08.01.2018
Version 10

Emission Free public transport in Oslo and Akershus

(English translation of original document in Norwegian)
Original document located here:
https://ruter.no/om-ruter/prosjekter/fossilfri2020/

Ruter#

Contents

Photo: Ruter AS

1. Introduction

Ruter will offer attractive and environmentally friendly public transport and create a sustainable and vibrant metropolitan environment. Public transport plays an important role in reaching the region's ambitious climate and environmental goals, by absorbing the growth in passenger transport together with cycling and walking, and helping to reduce motor traffic in Oslo by 20 percent by 2020. In addition, Ruter will reduce the environmental impact of public transport.

Ruter has an approved objective of operating all public transport with only renewable energy by the end of 2020.

In May 2017, Oslo City Council, through the City Council Department for the Environment and Transport, asked Ruter to:

> *... report on the scope of action, challenges and consequences of stepping up the level of ambition in Fossil-free-2020 through a faster rollout of completely emission-free public transport We ask Ruter to aim at solutions which allow for maximum reduction in greenhouse gas emissions, as well as solutions that will be cost- effective in the long term. On this basis, we are asking Ruter to develop proposals for a revised vision for the company's environmental strategy, including estimates for changeover costs and any long-term increases in operating costs."*

This report seeks to respond to the order from Oslo City Council. The report is made up two parts. The first part (chapters 2 and 3) defines what emission-free public transport will entail. The second part (chapters 4 to 6) clarifies the possibilities and consequences of a transition to emission-free public transport.

2. What does emission-free public transport mean?

The underground and trams operated by Ruter are emission-free today. Other public transport services in Oslo and Akershus are delivered by a fleet of around 1,150 buses, 10 boats and special transport based on about 200 minibuses and a smaller fleet of taxis. Apart from ten electric minibuses, five hydrogen buses and six battery-powered electric buses, everything in today's fleet must be replaced with material with zero emission technology. The greatest emissions come from bus operation.

In order to achieve this, the necessary energy supply and charging infrastructure must be in place on today's 23 bus systems, relevant piers and at a number of selected terminals where there is a need for quick charging. Charging infrastructure will mainly be a connection for charging at low power at the bus stations and quays at nighttime, and high-power rapid charging via pantograph at bus depots, or other automatic connection for boats. Infrastructure for filling of hydrogen is expected to be established at, or close to bus stations.

In Oslo the transport sector accounts for 65 percent of greenhouse gas emissions, of which public transport accounts for 4 percent.[1] Although public transport's share of emissions in the region is small, the city and densely-populated areas will enjoy improved air quality and less noise as a result of the transition to emission-free solutions. A good public transport system is also a prerequisite for reducing the use of cars, and contributes to increasing the proportion of use of public transport, cycling and walking.

Definition «emissions-free»

In its environmental work, Ruter has chosen to focus on the part of its own value chain where emissions are the highest and where Ruter has a large impact on the result. This lies in the operating phase of the vehicles, as well as in the selection of the energy carrier (fuel).

This report defines emission-free or zero-emission technology as vehicles or vessels from which there are no greenhouse gas emissions, emissions of NO_x or particles from the vehicle's engine. An emission-free vehicle will nonetheless create particles from the friction between the tires and the road. Today, it is common in cold climates to use combustion-based additional heating in the E-buses on cold days, so as not to reduce the range of the buses too much. Ruter's E-bus tests, which started in November this year, have such a solution based on biodiesel and will thus have emissions on cold days. The purpose of the testing includes finding out how this can be replaced in the long term with electrical heating alone. Figure 1 below in shows the definitions Ruter bases on.

Fossilfri 2020:

- ✓ Elektrisitet med opprinnelsesgaranti
- ✓ Hydrogen fra fornybar kilde
- ✓ Biodrivstoff som tilfredsstiller bærekraftkriteriene (jf Produktforskriften, § 3-6)

Utslippsfri:

- ✓ Elektrisitet med opprinnelsesgaranti
- ✓ Hydrogen fra fornybar kilde

Utvide systemgrensen over tid:

- ✓ I dag: Utslipp i driftsfasen
- ✓ Fremover: Øke vekt på indirekte utslipp

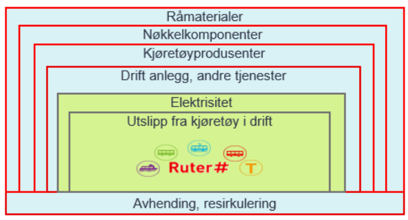


Figure 1 Definition and delimitation emission-free

Ruter buys the warranty of origin for all electricity used, to ensure that it comes from renewable sources. In our greenhouse gas accounting, emissions from use of electricity are therefore set at zero.

Over time it will be natural to extend the current system boundary, and increasingly include indirect emissions. This depends on developments in the market and when it is practicable and appropriate to set requirements to, and consider indirect emissions from services and material. Today, there

[1] From Oslo City Council's emission accounting, based on emission figures from 2015.

are insufficient documentation- and monitoring mechanisms in the supply chain to track requirements, for example, to emissions in the production of individual components of a bus.

3. Technology development and public transport

Four major trends affect development within mobility. Electrification is one of them, while digitization, autonomous vehicles and “shared' mobility are the others. The main driving forces behind the rapid electrification are: better battery technology, increasing shares of renewable power and more stringent public emission requirements. New mobility solutions could be emissions-free.

The E-bus technology is being commercialized more slowly than that of electric cars, so we will still have limitations for some time that make it challenging to move directly from today's technology to all-electric public transport.

Battery-powered E-buses are expected to be competitive on price compared to the ordinary Euro VI-buses powered by HVO biodiesel (HVO) over the next five to ten years, depending on the bus type. The timing will depend on the operating system necessary to electrify a route.

