ELECTRICITY

Cooperation on the electrified transport solutions of the future

PROGRESS REPORT 2020

ELECTRICITY

Progress Report 2020 | Jan 2016–Dec 2019

Contents

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Introduction

The ElectriCity project has been underway in Gothenburg since the spring of 2013. It is a collaborative, cross-functional project with partners from industry, the academic world and the public sector. ElectriCity involves developing, testing, demonstrating and evaluating solutions which will contribute to sustainable, electrified travel and transport systems and, as a result, open up new opportunities for urban planning in the future. The project was launched with the goal of promoting the electrification of public transport and has achieved good results in several areas. This has attracted more partners to the project, which has become broader and deeper in its scope. The breadth of the cooperation will create new opportunities for travelling, building and living in the cities of the future.

ElectriCity is driven by the partners' shared vision of the cooperation:

- An innovative and forward-thinking partnership between the city, the region, industry and the academic world in the field of sustainable and electrified travel and transport.
- A region at the cutting edge of sustainable solutions and mobility that attracts skilled people, investments and start-ups.
- An arena for testing new products and services in the field of travel and transport.
- A source of inspiration and motivation for future urban development.
- A world-class automotive and ICT industry.

The content of the vision is put into practice at ElectriCity's demonstration arenas, which are real-life environments where residents can become involved and assess the products and services that are being tested. The cooperation expands the interfaces between the partners and, by means of dialogue, builds the trust that is needed for all the stakeholders to share knowledge and resources in order to bring the vision to life.

Organisation

The partners in ElectriCity are ABB, Akademiska Hus, Chalmers University of Technology, Chalmersfastigheter, the Swedish Energy Agency, Ericsson, Göteborg Energi, the City of Gothenburg, Johanneberg Science Park, Keolis, Lindholmen Science Park, Transdev, the Volvo Group, Region Västra Götaland, Västtrafik and Älvstranden Utveckling. ABB and Transdev joined the partnership in 2019.

The partners test new technology and, because of the open communication between them, they encourage innovation. Mutual understanding is an important feature of ElectriCity. To promote this the organisation has a partner group where all the partners are represented and a steering group with representatives from Volvo, the City of Gothenburg, Region Västra Götaland, Ericsson and Chalmers University of Technology. There are coordinators for the project and the practical work relating to the different activities is carried out in project groups. The partners in ElectriCity have also formed a communication group to publicise the project. ElectriCity will play an important part in the Smart Traffic anniversary project before and during the 400th anniversary of the city of Gothenburg in 2021.

A cooperation that has grown

What began as a project to promote and test the electrification of public transport in Gothenburg has increased in scope and now covers issues relating to the electrification of transport which are linked to the city environment as a whole. The current cooperation period will last until 2021, but the intention is for the project to continue after that.

Important results and ongoing activities

- Route 55: The operation of the demonstration arena has been extended and new buses are being tested on the route.
- Route EL16: New fully electric high-capacity buses for extra services on route 16.
- Fast charging stations with a high power output for routes with high levels of traffic.
- New indoor and outdoor test bus stops designed for the quieter and cleaner electric buses.
- More satisfied passengers and drivers due to the electrified buses.
- Functioning geofencing/zone management for route 55 and route EL16.
- A digital platform where initial ideas for products and services have been developed.
- A marine demonstration arena for testing the electric operation of commuter ferries is under development.

Spin-off-effects and indirect results

In addition to the results listed above, ElectriCity has also led to new cooperations, tender processes and further research. Among other things, major tenders have been held for more electric buses in Gothenburg. Some other examples include cooperative projects relating to the standardisation of buses' IT systems, research projects into noise and air quality measurements along electric bus routes and tests of a new steering system (Volvo Dynamic Steering) on route 55. The impact that electrified transport systems can have in a city has also been demonstrated and has given rise to new discussions about urban planning.

ElectriCity - inspiration and engagement

There is a great deal of interest in the activities that make up ElectriCity. The form of the partnership and the results of the project have been presented in a number of different international contexts. So far, more than 10,000 people have visited ElectriCity, route 55 and route EL16.

The road ahead

The wide-ranging cooperation within the ElectriCity project is now continuing with a focus on existing and potential new projects. The testing of electric buses is still ongoing and new demonstration arenas are being created for commuter ferries and construction machinery. The goal is always for the ElectriCity activities to be scaled up and this has already happened in several cases. This has given rise to new studies of system effects and new initiatives relating to urban planning and construction workplaces.

