Arr. Faaborg	0550	0950	1405	2120
Dep. Als	0555	0955	1410	2125
Arr. Soeby	0645	1045	1500	2215

Schedule of principle Scenario Rantzausminde and Rudkoebing
Shoulder Season (13 weeks) Saturday and Sunday

Ferry A	Sailing time approx. 50 minutes							
Dep. Aeroe		0730	0930	1230	1430	1630	1930	
Arr. Fyn		0820	1020	1320	1520	1720	2020	
Dep. Fyn		0825	1025	1325	1525	1725	2025	
Arr. Aeroe		0915	1115	1415	1615	1815	2115	
		Short crew watch		Crew			Crew	
Ferry B	Sailing time approx. 50 minutes							
Dep. Aeroe	0630	0830	1030		1530	1730		2130
Arr. Fyn	0720	0920	1120		1620	1820		2220
Dep. Fyn	0725	0925	1125		1625	1825		2225
Arr. Aeroe	0815	1015	1215		1715	1915		2315

Ferry C	Sailing time approx. 50 minutes							
Dep. Soeby		0700		1115		1530	1730	
Arr. Als		0750		1205		1620	1820	
Dep. Als		0755		1210		1625	1825	
Arr. Soeby		0845		1300		1715	1915	

Ferry C	Sailing time approx. 50 minutes							
Dep. Soeby			0900		1315			2030
Arr. Faaborg			0950		1405			2120
Dep. Als			0955		1410			2125
Arr. Soeby			1045		1500			2215

Schedule of principle Scenario 1 & 2
Off Season (26 weeks) Monday to Friday (Each ferry docking 7-10 days)

Ferry A	Sailing time approx. 50 minutes							
Dep. Aeroe	0530	0730	0930	1230	1430	1630	1930	
Arr. Fyn	0620	0820	1020	1320	1520	1720	2020	
Dep. Fyn	0625	0825	1025	1325	1525	1725	2025	
Arr. Aeroe	0715	0915	1115	1415	1615	1815	2115	

Short crew watch

Crew

Crew

Ferry B	Sailing time approx. 50 minutes							
Dep. Aeroe	0630	0830	1030	1330	1530	1730	2130	
Arr. Fyn	0720	0920	1120	1420	1620	1820	2220	
Dep. Fyn	0725	0925	1125	1425	1625	1825	2225	
Arr. Aeroe	0815	1015	1215	1515	1715	1915	2315	

Ferry C	Sailing time approx. 50 minutes							
Dep. Soeby		0700		1115	1530		1730	
Arr. Als		0750		1205	1620		1820	
Dep. Als		0755		1210	1625		1825	
Arr. Soeby		0845		1300	1715		1915	

Ferry C	Sailing time approx. 50 minutes							
Dep. Soeby	0500		0900		1315			
Arr. Faaborg	0550		0950		1405			
Dep. Als	0555		0955		1410			
Arr. Soeby	0645		1045		1500			

Schedule of principle Scenario 1 & 2
Off Season (26 weeks) Saturday and Sunday (Each ferry docking 7-10 days)

Ferry A	Sailing time approx. 50 minutes							
Dep. Aeroe				1230	1430	1630	1930	
Arr. Fyn				1320	1520	1720	2020	
Dep. Fyn				1325	1525	1725	2025	
Arr. Aeroe				1415	1615	1815	2115	
	Short crew watch			Crew			Crew	
Ferry B	**Sailing time approx. 50 minutes**							
Dep. Aeroe	0630	0830	1030		1530	1730		2130
Arr. Fyn	0720	0920	1120		1620	1820		2220
Dep. Fyn	0725	0925	1125		1625	1825		2225
Arr. Aeroe	0815	1015	1215		1715	1915		2315

Ferry C	Sailing time approx. 50 minutes						
Dep. Soeby	0700			1115	1530	1730	
Arr. Als	0750			1205	1620	1820	
Dep. Als	0755			1210	1625	1825	
Arr. Soeby	0845			1300	1715	1915	

Ferry C	Sailing time approx. 50 minutes						
Dep. Soeby		0900			1315		
Arr. Faaborg		0950			1405		
Dep. Als		0955			1410		
Arr. Soeby		1045			1500		