The introduction of E-buses on many of the routes in Oslo and Akershus will create the need for more buses. If there is little or no adjustment time available for a rapid charge at the bus terminal, more buses will have to be put into operation in order to maintain the same service. For buses with depot charging, the need for additional buses will arise where the range of an E-bus is not sufficient. An optimised operating system will be important for limiting the need for additional buses.

Figur 2 Illustrates the difference between phasing-in without having to increase the number of buses, versus a situation in which phasing-in will require 10 percent more buses during rapid charging and 12 percent for depot charging.

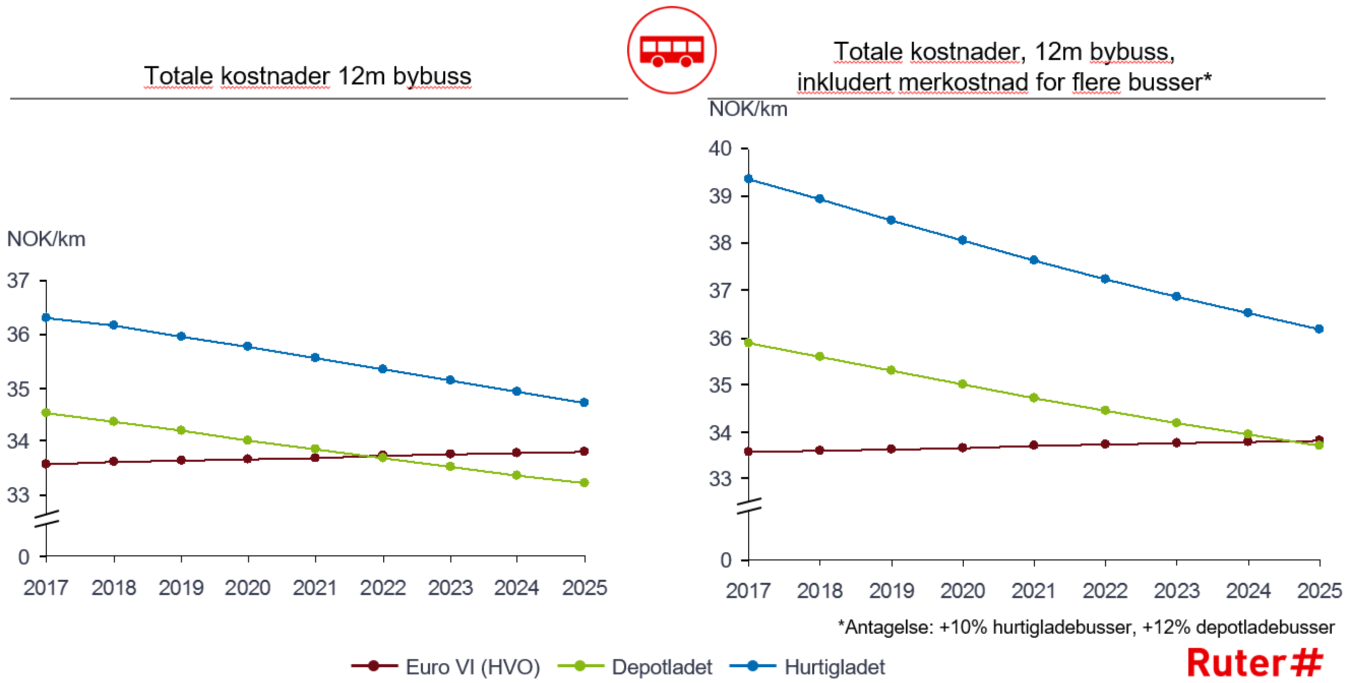
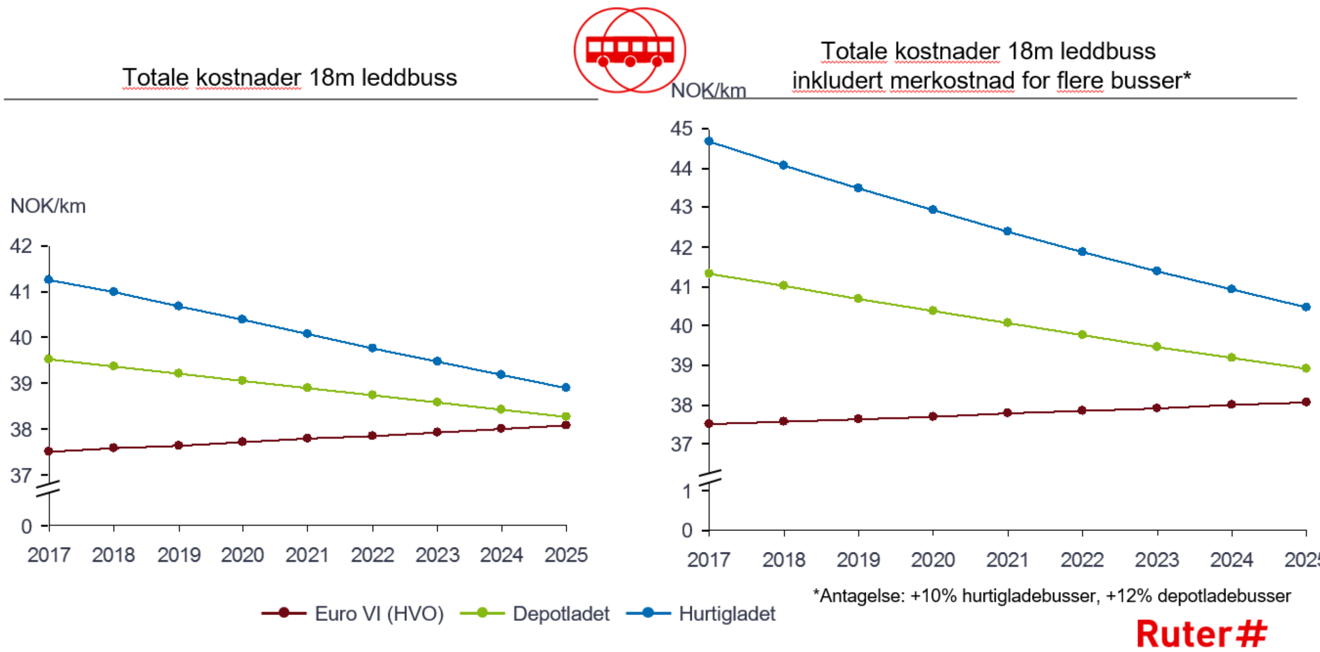


Figure 2 Battery-powered electric 12m. city bus (depot charged) can be competitive from 2022, but this date will be extended with the need for more buses

It is expected to take longer before the 18m. articulated buses become competitive, both with and without an assumption of the need for an increased number of buses.