Transport now and in the future

Electrified transport lies at the heart of the ElectriCity project. Electric buses have been in operation in central Gothenburg since 2015 as a testing and demonstration arena for the project. The buses are powered by renewable electricity[1]. They are highly energy-efficient and quiet and produce no emissions when running on electricity. Silent, emission-free public transport can operate in places that are not currently accessible to traffic. This opens up new possibilities for urban planning. A sustainable, electrified and connected public transport system can also lead to the creation of new products and services, the development of traffic planning and new solutions that are safer for passengers, drivers and the environment.

Route 55

ElectriCity's first demonstration arena, electric bus route 55, was launched in 2015 and has continued to be one of the most public aspects of the project. The route runs between the two campuses of Chalmers University of Technology, Johanneberg Science Park and Lindholmen Science Park, and originally used three fully electric concept buses and seven hybrid buses. In 2017 a pre-production version of another fully electric bus was added and in 2019 a new fully electric 12-metre bus came into operation on the route.

This is a test bus fitted with Volvo's newest powertrain and batteries. It has a total battery capacity of 200 kWh, compared with 76 kWh for the other electric buses on the route. During 2018 one of the three concept buses was phased out and in 2020 the other concept buses will be taken out of operation. The concept buses

> "The ElectriCity project has given us important experience and the courage to start the large-scale electrification of public transport that is now underway in Gothenburg and western Sweden."
>
> Roger Vahnberg, Senior Vice President of Västtrafik

1 All the energy used to charge the ElectriCity buses comes from renewable sources, such as wind and hydroelectric power. A statutory guarantee of origin for electricity is provided to ensure that this is the case. This means that all electricity suppliers must be able to demonstrate which energy sources their electricity comes from. When a customer enters into a contract to buy only renewable electricity, the electricity supplier must buy the equivalent quantity of electricity from renewable energy sources. In Sweden this is monitored by the Swedish Energy Agency.

have been a key part of the ElectriCity project, but the need for them has been reduced as new electric buses have been introduced into the demonstration arena. The tests on route 55 have produced very good results. In addition to adding further electric buses, Volvo has also used the routes for different types of testing. It has evaluated a new alcolock system, a new power steering system and new tyres specially designed for electric buses. The operation period has been extended and services on the route, which is managed by Keolis, will continue until December 2020 at the earliest.

Around 115,000 passengers travel on route 55 every month. Between June 2015 and October 2019 approximately 132,000 journeys were made by buses on the route. The service has been highly punctual, with very few cancellations.

Route EL16

Additional operations between Eriksbergstorget and Sahlgrenska

In 2016 the partners decided to expand ElectriCity's demonstration arena to include parts of route 16. The aim was to test and evaluate the vehicles and charging infrastructure needed for electrified high-capacity services in a dense urban environment in order to be able to make better-informed decisions about future investments in electric buses.

Volvo applied for and was granted funding by the Swedish Energy Agency to develop a demonstration platform for an electrified transport system with medium-sized trucks and high-capacity buses. As part of the project, two prototypes of fully electric articulated buses were developed for use in demonstrations and test operations during a three-year period.

The two electric articulated buses have been in operation since 25 June 2018 on parts of route 16 (EL16). The articulated buses operate between Eriksbergstorget and Sahlgrenska University Hospital during off-peak periods, while in the rush hour they run from Eriksbergstorget to Nordstan.

The buses are used to provide extra services and do not form part of the standard timetable. The operator Transdev is responsible for providing drivers and for the operation of the buses. The buses are maintained in Volvo's depot in Arendal which has been adapted to handle longer buses and a new type of charging system.

In the depot, the buses are charged at night using 150 kW CCS chargers. During the day they are charged at the end bus stops with 450 kW OppCharge systems. The charging concept and the large energy storage capacity of the buses make it possible for them to be charged less during the rush hour and more during off-peak periods. This means that the charging process can be adapted to suit how the bus is being used.

"Route 16 gives us the opportunity to really put the technology to the test. Electric buses are quiet, produce zero emissions and open up new opportunities for urban planning."

Håkan Agnevall, President of Volvo Buses

Three stops on route 16 have been converted and adapted for use with electric buses. A new charging location has been created in Sahlgrenska, with a bus parking space and a new charging station. At Eriksbergstorget, a new charging location has been built with a new approach and a new charging station. At the same time, the bus stop has been upgraded with a new shelter, among other things. At the Lindholmen stop a new bus shelter 4 × 20 metres in size has been built for use with the new buses.