3.2 Scenario 1 and 2 roundtrips and capacity with three E-ferries

Capacity comparison, Scenario 1 & 2
3x31 PCU E-ferries

Daily double trips

Peak season 13 weeks

	Monday-Friday		Saturday		Sunday		Trips	
	Today	E-ferries	Today	E-ferries	Today	E-ferries	Today	E-ferries
Ærøsk.-Fyn	11 *	14	10	13	10	13	975	1248
Søby-Fynshav	3	4	3	4	2	4	260	364
Søby-Fåborg	3	4	2	3	2	3	247	338
Total	17	22	15	20	14	20	1482	1950
PCU capacity	1152	1364	1104	1240	1104	1240	3360	3844

Shoulder season 13 weeks

	Monday-Friday		Saturday		Sunday		Trips	
	Today	E-ferries	Today	E-ferries	Today	E-ferries	Today	E-ferries
Ærøsk.-Fyn	11	14	8	12	8	12	923	1222
Søby-Fynshav	3	4	3	4	2	4	260	364
Søby-Fåborg	3	4	2	3	1	3	234	338
Total	17	22	13	19	11	19	1417	1924
PCU capacity	1152	1364	930	1178	870	1178	2952	3720

Off season 26 weeks (Docking 7-10 days)

	Monday-Friday		Saturday		Sunday		Trips	
	Today	E-ferries	Today	E-ferries	Today	E-ferries	Today	E-ferries
Ærøsk.-Fyn	11	14	8	10	8	10	1704	2160
Søby-Fynshav	3	4	3	4	2	4	480	672
Søby-Fåborg	3	3	2	2	1	2	432	456
Total	17	21	13	16	11	16	2616	3288
PCU capacity	1152	1302	930	992	870	992	2952	3286
								11%

*12 at thursdays and fridays

NB: Nominal capacity for M/F Skjoldnæs reduced to 33 PCU. All ferries loose 6 PCU if suspended car decks are blocked by trucks

3.3 Scenario 3 time-tables with three E-ferries

Schedule of principle Scenario 3 Ærøskøbing-Svendborg
Peak Season (13 weeks) Monday to Friday

Ferry A	Sailing time approx. 65 minutes							
Dep. Aeroe	0500	0730	1000	1330	1600	1830	2130
Arr. Fyn	0605	0835	1105	1435	1705	1935	2235
Dep. Fyn	0615	0845	1115	1445	1715	1945	2245
Arr. Aeroe	0720	0950	1220	1550	1820	2050	2350

Ferry B	Sailing time approx. 65 minutes						
Dep. Aeroe	0600	0830	1100	1430	1700	1930	
Arr. Fyn	0705	0935	1205	1535	1805	2035	
Dep. Fyn	0715	0945	1215	1545	1815	2045	
Arr. Aeroe	0820	1050	1320	1650	1920	2150	

Ferry C	Sailing time approx. 50 minutes					
Dep. Soeby	0700	1115	1530	1730
Arr. Als	0750	1205	1620	1820
Dep. Als	0755	1210	1625	1825
Arr. Soeby	0845	1300	1715	1915

Ferry C	Sailing time approx. 50 minutes				
Dep. Soeby	0500	0900	1315	2030
Arr. Faaborg	0550	0950	1405	2120
Dep. Als	0555	0955	1410	2125
Arr. Soeby	0645	1045	1500	2215

Schedule of principle Scenario 3 Ærøskøbing-Svendborg
Peak Season (13 weeks) Saturday and Sunday

Ferry A	Sailing time approx. 65 minutes							
Dep. Aeroe		0730	1000	1330	1600	1830	2130
Arr. Fyn		0835	1105	1435	1705	1935	2235
Dep. Fyn		0845	1115	1445	1715	1945	2245
Arr. Aeroe		0950	1220	1550	1820	2050	2350

Ferry B	Sailing time approx. 65 minutes						
Dep. Aeroe	0600	0830	1100	1430	1700	1930	
Arr. Fyn	0705	0935	1205	1535	1805	2035	
Dep. Fyn	0715	0945	1215	1545	1815	2045	
Arr. Aeroe	0820	1050	1320	1650	1920	2150	

Ferry C	Sailing time approx. 50 minutes				
Dep. Soeby	0700		1115	1530	1730
Arr. Als	0750		1205	1620	1820
Dep. Als	0755		1210	1625	1825
Arr. Soeby	0845		1300	1715	1915

Ferry C	Sailing time approx. 50 minutes			
Dep. Soeby		0900	1315	2030
Arr. Faaborg		0950	1405	2120
Dep. Als		0955	1410	2125
Arr. Soeby		1045	1500	2215