3Figure The battery-powered electric 18m. articulated bus (depot charged) is anticipated to be competitive from 2025, but this date will be extended with the need for more buses

Figur 4 below is a cost comparison between different technologies, where the cost is included with the need for more buses as a result of electrification.

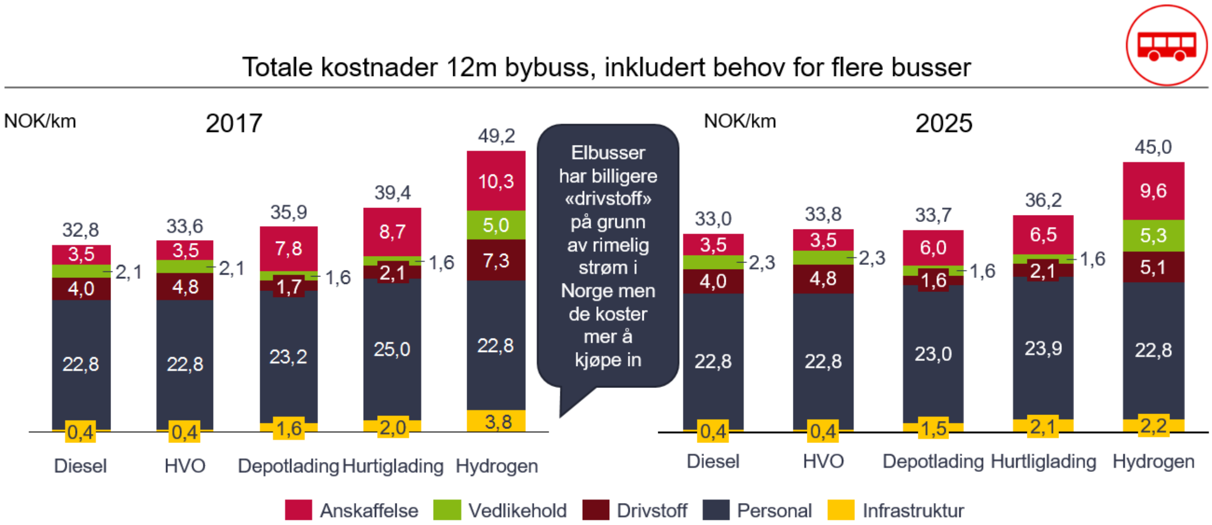


Figure 4 . In 2025, a depot-charged city bus may have lower costs per km. than a Euro VI-bus on HVO biodiesel

Hydrogen and fuel cells are expected to be more expensive and less technologically advanced than battery-powered electric for many years to come. Although hydrogen-based fuel cell technology is still at the development stage, buses have a potential for driving where battery-powered electric solutions do not have sufficient range. They will thus be the only emission-free option for solving certain transport tasks, especially in Akershus.

Following agreement with Oslo City Council and Oslo and Akershus County Council, Ruter is participating in a European Joint Hydrogen Vehicle Initiative, JIVE 2, which is part-funded by the EU research and innovation programme «Horizon 2020». The project is intended to promote the commercialization of fuel cell buses, and thus speed up the timing for when this becomes a more cost- effective and reliable alternative.

On the basis of a lower cost difference and technological maturity, Ruter has based its cost estimates in this report on battery-powered electric solutions. That does not mean that hydrogen may not be an option. The choice of solutions must be made based on the specific routes to be serviced and the service one wishes to provide, at the time when replacement of material will take place. Emission-free operations will more than previously involve an optimization of material and operations for the transport work to be carried out.

Development of battery technology

The cost of zero emission technology has been considerably reduced in recent years. In the last ten years, there has been a reduction in the cost of batteries of 88 percent[2], while the weight and

[2] Rapidly Falling Costs of Battery Packs for Electric Vehicles, "Nature Climate Change, 2015

volume have been reduced by about 20 percent. The weight is expected to be reduced by 6 percent annually until 2020[3]. The rapid transition to batteries has until now primarily made itself felt in the passenger car market, but also the buses benefit from better and cheaper battery technology.

Looking at the emissions from a vehicle in a life-cycle perspective, about 82 percent of the emissions from a diesel vehicle are generated in the operational phase. The remaining 18 percent are generated during the manufacture and disposal of the product. Electric car technology is just as "emission-free" as the sum of all emissions generated during the manufacture of the vehicle and in its operation. The factor that has the greatest impact on the amount of emissions is the power generation the electric vehicles charge from in their operating phase.