In addition to developing vehicles, bus stops and charging locations, ElectriCity's partners have also cooperated to create an IT system for public transport (ITxPT). The electric buses on route 16 have been equipped with an IT

The two electric articulated buses on route EL16 transport around 30,000 passengers per month. Between June 2018 and October 2019 approximately 13,000 journeys were made by buses on the route.

network to allow for demonstrations of the functions which could make public transport more attractive and cost-effective in the long term.

The tests on route EL16 have produced very good results. The buses have been continuously evaluated and upgraded with new control units and new software. The current plan is for the buses to remain in operation until December 2020.

Route 60 and new tender processes

Following the announcement by the Swedish Energy Agency of its electric bus subsidy[2], Västtrafik was commissioned by the Public Transport Committee for Region Västra Götaland to produce a proposal for replacing buses covered by existing transport contracts in order to speed up the introduction of electric buses on the fixed route bus services in the region.

> "The experience of the ElectriCity project on route 55 and route EL16 has given the partners confidence that the electric bus system will function and is ready to be scaled up to produce a commercial solution."
>
> Peter Nordin, City Mobility Director, Volvo Buses

2 The electric bus subsidy is aimed at regional public transport authorities and transport companies that run public transport systems. The subsidy is intended to cover part of the additional costs of buying an electric bus, when compared to a bus with a combustion engine.

This was done in order to enable everyone involved to learn lessons for the future and to acquire valuable knowledge of how to best meet the aims of future tender processes. This include for example: effective cooperation between municipalities, energy companies and public transport authorities, the ownership and operation of the charging infrastructure and a better understanding of the costs of electrification. In addition, the participants gained useful experience of the necessary modifications to bus stops and depots, the business models for managing vehicles and the charging infrastructure at the end of the contract, the choice of charging infrastructure, the effect on services, the impact of the reduction in noise and the training of drivers and depot staff.

> Preliminary studies are already underway ahead of the 2022 public transport tender processes. By the end of 2020 almost 200 electric buses will be operating in the Gothenburg area. Västtrafik's goal is for all the public transport in western Sweden to be electrified by 2030 at the latest.

The project had to be part of normal operations and so route 60, a busy route in central Gothenburg where residents experience problems with noise, was chosen. In the autumn of 2019 a total of 30 electric buses were delivered to the operator GS Buss and by December 2019 all the buses were in operation.

A tender process, which was won by Transdev, was also completed in the summer of 2019. This involves another 157 electric buses that will operate in western Gothenburg, Mölndal and Partille from December 2020 onwards. These are high-capacity articulated buses supplied by Volvo.

The procurement and introduction of new electric buses has led to a more in-depth cooperation between the partners, a broader view of the issues and a more detailed discussion of the structure of services and charging. The importance of a broad-based cooperation for the electrification of public transport has become increasingly clear.

Charging stations

Work on installing the charging stations for electric buses in the project began in 2011 with the so-called Hyper Buses[3], which ran partially on electricity. The installation of charging stations continued until route 55 was set up in 2015. The end bus stops on the route at Lindholmen Science Park and Johanneberg Science Park were each fitted with a charger with a power output of 300 kW. The ongoing development work led to the OppCharge charging concept, which is an open interface for the fast charging of heavy vehicles. OppCharge is now a standard solution

3 Hyper Bus stands for Hybrid and Plug-in Extended Range Bus system. The project demonstrated plug-in technology for hybrid buses and fast charging stations on bus route 60 in Gothenburg. The project ran from 2011 to 2014.

which is recommended by the ACEA, the European Automobile Manufacturers Association.

After this the planning process began with the aim of extending the use of electric transport by introducing high-capacity buses on route 16 in Gothenburg. Chargers with a power output of 450 kW were installed to allow the electric articulated buses to be charged quickly. A pantograph on the roof of the bus is used for charging purposes. The charging stations are located at the Sahlgrenska and Eriksberg bus stops. The electricity grid at Sahlgrenska needed improvements. Genab, the Town Planning Office in Gothenburg and Göteborg Energi produced a solution that had no impact on the detailed development plan for the area.

These earlier projects allowed the partners to gain experience and valuable knowledge which will make the development of the charging infrastructure easier during the forthcoming large-scale implementation of electric buses. For example, prefabricated foundations for chargers and charging posts are now available. A commissioning process with completed test reports has also been developed.