Schedule of principle Scenario 3 Ærøskøbing-Svendborg
Shoulder Season (13 weeks) Monday to Friday

Ferry A	Sailing time approx. 65 minutes							
Dep. Aeroe	0500	0730	1000	1330	1600	1830	2130
Arr. Fyn	0605	0835	1105	1435	1705	1935	2235
Dep. Fyn	0615	0845	1115	1445	1715	1945	2245
Arr. Aeroe	0720	0950	1220	1550	1820	2050	2350

Ferry B	Sailing time approx. 65 minutes					
Dep. Aeroe	0600	0830	1100	1430	1700	
Arr. Fyn	0705	0935	1205	1535	1805	
Dep. Fyn	0715	0945	1215	1545	1815	
Arr. Aeroe	0820	1050	1320	1650	1920	

Ferry C	Sailing time approx. 50 minutes				
Dep. Soeby	0700	1115	1530	1730
Arr. Als	0750	1205	1620	1820
Dep. Als	0755	1210	1625	1825
Arr. Soeby	0845	1300	1715	1915

Ferry C	Sailing time approx. 50 minutes			
Dep. Soeby	0500	0900	1315	2030
Arr. Faaborg	0550	0950	1405	2120
Dep. Als	0555	0955	1410	2125
Arr. Soeby	0645	1045	1500	2215

Schedule of principle Scenario 3 Ærøskøbing-Svendborg
Shoulder Season (13 weeks) Saturday and Sunday

Ferry A	Sailing time approx. 65 minutes							
Dep. Aeroe		0730	1000	1330	1600	1830	2130
Arr. Fyn		0835	1105	1435	1705	1935	2235
Dep. Fyn		0845	1115	1445	1715	1945	2245
Arr. Aeroe		0950	1220	1550	1820	2050	2350

Ferry B	Sailing time approx. 65 minutes					
Dep. Aeroe	0600	0830	1100	1430	1700	
Arr. Fyn	0705	0935	1205	1535	1805	
Dep. Fyn	0715	0945	1215	1545	1815	
Arr. Aeroe	0820	1050	1320	1650	1920	

Ferry C	Sailing time approx. 50 minutes				
Dep. Soeby	0700		1115	1530	1730
Arr. Als	0750		1205	1620	1820
Dep. Als	0755		1210	1625	1825
Arr. Soeby	0845		1300	1715	1915

Ferry C	Sailing time approx. 50 minutes			
Dep. Soeby	0900	1315		2030
Arr. Faaborg	0950	1405		2120
Dep. Als	0955	1410		2125
Arr. Soeby	1045	1500		2215

Schedule of principle Scenario 3 Ærøskøbing-Svendborg
Off Season (26 weeks) Monday to Friday (Each ferry 7-10 days of drydocking)

Ferry A	Sailing time approx. 65 minutes							
Dep. Aeroe	0500	0730	1000	1330	1600	1830	2130
Arr. Fyn	0605	0835	1105	1435	1705	1935	2235
Dep. Fyn	0615	0845	1115	1445	1715	1945	2245
Arr. Aeroe	0720	0950	1220	1550	1820	2050	2350

Ferry B	Sailing time approx. 65 minutes					
Dep. Aeroe	0600	0830	1100	1430	1700	
Arr. Fyn	0705	0935	1205	1535	1805	
Dep. Fyn	0715	0945	1215	1545	1815	
Arr. Aeroe	0820	1050	1320	1650	1920	

Ferry C	Sailing time approx. 50 minutes				
Dep. Soeby	0700	1115	1530	1730
Arr. Als	0750	1205	1620	1820
Dep. Als	0755	1210	1625	1825
Arr. Soeby	0845	1300	1715	1915

Ferry C	Sailing time approx. 50 minutes			
Dep. Soeby	0500	0900	1315	
Arr. Faaborg	0550	0950	1405	
Dep. Als	0555	0955	1410	
Arr. Soeby	0645	1045	1500	

Schedule of principle Scenario 3 Ærøskøbing-Svendborg
Off Season (26 weeks) Saturday and Sunday (Each ferry 7-10 days of drydocking)

Ferry A	Sailing time approx. 65 minutes							
Dep. Aeroe			1000	1330	1600	1830	2130	
Arr. Fyn			1105	1435	1705	1935	2235	
Dep. Fyn			1115	1445	1715	1945	2245	
Arr. Aeroe			1220	1550	1820	2050	2350	