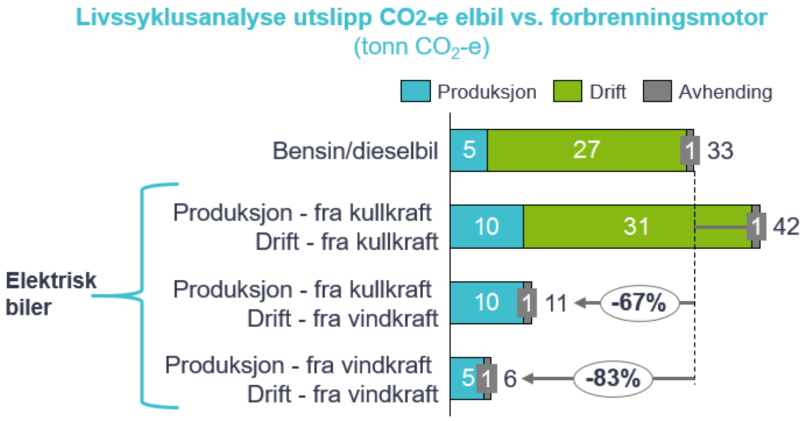


Figure 5. Emissions (tonnes of CO_2equivalents) from electrical vehicles are determined by what the electricity is produced by [4]

The global fleet of E-buses is estimated at closer to 350 000, of which 99 per cent is in China. In Europe today there are approximately 1,000 E-buses[5]. The proportion of E-buses in Europe's bus fleet is estimated to approach 20 percent in 2020 and is expected to reach above 50 percent by 2030[6]. This means that the speed of electrification of public transport in Europe is accelerating, which could provide further momentum in the development of bus technology, increase competition and bring down the price.

Many European cities have already set themselves ambitious targets for emission reductions from public transport and phasing in of E-buses increases.

---

[3] Nature Energy, 2016, A solid future for battery development
[4] Ellingsen et al. Environmental Research Letters 2016, NTNU Trondheim Norway
[5] Alexander Dennis Ltd.
[6] ZeEUS and UITP VEI Committee

Innkjøpsmål
Mål for bussflåten

År	Målsetninger buss	By
2018	• 100% 2. etg. Bybusser elektrisk/hydrogen/hybrid	• London[2]
2019	• 100% batterielektrisk	• København
2020	• 100% batterielektrisk • 100% utslippsfri (bybusser)	• Hamburg[1] • London[2]
2025	• 100% batterielektrisk • 100% utslippsfri • 80% batterielektrisk, 20% fossilfri • 30% batterielektrisk	• Barcelona, Milan, Paris[3] • Assen[1] • Paris[4] • Helsinki[1]
2026	• 100% utslippsfri	• Amsterdam[1]
2027	• 100% utslippsfri	• Rotterdam[1]
2031	• 100% batterielektrisk	• København[1]
2037	• 100% utslippsfri	• London[2]

Figure 6. Objectives for the bus fleet in selected European cities[7]

With improvement in battery technology and a longer range, charging at a bus depot will be more attractive because it avoids the challenges associated with land use in urban centres, costs of investment and operation in the charging infrastructure, and offers greater flexibility in the operating system. This report does not provide an answer as to what solutions are to be used in the future, and has based the cost analyses on a combination of rapid-charging at terminal charging, and depot charging.

4. Feasibility and consequences of emission-free public transport in Oslo and Akershus

To assess the feasibility, limitations and consequences of the transition to emission-free public transport, Ruter has gone through available studies from Norway and abroad, collected information from suppliers of material and services, and from its own organization. Ruter has had assistance from the Material Economics and Arthur D. Little consultancy firms in assessing future technological development and cost prognoses, compared with possibilities and limitations with phasing in a zero-emission solution in the public transport system. We have also looked to what is being done in other European cities.

Feasibility for transfer to emission-free public transport

The feasibility is defined to a large extent by the speed at which it is possible to replace bus- and boat material, within acceptable costs and consequences. There are four conditions that in particular, set constraints to the speed at which a transition to emission-free public transport can be carried out:

[7] Source: 1) ZeEUS report 2017, 2) London TfL webpage, 3) Pledge by 12 Mayors Oct 23rd https://electrek.co/2017/10/23/electric-buses-12-major-cities-pledge-2025/, 4) RATP Bus 2025 Plan

1. Contractual considerations: When do committed contracts expire, and what can be done within the framework of existing contracts?
2. Material: When will emission-free vehicles and vessels that meet Ruter's requirements be available in the market?
3. Restructuring: The time it takes for completely emission-free operation in new contracts can be realized given increased complexity and the need for restructuring both within and outside of Ruter
4. Costs: When will the cost level for zero emissions become competitive?

Below, we describe each of these conditions in more detail and how they can influence the phasing-in speed. Complexity is greatest for the bus fleet, and this assumes it will take longer to make it emission-free than it would for boats and special transport. For buses, each of the four factors provides a theoretical phasing-in curve that indicates how quickly the bus fleet can become emission-free (Figur 7). The chart also shows the timing for when the special transport and the boat fleet can become emission-free.