Before charging stations can be installed, the sites have to be prepared. This work must be coordinated with the town planners and planning permission must

Sweden's first fast charging station for heavy trucks is located on Falutorget in Gothenburg.

be obtained. In addition, agreement must be reached on who is responsible for operating and maintaining the charging stations and who owns them. More recently, processes for allocating responsibility have been developed. An ongoing challenge is to ensure that the relevant bodies are informed quickly about problems with the charging process. This is important because the chargers must be seen in a wider context and can have an impact on many of the stakeholders, including operators and passengers, who need information on an appropriate level.

At the end of 2019 the introduction of a large number of chargeable buses and the accompanying infrastructure began in Gothenburg[4]. This is the direct result of the preparatory projects that formed part of ElectriCity over recent years.

4 The articulated buses have five batteries with a total capacity of 250 kWh. The batteries are charged at the end bus stops using OppCharge chargers supplied by ABB. The buses are designed to allow for efficient passenger flows and have large areas for standing passengers. The total capacity is 135 passengers.

Urban goods transports

Electrification creates new opportunities for freight transport in cities

Electrified vehicles open up new possibilities for transporting goods, including night-time deliveries. Lower levels of exhaust emissions and less noise help to improve the local environment and create a better working environment for drivers.

As part of a project funded by the Swedish Energy Agency, with the aim of creating a demonstration platform for an electrified transport system with medium-sized trucks and high-capacity buses, two prototypes of fully electric trucks were developed for use in testing and demonstrations.

An electric delivery truck and an electric refuse truck were presented during the Volvo Ocean Race in June 2018 to demonstrate the opportunities offered by electrified goods transport.

The trucks are now being used for testing purposes in the Gothenburg area. The refuse truck is being operated in field trials by Renova and the City of Gothenburg. The delivery truck is taking part in field trials involving Coop and Schenker/TGM. The field trials are part of the DenCity project, which is being run in the context of CLOSER.

Research, the environment and studies

Which new opportunities emerge when the public transport system in a city is electrified and noise and exhaust free? This is the question being asked by researchers studying the impacts and benefits of electrification for the city environment as part of the ElectriCity project. By focusing on noise, the environment, safety, technology, behaviours and sustainability, it has been possible to move forward with developments on behalf of the city and its residents.

Autonomous buses tested as part of ElectriCity

An autonomous Volvo bus was presented as part of the ElectriCity project during the Volvo Ocean Race in June 2018. This was the first time that Volvo had demonstrated an autonomous bus to the media, customers and other stakeholders. The demonstration took place in an area of Frihamnen made available by Göteborgs Frihamns AB.

Among other things, the demonstration showed how the technology can help people to travel more comfortably and safely, particularly the elderly and passengers with disabilities. This can be achieved, for example, by braking gently and approaching bus stops automatically, with the bus always stopping in the same position and at the same distance from the pavement or platform, to make it easier for people to get on and off. Precise positioning at the bus stop also reduces the wear on the tyres and the infrastructure.

The Volvo bus is part of the FFI[5] project ”City bus automation - bus trains, bus stop docking and depot processes” and the Drive Sweden project KRABAT, which in addition to the Volvo Group also involves Chalmers University of Technology, the Urban Transport Administration of the City of Gothenburg, Lindholmen Science Park, Region Västra Götaland, Västtrafik and Älvstranden Utveckling AB.

Since the demonstration in Frihamnen, the autonomous bus has been used for ongoing research and development. The technology also makes vehicle handling inside bus depots more efficient. Another demonstration of the technology was held in November 2019 at the Keolis depot in Partille outside Gothenburg. Visitors had the chance to see how the bus could operate autonomously during daily activities such as parking, cleaning, washing and charging.

Autonomous technology is being tested as part of the ElectriCity Innovation Platform

When services were launched on route 55 in Gothenburg, work began on creating a digital innovation platform – the ElectriCity Innovation Platform – to encourage innovations and development projects. By collecting and sharing data from ElectriCity's partners, it was possible to lay the foundations for the development of digital services. The first project on the platform was ElectriCity's major innovation competition in 2015, with 48 teams presenting proposals for innovations which could help to make bus travel more attractive in the future.