Ferry B	Sailing time approx. 65 minutes					
Dep. Aeroe	0600	0830	1100	1430	1700	
Arr. Fyn	0705	0935	1205	1535	1805	
Dep. Fyn	0715	0945	1215	1545	1815	
Arr. Aeroe	0820	1050	1320	1650	1920	

Ferry C	Sailing time approx. 50 minutes					
Dep. Soeby		0700		1115	1530	1730
Arr. Als		0750		1205	1620	1820
Dep. Als		0755		1210	1625	1825
Arr. Soeby		0845		1300	1715	1915

Ferry C	Sailing time approx. 50 minutes					
Dep. Soeby			0900	1315		
Arr. Faaborg			0950	1405		
Dep. Als			0955	1410		
Arr. Soeby			1045	1500		

3.4 Scenario 3 roundtrips and capacity with three E-ferries

Capacity comparison, Scenario 3 Ærøskøbing-Svendborg
3x31 PCU E-ferries

Daily double trips

Peak season 13 weeks

	Monday-Friday		Saturday		Sunday		Trips	
	Today	E-ferries	Today	E-ferries	Today	E-ferries	Today	E-ferries
Ærøsk.-Fyn	11 *	13	10	12	10	12	975	1157
Søby-Fynshav	3	4	3	4	2	4	260	364
Søby-Fåborg	3	4	2	3	2	3	247	338
Total	17	21	15	19	14	19	1482	1859
PCU capacity	1152	1302	1086	1178	1104	1178	3342	3658

Shoulder season 13 weeks

	Monday-Friday		Saturday		Sunday		Trips	
	Today	E-ferries	Today	E-ferries	Today	E-ferries	Today	E-ferries
Ærøsk.-Fyn	11	12	8	11	8	11	923	1066
Søby-Fynshav	3	4	3	4	2	4	260	364
Søby-Fåborg	3	4	2	3	1	3	234	338
Total	17	20	13	18	11	18	1417	1768
PCU capacity	1152	1240	930	1116	870	1116	2952	3472

Off season 26 weeks (Docking 1 week each ferry)

	Monday-Friday		Saturday		Sunday		Trips	
	Today	E-ferries	Today	E-ferries	Today	E-ferries	Today	E-ferries
Ærøsk.-Fyn	11	12	8	10	8	10	1704	1920
Søby-Fynshav	3	4	3	4	2	4	480	672
Søby-Fåborg	3	3	2	2	1	2	432	456
Total	17	19	13	16	11	16	2616	3048
PCU capacity	1152	1178	930	992	870	992	2952	3162

*12 at thursdays and fridays
NB: Nominal capacity for M/F Skjoldnæs reduced to 33 PCU. All ferries loose 6 PCU if suspended car decks are blocked by trucks

4 Extra scenario case study calculations

4.1 Scenario 1 with three E-ferries

Investment costs

New building prices of the extended E-ferry designs are subject to some uncertainty as no indication price exists for the larger ferry design. Estimates are based on roughly made corrections to steel weights and requirements for extra equipment etc.

The battery pack has been added 570 kWh (or 15 %) to cope with a higher average weight of cargo and more frequent delays according to discussions in chapter 2. This of course also adds extra cost to the replacement of battery packs.

Land infrastructure

Due to the higher number of vehicles to be loaded and discharged during each port call the turnaround time in Rantzausminde, Lehnskov or Vesterrøn is not expected to be kept within 6-8 minutes. Therefore shore charging station on both sides of the central routes has been implemented in this extra scenario with only three E-ferries serving Aeroe.

Extra shore charging stations has not been added in Fynshav and Faaborg. Instead extra port time has been added the sailing schedule, see chapter 3. The schedule from Søby will then not allow for departures at fixed minutes of the hour but this is a better price to pay than adding two expensive extra shore charging stations for only one E-ferry.

In Søby upgrading for a secondary ferry berth is no longer needed as it was in scenario 1 in the case study with a four E-ferry solution.

Docking periods

No extra assistance is assumed during dry docking periods of the E-ferries. As for today the remaining two ferries must cope with demand during docking periods. Peak capacity was found to be reduced quite significantly compared to the four E-ferry solution in chapter 2 and 3.

Dredging

Same demand for dredging has been assumed in this extra scenario with three E-ferries.

Operating costs

Adjustments have been made to most operating cost including manning cost. On average manning has been increased by one crew member being one extra AB due to higher average passenger numbers and a higher minimum safe manning for the longer ferry with Man-Over-Board (MOB) boat arrangements etc.