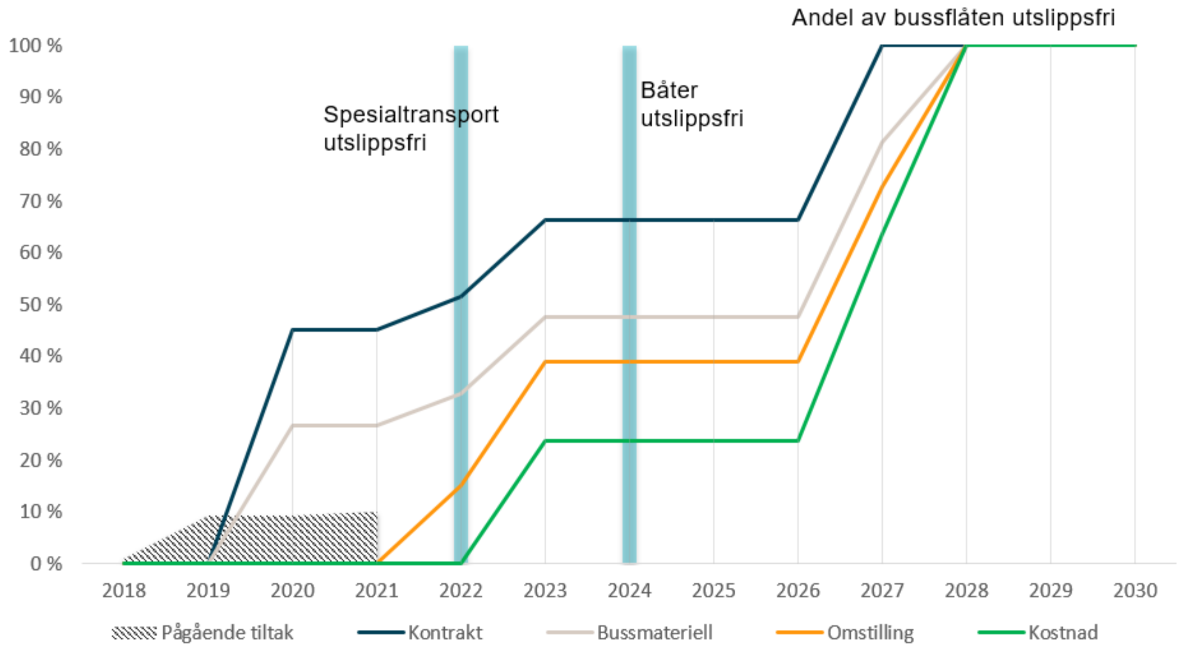


Figure 7 Alternative phasing-in speeds for the bus fleet based on limiting factors and the timing of emission-free special transport and boats

1. Contractual considerations

Ruter currently has twenty three contracts with bus operators, three contracts with boat operators, seven contracts with minibus operators and seven contracts with taxi companies. The Public Procurement Act sets limitations to the size of changes that can be made within an established contract. Therefore, the time at which a contract is renewed is of great significance in determining how quickly the transition can take place. However, it is possible to allow for more flexibility in new contracts.

The phasing-in "contracts" for the *bus fleet are* based on current contracts[8] and assume that all new contracts are completely emission-free. This shows that in theory Ruter can replace the current fleet with a zero emission fleet by 2027. This assumes that requirements are made to emission-free buses only in all bus service contracts that start up operations from 1st January 2020, and that there will be no extension option in the contracts. A contract duration of eight years is then assumed for all contracts signed from today until January 2020. However, this curve is not feasible since it depends on other factors which will not fall into place until later, such as available bus material and longer planning time to arrange for electrification.

Ruter has three contracts with two *boat operators*, all of which expire during the period 2018-2024. Two of the contracts may be extended to 2034. That means that, in theory, all vessels may be replaced by 2024.

Special transport contracts comprise minibuses and taxis. The current contract structure for the special transport makes it possible to replace all of today's minibuses in 2022. This assumes that no extension options will be triggered.

2. Material: Emission-free vehicles and vessels

There are currently a number of suppliers in the European market of electric battery-powered ordinary city buses (class 1, length 12 m. and 18 m.). The range of the buses is still limited, but this can be solved by rapid charging at the bus depot. Ruter's regional buses (class 2, length 13-15 m.) are not available on the market, and a battery-powered electric version is not expected to be available until after 2019. This means that emission-free regional buses can first be expected in contracts that come into effect after 1st January 2022, to allow for the time it takes to purchase and receive the buses and start up the operation. There are a few suppliers of hydrogen-powered city buses in the market today, but neither do these supply in the category of class 2 regional buses.

This means that the contracts for regional buses that are to be replaced during the next few years, will probably not be completely emission-free. Based on the assumption that when necessary emission-free bus material becomes available in the market, the phasing-in curve "bus material" shows that the bus fleet may be emission-free in 2028.

Ruter's analyses of technological feasibility for *boats*[9] show that electrical propulsion of the island boats and the Nesodden-Aker Brygge route is possible. Battery-powered electric operation is new technology in the maritime sector, but is still considered relatively easy to introduce. A battery-powered electric express boat that the developers believe can operate the Nesodden-Lysaker Pier route, was completed in 2017. However, new vessels cannot be introduced within the existing contract, which runs to 2024. A battery-powered electrical solution for the longest express boat routes is unlikely to come into place for a long time because of a too high energy requirement. Hydrogen operation might meet this need, but this is a less developed technology. Regulations for the use of hydrogen in the maritime sector are not currently available, but developments are

[8] Including an eight-year contract duration for a new contract in Romerike
[9] Potential and costs for the use of renewable energy on Ruter's boat service (2016); Electrification of the island boat connection (2017); Proposal for a zero-emission solution from Norled, the current operator of the Nesodden service.

underway that may allow for a hydrogen solution to be possible from 2024. If such a solution does not become available, 2029 is the next possible date for the transition to zero emissions according to the contract period.

There is currently a very limited range of emission-free minibuses available for *special transport* in the current market, but also here a development is expected that may enable the use of only electric minibuses from 2022. Since Oslo municipality will make demands to zero emissions to the taxi industry from 2022, it is anticipated that it will be possible to buy a completely emission-free taxi service from 2023. Today's challenges relating to range can be met by rapid-charging stations for the taxi business, as well as hydrogen vehicle development.

3. Restructuring: It will take longer time to realize completely emission-free operation

Perhaps the most demanding aspect of a rapid transition to emission-free public transport is the necessary restructuring of Ruter, both internally and externally. This includes supply- and operation planning that takes into account the requirements to charging and range, rapid establishment of a charging infrastructure, changes to business models and risk- and customer management to ensure a positive transition to emission-free public transport for customers. It will take time to build up sufficient expertise and capacity in Ruter, its suppliers and public authorities, with the consequence that over the next three years it is expected to take longer to prepare for the acquisition of new, completely emission-free contracts. This is reflected in the phasing-in curve "restructuring" for the bus fleet, where the phasing-in starts up later, but where the bus fleet will remain emission-free in 2028.