The next step was taken in 2017 when an experiment was started which used buses on route 55 as mobile measurement stations. Air quality and noise sensors were installed on the buses which record data every minute and upload it to the innovation platform. The Environment Administration of the City of Gothenburg became involved at the start of the experiment and calibrated the sensors on the buses against the permanent measurement stations. After this, a formal collaboration began on related projects run by the Environment Administration and the IVL Swedish Environmental Research Institute.

During 2018 conceptual tests were started with the aim of improving the safety of vulnerable road users, such as cyclists and road workers, by linking them to the innovation platform. The background for this is that large, almost silent buses are likely to be less noticeable and the project wanted to try out a system which informed drivers and cyclists that they were close to one another and that there was the risk of an incident occurring.

5 FFI stands for Strategic vehicle research and innovation programme and is a joint project between the automotive industry and the Swedish state.

”Drivers' stress levels are lower because the buses are quiet and, in addition, emissions are reduced.”

Ann-Sofie Aiazzi, Deputy Business Manager, Transdev

A so-called geofence was set up on the buses and on a number of Styr & Ställ (bike sharing) bikes to log the position, direction of travel and speed of the buses and the bikes. A geofence is a geographic area around the vehicle. In this case the area around the bus/bike was defined and if the circles overlapped, both the bus driver and cyclist were warned and given information about the location of the other vehicle. The results of the tests were positive and led to a number of follow-up projects, including one with semi-autonomous vehicles and a major initiative using dynamic geofences for the City of Gothenburg, run by the Urban Transport Administration.

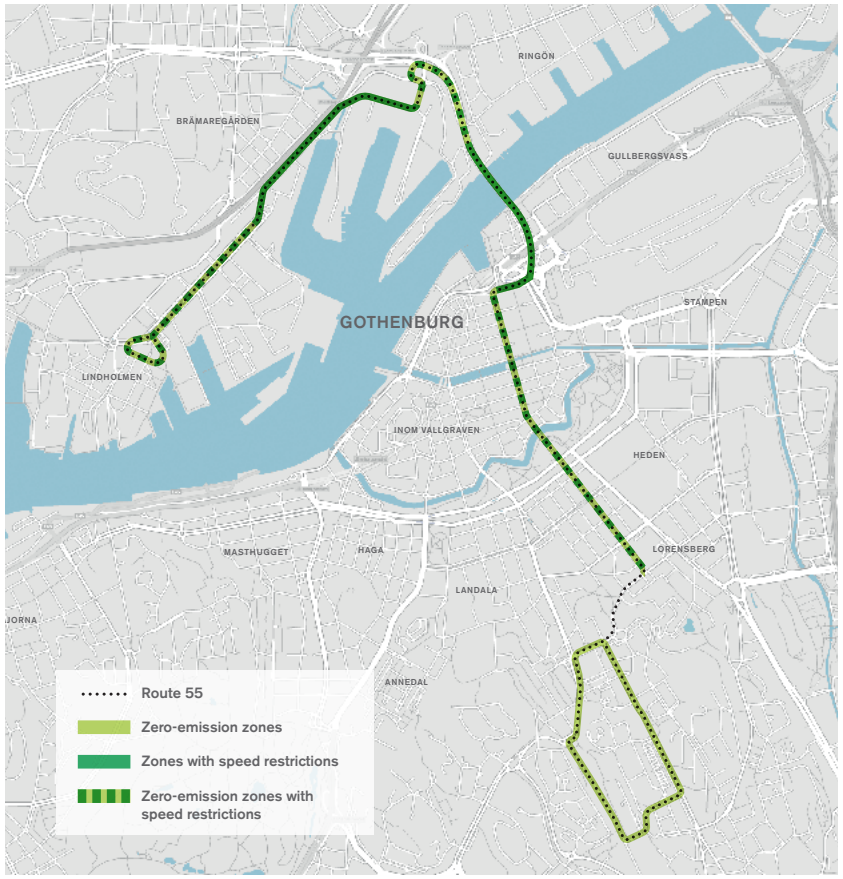
Geofencing /Zone Management

A geofence is a geographic area where access by vehicles and their speed and use of fuels can be controlled via digital systems. The aim is to improve road safety, reduce emissions, lower noise levels and create a better traffic flow in Gothenburg and other cities.

In Gothenburg geofences are used on the Volvo buses operated by Keolis and Transdev on routes 55 and EL16. The buses change over to electric operation and cannot run faster than the maximum speed limit (see the map on page 20).