This means that minimum safe manning of the larger E-ferry is assumed to be at least 4 crew members and the possibility to reduce to only two crew members if passenger numbers are below 99 is lost. In the base calculations of scenario 1 this possibility though was not exploited either but could add significant extra savings to base scenario 1 with four E-ferries.

Energy cost has been found according to sailing schedules in chapter 3 and adjustments to energy consumption of 15 % extra per trip for the larger E-ferry design as discussed in chapter 2.

Other operating cost such as maintenance, insurance and dry dockings have been adjusted to reflect the larger but fewer E-ferries.

Shuttle bus service

Is expected to remain unchanged as departure frequency on the central route is the same. Bus service for the two routes from Søby is not expected to be affected as no extra busses were added in the base scenario 1.

Scenario 1 Only 3 E-Ferries	Investment cost	Period of depreciation	Annual depreciation	Comments
	€	Years	€	
E-ferry A (36 PCU 198/147 PAX) Prototype design	16.840.271	30	561.342	Delivery 2017 incl. battery replacement
E-ferry B (31 PCU 147/98 PAX) 4.4 MWh	15.898.871	30	529.962	Delivery 2019 incl. battery replacement
E-ferry C (31 PCU 147/98PAX) 4.4 MWh	14.631.391	30	487.713	Delivery 2021 incl. battery replacement
Expected loss from sale of M/F Marstal	723.107	10	72.311	Assumed sale in 2022, price 1.2 mill. €
Expected loss from sale of M/F Ærøskøbing	586.652	10	58.665	Assumed sale in 2023, price 1.1 mill. €
Deduction scrap value M/F Skjoldnæs	-40.000	30	-1.333	Assumed scrapping in 2019
Deduction recycling value E-ferries & batteries	-3.315.937	30	-110.531	Assumed value 7 % at end of economic life
Total	45.324.354		**1.598.129**	

Scenario 1 Land infrastructure	Investment cost	Period of depreciation	Annual depreciation	Comments
	€	Years	€	
New ferry port W of Svendborg (Aeroe's share)	2.657.719	40	66.443	To be completed by 2021
Dredging Højestene Channel (Aeroe's share)	800.000	10	80.000	To be completed as soon as possible
Land installations in Søby, Fynshav and Fåborg	2.179.197	20	108.960	To be completed by 2017
Land installations in Ærøsk. and new ferry port	3.215.383	20	160.769	To be completeed by 2021
Total	8.852.299		**416.172**	

Scenario 1 Interest payments	Cost	Period of payments	Interests	Comments
	€	Years	€	
Total investment cost and total interests	54.176.652	30	21.979.399	Based on fixed interest rate of 2.4 per cent
Interests including cost of loan (1.5 per cent)	22.792.049	30	**759.735**	Annual interest & loan costs

Table 4.1 Investment costs for scenario 1 with only three E-ferries including annual depreciation and interest cost prepared for comparison to budget 2014 and base scenario 1 with four E-ferries.

The total cost of investments and interests for scenario 1 with three E-ferries is around 2.8 million € per year. This should be compared to base scenario with four E-ferries being 3.1 million € per year and present leasing/depreciation costs from 2014 budget for the existing ferries for Aeroe of only 1.2 million €.

Scenario 1 Operating costs	Existing ferries (2014)	All routes with 4 E-ferries	All routes with only 3 E-ferries
	€	€	€
Cost of bunker and energy	2,752,386	870,269	856,621
Mannning costs incl. catering saleries	4,760,772	2,610,090	2,830,390
Lub oil	45,772	-	-
Maintenance and repair	251,812	168,543	145,369
Sevice contract	-	214,477	184,987
Dry docking	540,403	476,616	411,081
Classiffication & safety	138,523	184,450	159,088
Insurance H&M, P&I	178,792	268,097	231,233
Uncovered average	71,007	94,549	81,548
Maintenance land infrastructure	251,544	377,315	377,315
Catering excl. saleries	-563,356	-300,000	-300,000
Administration, tax and harbor fees	645,311	645,311	645,311
New shuttle bus service (Aeroe's share)	-	249,125	249,125
Total	**9,072,965**	**5,858,843**	**5,872,069**
Annual savings		**3,214,123**	**3,200,897**

Table 4.2 Comparison of operating cost based on 2014 budget, base scenario 1 with 4 E-ferries and extra scenario 1 with 3 E-ferries for the ferry service of Aeroe.