4. Costs: When will zero emissions become economically viable?

Our analysis estimates that *bus services* operated with battery-powered electric buses will become economically viable compared to diesel buses (Euro VI with HVO) between 2023-2028, depending on the bus types, routes and operating system that is necessary for complete electrification of the service. Assuming that battery-powered electric buses can become competitive on price from 2023, the phasing-out rate could be as shown in the "Cost" curve. For routes where more buses are needed as a result of electrification, the timing will occur later.

For minibuses used for *special transport*, a similar price development is expected as in buses, where the cost per hiring hour for electric minibuses will be competitive with fossil-free options in approximately 2022-23.

For *boats*, both bio-fuel and emission-free solutions will incur additional costs of operation and investment. The high cost of building new boats as well as the boat's long life imply that the contract duration will be decisive as to whether and when emission-free solutions can become cost-effective compared with today's solutions.

The four phase-in curves for the bus fleet,and the times at which the special transport and boat lines could become emission-free, shows that public transport as a whole could be emission-free by 2028, and that there is a scope as to how quickly the phasing-in can occur (Figur 7).

Consequences of transitioning to emission-free public transport

Satisfied customers - attractive service
Emission-free, quiet, clean and efficient public transport will provide a more attractive service to the inhabitants of the region. If the phasing-in should take place faster than what the curves above indicate, there will be an increased risk of reduced customer satisfaction. Operational risk, or delivery problems related to newly-developed material, or a faster introduction than there is sufficient competence to handle, are some examples. Another is the customer's experience of reduced comfort or safety if Ruter makes changes to enable faster phase-in, such as changing from bus class 2 to 1, or changes to services that result in shorter routes and more changes. Thorough communication with, and acceptance of such changes by, customers and the county council will be necessary so that they experience that the benefits outweigh the disadvantages.

Costs
The costs of the transition are primarily related to higher material- and infrastructure costs for emission-free vehicles and vessels. In addition it is expected that in the case of E-bus it will be necessary with more buses for some years ahead to be able to provide the same service. Ruter can wait with phasing in until the cost difference is small (phasing- in "Cost"), while the additional cost of emission-free public transport increases the faster we want to carry out the transition.

Tabell 1 displays estimated additional costs at different phasing-in speeds[10]. The estimates include changes to operating costs as a result of electrical operation, as well as additional costs related to investments in material and charging infrastructure. However, no costs have been entered for major changes to the existing bus facilities, or investments in new ones. Electrification of the bus fleet will require investment in the bus facilities. Nor are the Ruter organization’s restructuring costs included.

	Phasing-in curve	Accumulated estimated additional costs compared to the fossil-free alternative[11] 2018-2030 MNOK	Estimated cost change emission-free vs. fossil-free 2018-2030
Buses	*Curve «Bus Material»*	*630*	*5%*
	Curve “Restructuring”	*340*	*3%*
	Curve «Cost»	*130*	*1%*
Special transport		*200*	*18%*
Ferry		*400*	*20%*

Table 1 Estimated additional costs at different phasing-in speeds for bus, special transport and boat[12].

A great deal of uncertainty is associated with these estimates.

Environment

[10] The "Contract" curve is not a realizable curve and costs have therefore not been calculated
[11] Bus is compared to Euro VI with biodiesel (HVO), boat is compared to the current service
[12] There is considerable uncertainty with the estimates. There has been assumed a flat price development for biodiesel (HVO) and electricity in the period ahead.

The speed at which the environmental benefit of phasing in emission-free solutions can be realized, depends on its speed, but by 2027-2028 all direct emissions from engines should be removed.

Based on the estimated time when the boats may be emission-free and the different phasing-in curves of the bus fleet, the annual discharge of CO_2 is expected to be reduced as shown in Figure 8. The starting point for 2016 is the emission figures provided in Ruter's annual report.

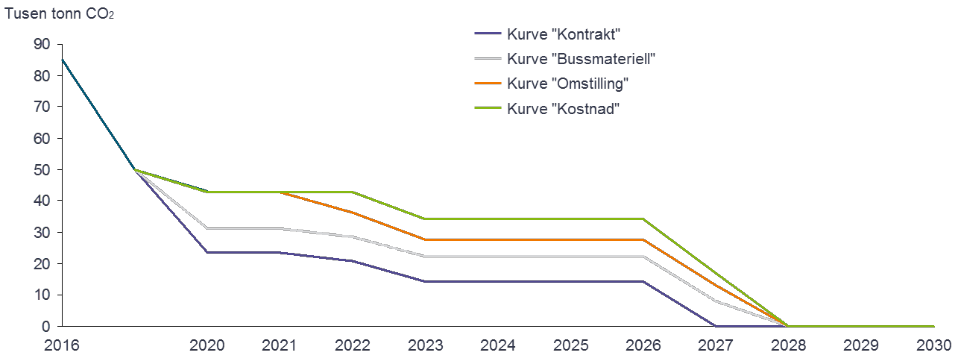


Figure 8 estimated annual CO_2 emissions from public transport at various phasing-in curves for the bus fleet[13]

Estimated emission reductions of NO_x on different phasing-in curves for the bus fleet are shown in Figur 9.

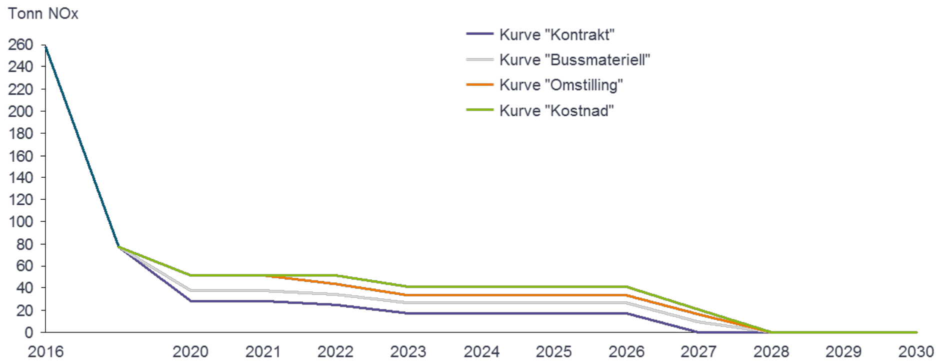


Figure 9 Estimated annual emissions of NO_x from public transport at various phasing-in curves for the bus fleet[14]

Estimated annual emission reductions of particles from exhaust (PM_{10}) are shown in Figur 10 .