Photo: Patrik van Meer

A geofence is used to limit the speed of the buses on routes 55 and EL16 to 15 km/h, which is the current speed limit for heavy vehicles crossing the bascule of the Göta Älv bridge. The purpose is to reduce the stress on the bridge.



The experience gained has been positive. Drivers' stress levels are lower because the buses are quiet and, in addition, emissions are reduced.

Now geofences are being set up so that vehicles are guided through zones that have been manually defined in Volvo's Fleet Management system and then downloaded to the vehicle. The Digitalised Infrastructure Zone (DIZ2) project, which began in 2019, will investigate whether traffic regulations and zones can be controlled digitally via a cloud service and identify what advantages this could bring. The project is being managed by the Urban Transport Administration of the City of Gothenburg.

The goal of the DIZ2 project is to identify what is needed by a road maintenance authority to set up and make available geofenced zones for restricting speeds and controlling powertrains. A technical solution will be developed to make zones and the relevant zone attributes available to vehicle manufacturers and other stakeholders in real time.

The project will also identify the organisational requirements and the processes and tools needed to allow the Urban Transport Administration and, in the long term, road maintenance authorities in other cities to provide geofences.

The City of Gothenburg is also investigating the possibility of improving driver assistance systems in all the forms of transport and vehicle fleets that the city itself is responsible for.

Noise study

According to the World Health Organisation (WHO), loud and disruptive noise is a growing and underestimated health problem in Europe. The organisation estimates that one in every five European citizens is regularly exposed to noise levels which are so high that they can have a negative effect on health. A noise survey published by the The Environment Administration in the City of Gothenburg based on traffic data from 2018 indicated that around 135,000 of Gothenburg's residents are exposed to traffic noise above 55 dBA in their homes everyday. In a study commissioned by Volvo in 2015, seven out of ten residents of Gothenburg said that they were disturbed by high levels of noise in the city. The majority were

troubled by traffic noise and more than half said that they had suffered physical or mental health problems as a result of loud noise.

A noise study was carried out as part of the ElectriCity project in 2016 which involved comparing differences in the noise patterns of electric buses, diesel buses and LNG buses. The study showed significant differences in noise levels at speeds up to 40–50 km/h. The electric buses were obviously quieter than the others. The

differences were greatest in relation to low frequency noise which is most difficult to block out using noise insulation, facade materials and windows.

A shift to electrified buses and other heavy vehicles in Gothenburg and other cities would likely lead to a reduction in the need for noise insulation measures and additional sound-absorbing facades in some areas.

When electric buses are introduced on a large scale in Gothenburg, detailed studies will be carried out to evaluate how people living along the electric bus routes are affected. This will take the form of new noise measurements and interviews with residents. The Sound Environment and Health research group at Sahlgrenska Academy, which is part of University of Gothenburg, is studying the effects of the sound environment following the electrification of route 60. The route passes through vulnerable areas of the Lunden and Masthugget districts where the hilly city environment means that vehicles work hard when climbing the hills and produce low frequency noise as a result. The study analyses changes in the sound environment by measuring noise in people's homes and carrying out surveys of the groups exposed to noise in the vulnerable areas. At the same time, work is continuing to further reduce the disruptive noise caused by buses by damping the noise from the buses' assistance systems and by using low-noise tyres designed for electric vehicles.

Air quality study and the involvement of students

One of the buses on route 55 is equipped with a sensor that can measure the levels of particulate matter in the air. Ericsson connected the sensor to the ElectriCity Innovation Platform to investigate the air quality along route 55. However, it was not clear how good the quality of measurement data from the simple sensor on the bus was in comparison with measurement data generated by advanced sensors in the permanent measurement stations operated by the The Environment Administration in the City of Gothenburg. In a project involving Chalmers University of Technology, Ericsson, Västtrafik, Volvo, Johanneberg Science Park and RISE, students on the computer science and engineering course who took the sustainable development module in the autumn of 2018 were presented with a number of challenges. The students investigated how the data from the air quality measurements could be used. After the module had finished, the students continued working on the problem in their dissertations and then as part of their summer jobs at Ericsson.