Profitability

Based on and Table 4.1 and Table 4.2 annual savings after full implementation of scenario 1 with three E-ferries will be 1.55 million € per year based on today's energy

prices and cost levels. This is 277,000 € better savings than base scenario 1 with four E-ferries. But again revenues and external social costs such as saved transport time and waiting time is not included yet in the calculation and estimates. These are discussed in chapter 5 of this annex IV.

Extra savings of around 580,000 € annually can be expected if the price span between MGO and electricity follows the forecasted trend towards year 2020.

4.2 Scenario 2 with three E-ferries

Investment costs

New building prices of the extended E-ferry is as found in scenario 1 with three E-ferries.

The battery pack has been added 720 kWh (or 15 % compared to base scenario 2) to cope with a higher average weight of cargo and more frequent delays according to discussions in chapter 2.

Land infrastructure

An extra shore charging station on both sides of the central route has already been implemented in the base scenario 2 therefore no extra stations are needed.

Dredging

Same demand for dredging has been assumed in this extra scenario with three E-ferries as for the base scenario 2 with dredging done between Marstal and Rudkøbing.

Operating costs

Same adjustments have been made to operating cost as for scenario 1 with three E-ferries. This means that minimum safe manning of the larger E-ferry is assumed to be at least 4 crew.

Energy cost has been found according to sailing schedules in chapter 3 and adjustments to energy consumption of 15 % extra per trip for the larger E-ferry design as discussed in chapter 2.

Scenario 2 Three E-Ferries	Investment cost	Period of depreciation	Annual depreciation	Comments
	€	Years	€	
E-ferry A (36 PCU 198/147 PAX) Prototype design	16.840.271	30	561.342	Delivery 2017 incl. battery replacement
E-ferry B (31 PCU 147/98 PAX) 5.1 MWh	17.017.132	30	567.238	Delivery 2019 incl. battery replacement
E-ferry C (31 PCU 147/98PAX) 5.1 MWh	15.593.901	30	519.797	Delivery 2021 incl. battery replacement
Expected loss from sale of M/F Marstal	723.107	10	72.311	Assumed sale in 2022, price 1.2 mill. €
Expected loss from sale of M/F Ærøskøbing	586.652	10	58.665	Assumed sale in 2023, price 1.1 mill. €
Deduction scrap value M/F Skjoldnæs	-40.000	30	-1.333	Assumed scrapping in 2019
Deduction recycling value E-ferries & batteries	-3.461.591	30	-115.386	Assumed value 7 % at end of economic life
Total	47.259.471		**1.662.633**	

Scenario 2 Land infrastructure	Investment cost	Period of depreciation	Annual depreciation	Comments
	€	Years	€	
New and updated ferry berths Marstal/Rudk.	1.350.000	40	33.750	To be completed by 2021
Dredging sailing Channel (Aeroe's share)	533.333	10	53.333	To be completed as soon as possible
Land installations in Søby, Fynshav and Fåborg	2.179.197	20	108.960	To be completed by 2017
Land installations in Marstal and Rudkøbing	2.766.523	20	138.326	To be completeed by 2021
Total	6.829.054		**334.369**	

Scenario 2 Interest payments	Cost	Period of payments	Interests	Comments
	€	Years	€	
Total investment cost and total interests	54.088.525	30	21.943.841	Based on interest rate of 2.4 per cent
Interests including cost of loan (1.5 per cent)	22.755.169	30	**758.506**	Annual interest & loan costs

Table 4.3 Investment costs for scenario 2 with only three E-ferries including annual depreciation and interest cost prepared for comparison to budget 2014 and base scenario 2 with four E-ferries.

The total cost of investments and interests for scenario 2 with three E-ferries is also around 2.8 million € per year. This should be compared to base scenario with four E-ferries being 3.1 million € per year and present leasing/depreciation costs from 2014 budget for the existing ferries for Aeroe of only 1.2 million €.