[13] The special transport is not included. For the material that is not emission-free, HVO biodiesel is assumed, with 70% lower emissions than the current average.
[14] Special transport is not included. Bus material that is not emission free is assumed to have Euro VI standard and 80% lower emissions than the current average.

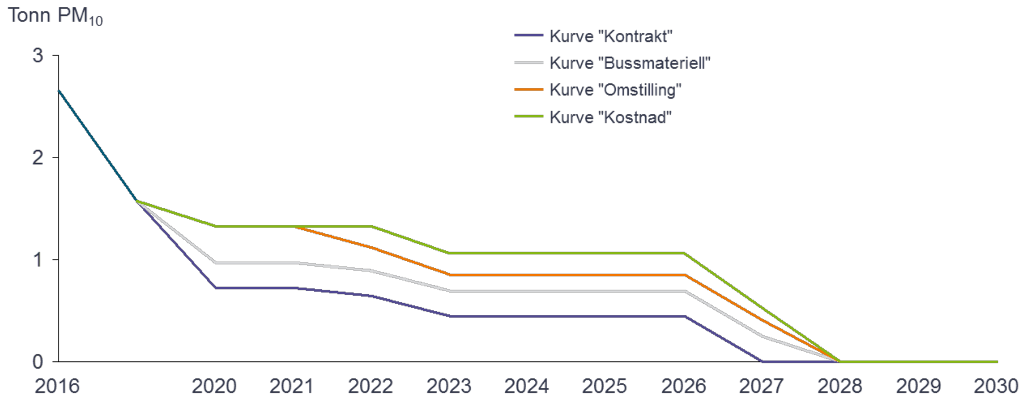


Figure 10 Estimated annual emissions of particles from exhaust (PM10) from public transport at various phasing-in curves for the bus fleet[15]

The socio-economic savings from reduced emissions during the period 2020-2030 are estimated to be in the range of NOK 130 million (phasing-in basket “Cost” and boat) to NOK 240 million (at the phasing-in curve) and includes greenhouse gas reductions and reduced health problems from local air pollution[16]. Estimated reductions and costs are rendered in Tabell 2.

Phasing-in curve	Emission-free in the year	Socio-economic value of avoided emissions (MNOK)	Avoided tonnes CO_2 2020-2030	Avoided tonnes NO_x 2020-2030	Avoided tonnes PM10 2020-2030
Contract	2027	236	344 619	416	11
Bus material	2028	193	280 985	339	9
Restructuring	2028	154	224 678	271	7
Cost	2028	129	188 316	228	6

Table 2 Estimated emission reductions and associated socio-economic savings

The target of emission-free public transport can be realized by the end of 2028. The phasing-in rate will mainly be affected by technological development, and commercialization and restructuring ability within its own organisation as well as with partners and suppliers.

The realization of emission-free public transport requires significant restructuring in Ruter’s own organisation, both in terms of the need for new skills and the capacity to deal with increased complexity and rapid changes. For the fastest possible phase-in, the organisation must be strengthened and adapted so that the zero emission solutions can be used as soon as they are commercially available in the market.

[15] Special transport is not included. Bus material that is not emission-free is assumed to have Euro VI standard and 50% lower emissions than the current average.
[16] Based on the following costs: 350 NOK/tonnes of CO2, 200,000 NOK/tonnes of NOX, NOK 3 mill. tonnes PM. Sources: Vista Analysis 2014 and 2015, TØI 2014.

The transition is expected to lead to increased costs during the period compared with fossil-free operations and the current services.

5. Measures to expedite the transition to zero emissions

Ruter has several ongoing measures where emission-free solutions are on the way in, or are already in operation, illustrated by the shaded area in Figur 7. Five hydrogen buses have been operating since 2012, initially as part of the technology demonstration project CHIC (Clean Hydrogen in European Cities) and, on completion of the project, extended into ordinary operation. Since August of this year, ten battery-operated electric minibuses have been in ordinary operation in special transport. At the end of November, three E-bus tests started up with a total of six buses. Ruter is also working on a new hydrogen bus project, JIVE 2, ordered by Akershus County Council and Oslo Municipality, and we are laying the foundation for a possible electrification of the island boats and the Nesodden-Aker Brygge route.

All four of the phasing-in curves for the bus fleet in Figur 7 are based on when *the contracts* are to be renewed, since it is then that the major changes in technology can take place. In addition, Ruter has different measures that may affect the rate of phase-in. For example, it is possible to replace material by change orders within existing contracts. Ruter is preparing to phase in a larger number of Elbuses (50 +) in existing contracts, in the first instance in Oslo, from 2019. This enables a "soft" transition and prepares the ground for full electrification when the contracts are due for renewed at a later date. In future contracts, flexibility can be introduced with the ability to replace the material along the way to a far greater extent than in today's contracts. All new contracts that are prepared according to such a format increase the scope for a faster phasing-in.

Shorter contract lengths also make it possible to replace the material more quickly in new contracts, combined with a requirement to a proportion of emission-free. Incentive arrangements for the market are an important tool, by using bonus schemes, a high environmental weighting or similar, stimulate the market to faster delivery of emission-free solutions.