The students identified and implemented a possible solution for connecting and providing a power supply to several small, cheap sensors on the ElectriCity vehicles and the bus stops at Chalmersplatsen, Teknikgatan and Kungsportsplatsen. They developed a web application which showed the figures from the buses on a map together with the figures from the Environment Administrations permanent measurement stations. Subsequently they carried out a comparative analysis which indicated that the cheap sensors correlated with the Environment Administrations advanced sensors, but that the precise figures could differ and so it was not appropriate to make the measurements publicly available. All the partners were satisfied with the project and the same module was run again with the same structure during the late autumn of 2019. In addition, Jonas Wilhelmsson at Ericsson was awarded collaborator of the year at Lindholmen, the students were awarded the Chalmers prize for entrepreneurship and Frances Sprei and Håkan Burden received the Chalmers educational prize. The experience gained during the project forms the basis for an application to the EU for a project to scale up the measurements and use the analysis of the data to introduce measures that could improve the air quality in urban environments.

Passenger surveys

The customer satisfaction surveys carried out on the electric buses show that the passengers had more positive experiences of route 55 and route EL16 than of other types of public transport. The passengers felt that they received more positive treatment from the drivers, the electric buses were more comfortable, gave a smoother ride and were cleaner and quieter, the information on the signs was better and the atmosphere was more pleasant. The passengers also believed that routes 55 and EL16 contribute to creating a better urban environment because the buses are quieter and produce no exhaust emissions.