Scenario 2 Operating costs	Existing ferries (2014)	All routes with 4 E-ferries	All routes with 3 E-ferries
	€		€
Cost of bunker and energy	2,752,386	1,104,178	1,125,629
Mannning costs incl. catering saleries	4,760,772	2,610,090	2,830,390
Lub oil	45,772	-	-
Maintenance and repair	251,812	168,543	145,369
Sevice contract	-	214,477	184,987
Dry docking	540,403	476,616	411,081
Classiffication & safety	138,523	184,450	159,088
Insurance H&M, P&I	178,792	268,097	231,233
Uncovered average	71,007	94,549	81,548
Maintenance land infrastructure	251,544	377,315	377,315
Catering excl. saleries	-563,356	-300,000	-300,000
Administration, tax and harbor fees	645,311	645,311	645,311
New shuttle bus service (Aeroe's share)	-	432,680	432,680
Total	**9,072,965**	**6,276,307**	**6,324,632**
Annual savings		**2,796,658**	**2,748,334**

Table 4.4 Comparison of operating cost based on 2014 budget, base scenario 2 with 4 E-ferries and extra scenario 2 with 3 E-ferries for the ferry service of Aeroe.

Profitability

Based on and Table 4.3 and Table 4.4 annual savings after full implementation of scenario 2 with three E-ferries will be 1.1 million € per year based on today's energy prices and cost levels. This is 323,000 € better savings than base scenario 2 with four E-ferries. But again revenues and external social costs such as saved transport time and waiting time is not included yet in the calculation and estimates. These are discussed in chapter 5 of this annex IV.

Extra savings of around 560,000 € annually can be expected if the price span between MGO and electricity follows the forecasted trend towards year 2020.

4.3 Scenario 3 with three E-ferries

Investment costs

New building prices of the extended E-ferry is almost as found in scenario 1 and 2 with three E-ferries. The two E-ferries for the central route to Svendborg has been added suspended car decks as well in order to increase peak capacity which was found insufficient in chapter 2 of this annex IV.

The battery pack has been added 570 kWh (or 15 % compared to base scenario 3) to cope with a higher average weight of cargo and more frequent delays according to discussions in chapter 2.

Land infrastructure

An extra shore charging station on both sides of the central route has already been implemented in the base scenario 3 therefore no extra stations are needed.

Dredging

Same demand for dredging has been assumed in this extra scenario with three E-ferries as for the base scenario 1 and 3 with dredging done in Højestene Channel.

Operating costs

Adjustments have been made to operating cost as for scenario 1 and 2 with three E-ferries. This means that minimum safe manning of the larger E-ferry is assumed to be at least 4 crew members. But extra crew is also added in summer period compared to other scenarios caused by the highest expected passenger numbers.

Energy cost has been found according to sailing schedules in chapter 3 and adjustments to energy consumption of 15 % extra per trip for the larger E-ferry design as discussed in chapter 2.

Scenario 3 3 E-Ferries	Investment cost	Period of depreciation	Annual depreciation	Comments
	€	Years	€	
E-ferry A (36 PCU 198/147 PAX) Prototype design	16.840.271	30	561.342	Delivery 2017 incl. battery replacement
E-ferry B (36 PCU 147/98 PAX) 4.4 MWh	16.573.871	30	552.462	Delivery 2019 incl. battery replacement
E-ferry C (36 PCU 147/98PAX) 4.4 MWh	15.268.891	30	508.963	Delivery 2021 incl. battery replacement
Expected loss from sale of M/F Marstal	723.107	10	72.311	Assumed sale in 2022, price 1.2 mill. €
Expected loss from sale of M/F Ærøskøbing	586.652	10	58.665	Assumed sale in 2023, price 1.1 mill. €
Deduction scrap value M/F Skjoldnæs	-40.000	30	-1.333	Assumed scrapping in 2019
Deduction recycling value E-ferries & batteries	-3.407.812	30	-113.594	Assumed value 7 % at end of economic life
Total	46.544.979		**1.638.817**	

Scenario 3 Land infrastructure	Investment cost	Period of depreciation	Annual depreciation	Comments
	€	Years	€	
Dredging Højestene Channel (Aeroe's share)	800.000	10	80.000	To be completed as soon as possible
Land installations in Søby, Fynshav and Fåborg	2.179.197	20	108.960	To be completed by 2017
Land installations in Ærøskøbing and Svendborg	2.979.409	20	148.970	To be completeed by 2021
Total	5.958.607		**337.930**	

Scenario 3 Interest payments	Cost	Period of payments	Interests	Comments
	€	Years	€	
Total investment cost and total interests	52.503.586	30	21.300.835	Based on fixed interest rate of 2.4 per cent
Interests including cost of loan (1.5 per cent)	22.088.389	30	**736.280**	Annual interest & loan costs

Table 4.5 Investment costs for scenario 3 with only three E-ferries including annual depreciation and interest cost prepared for comparison to budget 2014 and base scenario 3 with four E-ferries.

