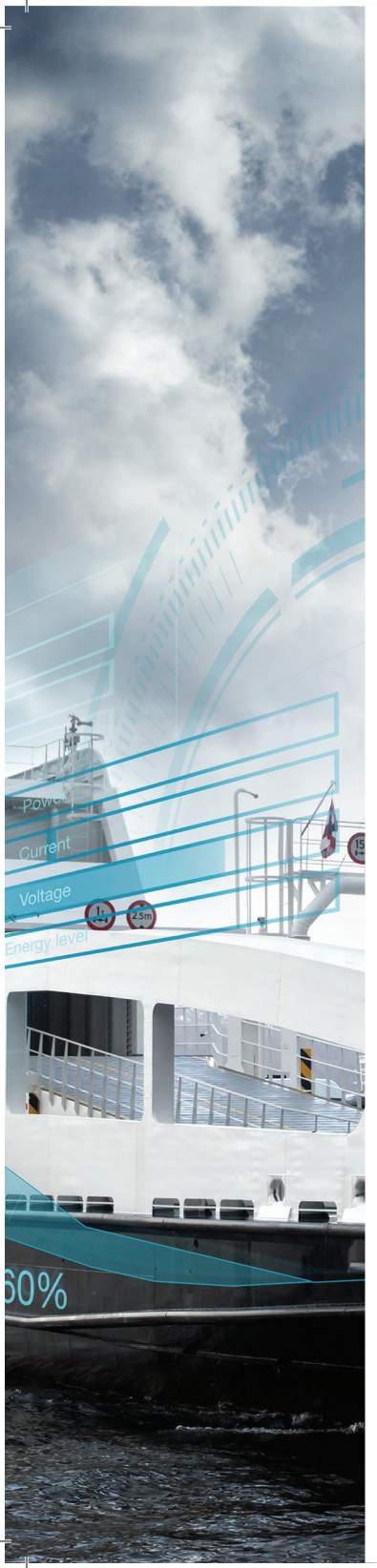
Electric operation makes

SEVEN out of TEN

ferries more profitable – a feasibility study

BELLONA SIEMENS



Introduction

In 2015, the world's first battery-driven car ferry came into service between Lavik and Oppedal on Sognefjord in western Norway. Just on this one route, the *Ampere* delivers significant savings in operational costs and greenhouse gas emissions for the shipowner.

Today, there are around 180 other ferries operating some 111 routes across Norway's fjords. How many of these would operate more profitably using only battery power or a hybrid solution?

For the answer, we've studied *Ampere*. As of August 2015, this innovative vessel has been operating for six months, which equates to thousands of running hours. This is valuable input for studying the potential of battery-powered or hybrid ferries.

Experience from *Ampere* is used as the basis to calculate investment and savings for other ferry routes in Norway. And the conclusion is: **It is profitable to substitute seven out of ten ferries with either battery-driven or hybrid alternatives.**

If Norway succeeds in implementing these innovations, the environmental benefits are considerable. Findings from the *Ampere* study reveal CO_2 reductions of 300,000 tonnes, which is 9% of annual emissions from domestic shipping and commercial fishing in the country (www.miljostatus.no).

Naturally these findings do not just apply to Norway. Any shipowner worldwide owning ferries operating with a similar profile to 70% of the Norwegian ferry fleet may benefit from running battery-driven or hybrid ferries.

Oslo, August 2015

Potential for pure battery-powered or hybrid ferries

As most ferries today operate on relatively short routes, they have operational profiles that mean pure battery power or hybrid solutions can be profitable. For longer routes, batteries with greater capacity are necessary, which incur higher costs of supercharging and make battery-powered solutions less competitive. Therefore it is economically and environmentally preferable to choose hybrid solutions for longer routes.

Furthermore, it may also be economic to invest in a supercharger on the quayside for longer routes.

Battery power is not viable for routes with low trip frequency, where reduced operating costs are too low to cover investment.

- **Battery operation:** Of 180 ferries in Norway, 84 have crossing times of less than 35 minutes and operate at least 20 trips on each of their 61 different routes during a 24-hour period. This operational profile makes battery-powered solutions profitable.

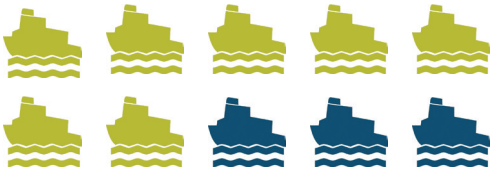
- **Hybrid operation:** 43 ferries operating on 32 routes have operational profiles that make hybrid solutions profitable. These hybrid solutions use a combination of battery power and either diesel- or gas-driven propulsion systems.