Instead of waiting for the necessary *material* to become available, we can endeavour to actively influence and speed up the market by demanding technological solutions that are not available today, such as for the regional buses. Ruter's participation in the new EU project for the commercialization of hydrogen buses, JIVE 2, must be seen in such a context, where we will endeavour to get the market to supply hydrogen buses that meet the requirements to region bus material. It costs to lead the way in the market this way. It is uncertain how large an order has to be in order to have the suppliers develop a new bus, to what additional costs or delivery time. Alternatively, we can change over to other types of material where we have belief in the offer and the customers can bear it.

When it comes to its own organisation, Ruter can expedite *restructuring* by strengthening competence and capacity to support the phasing in of new technology as soon as it becomes commercially available. By changing how the transport service is planned, we can lay the groundwork for E-buses earlier, for example by reducing the length of routes, or changing them so that they can be operated with the emission-free bus models available in the market. If Ruter leaves more of the planning and optimization for emission-free solutions to the bus operators, it can reduce the burden on its own organisation.

The time it takes to realize emissions-free solutions can be greatly reduced by Ruter, concerned agencies and co-operating partners finding more flexible and faster interaction processes, such as in the establishment of a charging infrastructure.

By choosing to accept higher costs for a period of time, the phasing-in may occur at faster rate than by waiting until the *costs* are more or less competitive.

For a future period of time, in five to ten years, the E-buses will continue to be more expensive, both for the purchase of buses and in their operation. Therefore, phasing-in during this period will entail an additional cost compared with a fleet with today's technology, increased costs associated with the annual transfers to operators, and increased requirements to investment in infrastructure.

6. How to ensure a successful implementation

The transition to emission-free public transport involves a system change and restructuring for Ruter, suppliers and government agencies. This is the biggest challenge associated with a quick transition to emissions-free public transport.

In order to effectuate a rapid transition to emission-free public transport without losing quality and customer satisfaction, Ruter must build up additional resources and expertise beyond the existing levels. Capacity and competence needs must reflect increased ambition, and new targets in the area must be firmly entrenched. The organisation must undertake competence- and capacity building activities, as well as communication efforts aimed at creating awareness of the necessary changes.

Access to centrally located bus facilities with sufficient capacity for a larger bus fleet may prove to be the key to realising a speedy electrification of the bus fleet in Oslo. The proximity between the bus facility and the routes to be serviced is particularly important for electric buses since the limited range of buses represents a challenge. The use of bus facilities outside the centre results in a great deal of empty driving to and from the routes to be operated, and a reduced range for use in scheduled traffic.

The operator's ability to deliver changes that are required in introducing electric bus fleets is yet another challenge. Weak value chains, whereby the suppliers are not capable of building up a system and capacity for fault recovery and maintenance sufficiently quickly, will result in operational challenges and potentially lower uptime for the material. Changes to the business model, compensation model, or changes to the contract terms may be important to incentivising the market.

Ruter must have the financial framework conditions that enable the transition to emission-free public transport, without compromising the target of absorbing the growth of passenger transport into public transport, cycling and walking, and helping to reduce motor traffic. In addition, Oslo Municipality and Akershus County Council must arrange for good interaction and progress associated with electricity supply, land use and the necessary planning- and application processes.

Addition after approval by Oslo City and Akershus County, February 2019:

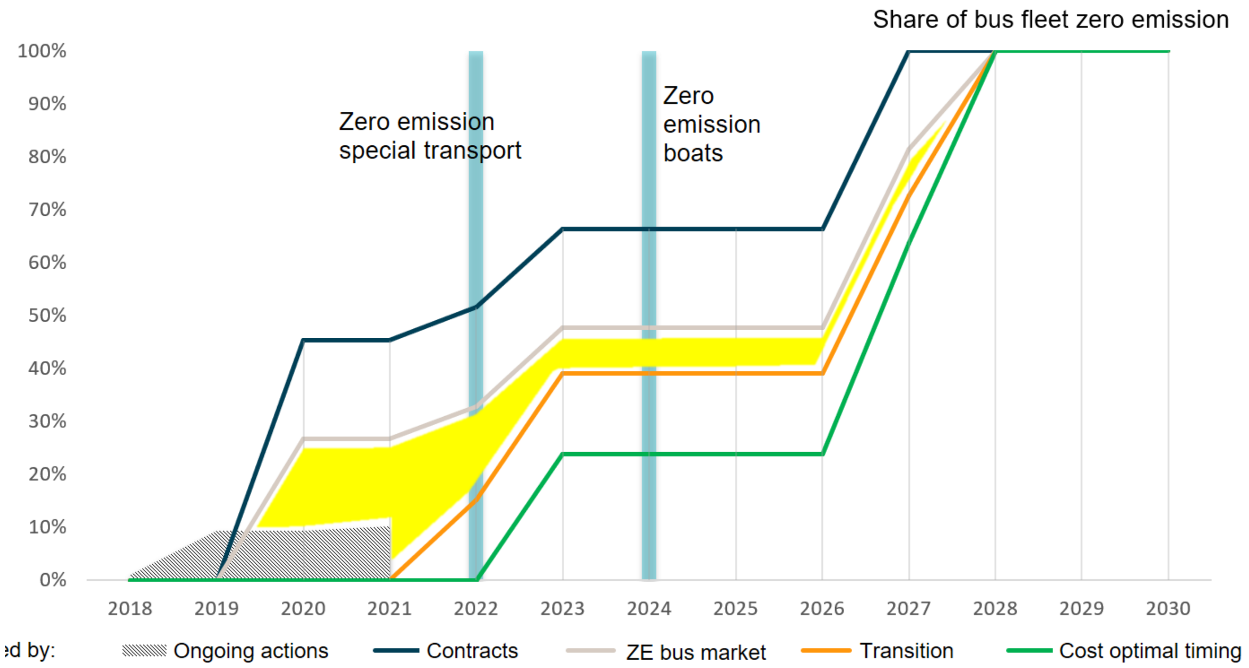


Figure: Concluded ambition level for phase-in of zero emission = yellow marked area, preferably faster if possible