The total cost of investments and interests for scenario 3 with three E-ferries is around 2.7 million € per year. This should be compared to base scenario with four E-ferries being 3.1 million € per year and present leasing/depreciation costs from 2014 budget for the existing ferries for Aeroe of only 1.2 million €.

Scenario 3 Operating costs	Existing ferries (2014)	All routes with 4 E-ferries	All routes with 3 E-ferries
	€	€	€
Cost of bunker and energy	2,752,386	999,989	1,005,811
Mannning costs incl. catering saleries	4,760,772	3,199,047	3,247,213
Lub oil	45,772	-	-
Maintenance and repair	251,812	168,543	145,369
Sevice contract	-	214,477	184,987
Dry docking	540,403	476,616	411,081
Classiffication & safety	138,523	184,450	159,088
Insurance H&M, P&I	178,792	268,097	231,233
Uncovered average	71,007	94,549	81,548
Maintenance land infrastructure	251,544	377,315	377,315
Catering excl. saleries	-563,356	-400,000	-400,000
Administration, tax and harbor fees	645,311	645,311	645,311
Total	**9,072,965**	**6,228,394**	**6,088,957**
Annual savings		**2,844,571**	**2,984,009**

Table 4.6 Comparison of operating cost based on 2014 budget, base scenario 2 with 4 E-ferries and extra scenario 2 with 3 E-ferries for the ferry service of Aeroe.

Profitability

Based on and Table 4.5 and Table 4.6 annual savings after full implementation of scenario 3 with three E-ferries will be 1.4 million € per year based on today's energy prices and cost levels. This is 486,000 € better savings than base scenario 3 with four E-ferries. The three ferry scenario does not allow for the same peak capacity as for other scenarios and again revenues and external social costs such as saved transport time and waiting time is not included yet in the calculation and estimates. These are discussed in chapter 5 of this annex IV.

Extra savings of around 570,000 € annually can be expected if the price span between MGO and electricity follows the forecasted trend towards year 2020.

5 Comparing all savings

Although savings from investment cost and operation in total indicates better performance of the three E-ferry solution analysed in this annex chapter 4, this is not the final or correct conclusion. Transport qualities and revenues must be part of the analysis as well. If better transport quality results in higher demand, this will affect bottom line also for the ferry operator.

A significantly higher peak capacity and higher departure frequency of all scenarios with a four E-ferry solution will affect revenues substantially as discussed in chapter 6 of the WP 4 Socio-economic Analysis. Here demand increases of the four ferry solution were suggested to be of a magnitude of 8-15 %.

Extra revenue [€] from increase in demand					
Segment	5%	10%	15%	20%	25%
Passengers	259,803	519,605	779,408	1,039,211	1,299,014
Cars	127,933	255,866	383,799	511,732	639,665
Trucks	42,953	85,906	128,860	171,813	214,766
Total	**430,689**	**861,378**	**1,292,067**	**1,722,755**	**2,153,444**

Table 5.1 Revenue increase from likely range of demand increases

If extra demand is reduced just one-third due to a significantly lower departure frequency from Søby and the limitations to capacity on the central route from the three ferry solution, this would result in a better overall performance of the four ferry solution instead.

In calculations below also "hidden" waiting time has been corrected for the longer time between departures in Søby again weighed with one-third while saved transit time or transport time is the same as for base scenarios;

Socio-economic impacts in €	With four E-ferries			With three E-ferries		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
Annual total savings from operation	1,272,552	792,618	907,497	1,549,411	1,115,376	1,393,532
Extra savings from forecasted oil price 2020	580,000	560,000	570,000	580,000	560,000	570,000
Value of total travel time savings	2,159,777	1,165,835	1,758,108	2,159,777	1,165,835	1,758,108
Value of saved "hidden" waiting time	1,854,101	1,854,101	927,051	1,236,068	1,236,068	618,034
New demand from better transport qualities	1,200,000	1,100,000	1,000,000	800,000	733,333	666,667
Saved external social cost from lower emission	1,248,266	1,248,266	1,248,266	1,248,266	1,248,266	1,248,266
Total socio-economic annual savings	**8,314,697**	**6,720,820**	**6,410,922**	**7,573,522**	**6,058,878**	**6,254,607**

Table 5.2 Although savings from operation, including investment cost, is higher with three E-ferry setup, this is not the optimal solution from an overall perspective, when for example extra revenue or value of extra capacity and departures are added to the equation.