Conclusion: Given today's technology, we estimate that it is profitable to substitute 127 of Norway's 180 ferries with either battery-powered or hybrid alternatives. This equates to over 70 percent of Norway's ferry fleet.

Profitable ferry routes for battery-powered vessels	
Andabeløy – Abelsnes	Lavik – Oppedal
Arasvika – Hennset	Leirvåg – Sløvågen
Aukra – Hollingsholmen	Lekneset – Sæbø
Bognes – Skarberget	Levang – Nesna
Brattvåg – Dryna	Lote – Anda 2
Breistein – Valestrandfossen	Mannheller – Fodnes
Brekstad – Valset	Melbu – Fiskebøl
Buavåg – Langevåg	Molde – Vestnes
Eidsdal – Linge	Mortavika – Arsvågen
Festvåg – Misten	Moss – Horten
Festøya – Solavågen	Måløy – Oldeide
Flakk – Rørvik	Refsnes – Flesnes
Forøy – Ågskardet	Sand – Ropeid
Gjermundshavn – Varaldsøy	Sandessjøen – Bjørn
Haldorsneset – Daløy	Sandvika – Edøya
Halhjem – Våge	Seivika – Tømmervågen
Halsa – Kanestraum	Skei – Gutvik
Hareid – Sulasundet	Skånevik – Utåker
Hattvol – Venjaset	Solholmen – Mordalsvågen
Hella – Dragsvik	Stornes – Bjørnerå
Hjelmeland – Nesvik	Storstein – Lauksundskaret
Hofles – Geisnes	Stranda – Liabygda
Horn – Anddalsvåg	Svelvik – Verket
Husavik – Sandvikvåg	Sølsnes – Åfarnes
Isane – Stårheim	Vennesund – Holm
Jektevik – Hodanes	Volda – Folkestad
Jondal – Tørvikbygd	Volda – Lauvstad
Klokkarvik – Hjellestad	Ølhammeren – Seierstad
Krokeide – Hufthamar	Ørsneset – Magerholm
Kvanne – Rykkjem	Årvika – Koparneset
Larsneset – Åram	

Profitable ferry routes for hybrid vessels	
Askvoll – Gjervik	Kilboghamn – Jektvik
Belvik – Vengsøy	Kinsarvik – Kvanndal
Bodø – Moskenes	Krakhella – Rysjedalsvika
Bodø – Værøy	Lyngseidet – Olderdalen
Bognes – Lødingen	Molde – Sekken
Dagsvik – Mosjøen	Nesna – Nesnaøyene
Drag – Kjøpsvik	Nordnesøy – Kilboghamn
Finnøya – Sandøya	Onøyan – Stokkvågen
Frøyasambandet	Ranavik – Skjersholmane
Geiranger – Hellesylt	Skjeltene – Haramsøya
Halhjem – Sandvikvåg	Stangnes – Sørrolnes
Hansnes – Skåningsbukt	Søvik – Herøy
Horn – Igerøy	Tjøtta – Forvik
Horsdal – Sund	Øksfjord – Bergsfjord
Igerøy – Tjøtta	Øksfjord – Hasvik
Kaljord – Hanøy	Ørnes – Meløysund

ELECTRIC OPERATION MAKES SEVEN OUT OF TEN FERRIES *MORE* PROFITABLE



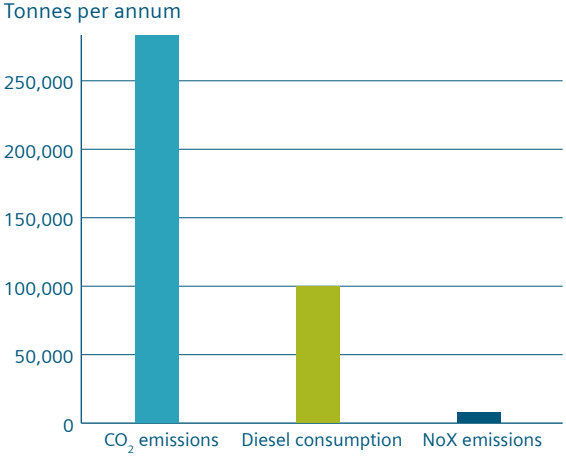
Emission reduction potential

To calculate potential for reducing emissions, our study looks at the feasibility of replacing 127 of Norway's ferries with either battery-powered (84) or hybrid alternatives (43). We then compare predicted emissions from the environmentally friendly vessels with 127 diesel-driven ferries. This comparison forms the basis for calculating emission reductions from battery-powered or hybrid ferries.

The following environmental benefits are provided by 127 battery-powered or hybrid ferries:

- CO_2 emissions cut by 300,000 tonnes per year
- Diesel consumption cut by 100,000 tonnes per year
- NoX emissions cut by 8,000 tonnes per year

EMISSION REDUCTIONS FROM BATTERY-POWERED OR HYBRID FERRIES COMPARED TO DIESEL-DRIVEN FERRIES



Profitability of battery-powered ferries

Replacing 84 ferries with battery-powered alternatives demands additional investment of around € 384 million[1)] compared to costs of building diesel-driven ferries.

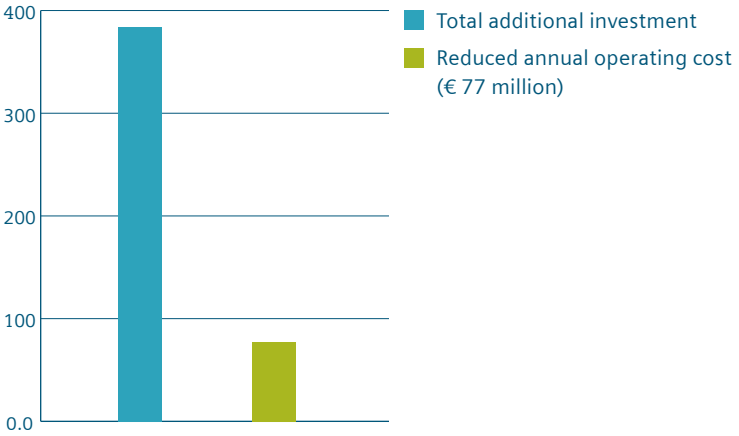
The additional investment comes largely from using aluminium in the new ferries, which makes them lighter and reduces energy use accordingly – an advantage that particularly benefits battery operation. Costs of land-based infrastructure, including recharging stations, are included in the total of € 384 million.

The additional investment pays dividends due to lower operational costs and emissions. Replacing 84 ferries with battery-powered alternatives delivers the following annual reductions in fuel use and emissions:

- 275,000 tonnes CO_2
- 89,000 tonnes diesel
- 4,600 tonn NoX

Over a ten-year period, these 84 ferries reduce operational costs by €77[1)] million each year. In other words, cost savings are double the additional investment of € 384 million after a decade.

ADDITIONAL INVESTMENT REQUIRED WITH BATTERY OPERATION Amounts in € (million)



[1)] *Exchange rate: € 1 = NOK 9.1186.*

Data collection and assumptions

Information from all existing ferries, including installed power, key dimensions and speed was collected. Based on known operational profiles, energy use in the form of diesel consumption was then calculated for Norway's ferry fleet.

Experience gained from *Ampere* was used as the basis to calculate investment and savings for each ferry route, which resulted in 84 ferries showing greater profitability from battery power compared to diesel power on their respective routes. In calculations for energy used per crossing, existing onboard solutions were replaced with technology used on *Ampere*. Furthermore, *Ampere*'s energy use was taken to calculate the amount of energy required per crossing, scaling up or down where appropriate.

We have assumed that all new battery-powered ferries are made from aluminium, which helps reduce onboard energy consumption and gives corresponding reductions in energy taken from the national power grid during supercharging. Ferries used on 61 routes are either larger or smaller than *Ampere* and values have been scaled up or down accordingly.

The calculations show that these 84 battery-powered ferries would use 237GWh of power annually, which corresponds to 0.002% of produced energy in Norway per annum. This is equivalent to the energy produced from 24 wind turbines every year.

Based on publically available information for Norway's national grid, we have estimated the cost of laying 22kV power lines to all ferry quays. These costs are included in the analysis.

A financial analysis has been generated to estimate profitability of battery-powered ferries. The costs of a ferry running on electricity are compared with those of a ferry running on diesel. The following costs are included in the analysis:

- Investment costs
- Operational costs
- Maintenance costs

In the study, a risk-adjusted discount rate of 7.1% regulated for inflation has been used. It is assumed that all investments are made in year zero and distributed over the period of analysis. As the lifetime of a ferry and its power grid are judged to be 30 and 40 years respectively, residual values are used to adjust investment costs accordingly at the end of the analysis period.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www.siemens.no/marine