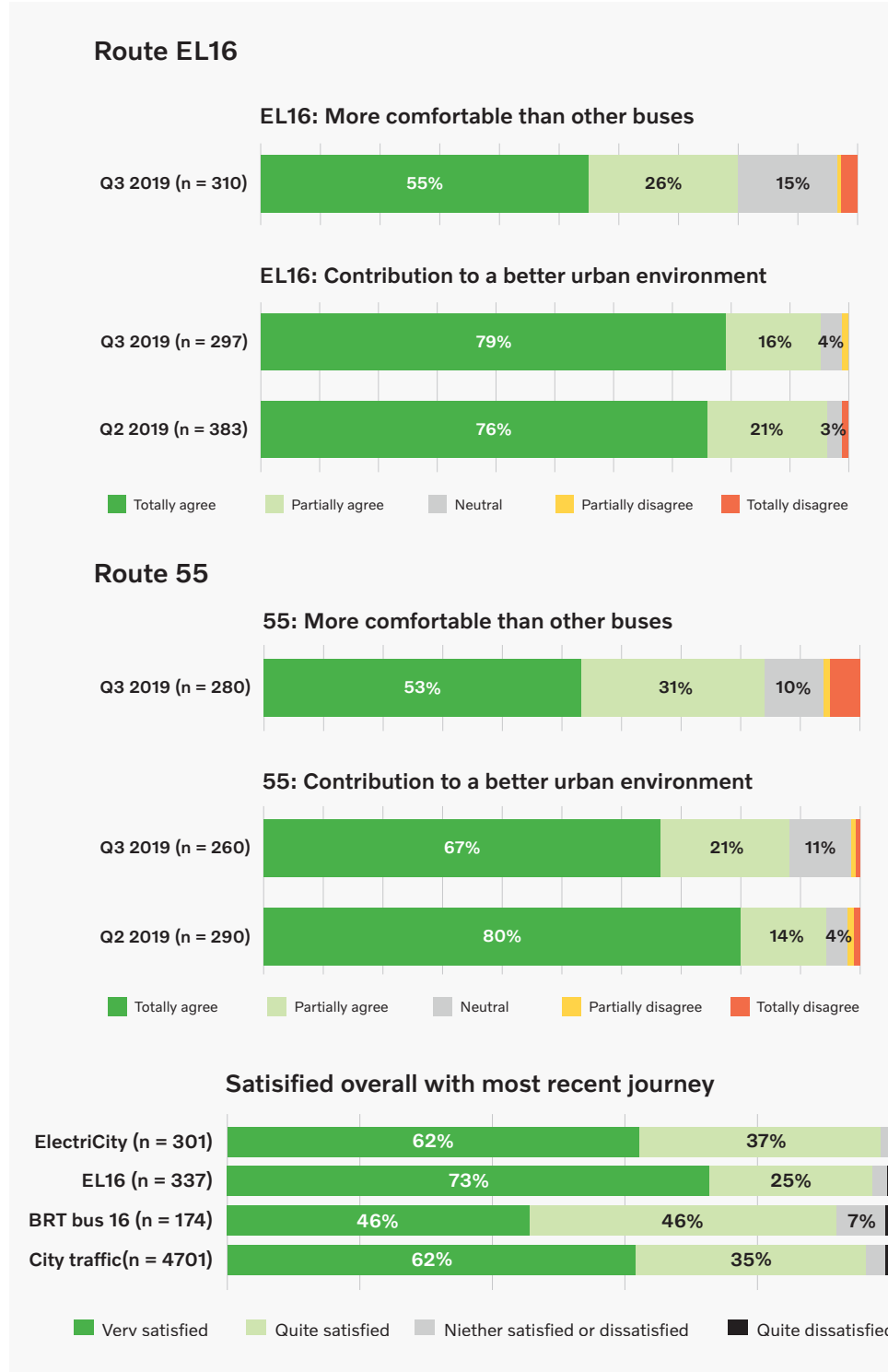
The drivers' working environment

The drivers are satisfied with the electric buses. When the drivers were surveyed, they said that they are proud of driving a modern vehicle which is valued by customers and helps to improve sustainability and create a more pleasant urban environment. The drivers also appreciated the fact that the electric buses give them a quieter and more comfortable working environment.

A new dynamic steering system tested in the ElectriCity buses provides effective support for drivers.

The Volvo Dynamic Steering system was tested and evaluated in the electric buses in Gothenburg. A study by Chalmers University of Technology showed that the system reduces drivers' problems with tiredness and pain.

Drivers of large vehicles with relatively heavy steering often suffer from pain in their arms and shoulders. To reduce the occurrence of this type of problem, Volvo developed Volvo Dynamic Steering (VDS), which eliminates vibrations and shocks that can be transmitted through the steering wheel. At the same time, it makes manoeuvring in tight spaces easier, because the steering wheel resistance is



reduced by up to 75 percent at slow speeds. The wheel also automatically returns to its starting point when the driver releases it.

> ”If you compare the noise levels with other buses, the difference is enormous.”
>
> Kristina Book, driver on route 55 2015-2018, Keolis

In the summer of 2017 Volvo Dynamic Steering was installed in seven of the buses on route 55. The results of a long-term study of the drivers of the buses on the route clearly showed that work-related physical problems can be reduced with the help of the new steering system. The study was carried out by researchers at Chalmers University of Technology over a period of 18 months. It showed that the drivers who reported moderate to severe problems before the study either found that their problems were reduced to the level of minor or non-existent or did not experience an increase in their problems when they were using VDS.

Viva housing project – bus batteries get a second life

The reuse and recycling of batteries is a key issue as more and more cities plan to move over to electrified transport systems. In September 2018 an energy storage of used electric bus batteries was created, probably for the first time in Europe. After the first operational period of three years, Volvo handed over 14 batteries from electric buses on route 55 to the Viva project. Since then the batteries have been used to store solar energy. This is part of a research project where Volvo, Göteborg Energi, Riksbyggen and Johanneberg Science Park are investigating the storage of electricity in residential buildings that produce their own electricity from solar panels.

The research is taking place in the Riksbyggen Viva residential development in Guldheden in Gothenburg which aims to become Sweden’s most innovative and sustainable housing association project. In the Viva development, which consists of 132 homes, the research project has created a unique system that stores energy from the solar cells on the buildings’ roofs in the second-hand electric bus batteries. The energy storage is used to shave power peaks at the property and to store and sell excess solar energy that is produced on site. It will also be possible to buy and store electricity from the grid when it is cheap and green for later use. In December 2019 the Viva project was named the best building development of the year in Gothenburg by the City of Gothenburg.

The battery storage consists of 14 used lithium ion batteries from the electric buses. They have been installed in a battery room and connected together to form a 200 kWh energy store.

An evaluation is now being carried out of how the system can be combined with smart algorithms to increase the environmental and cost benefits for the Viva project and, in the longer term, the city’s district heating network and electricity grid.

Göteborg Energi is cooperating with RISE and Chalmers University of Technology on several research projects to develop smart energy solutions. Volvo is assessing how well the batteries perform in the different types of operations that are being tested. The results so far have shown that the batteries are ideally suited to this type of application. However, there are some problems with the communications between the different systems involved in managing the facility.

IT for public transport

Existing technical solutions represent a challenge that innovations often have to adapt to, not least in the transport sector. The aim of the RIVSILON project is to overcome the obstacles between existing and new technology by enabling the creation of international standards for IT systems on board buses. Tests have been carried out in a local arena in Gothenburg close to the public transport system and in collaboration with various different stakeholders. The goal is to ensure that the technical equipment on board buses can function more effectively with new and different software solutions.

The standardisation work will contribute to the following areas:

- Increasing economic sustainability and reducing dependency on suppliers.
- In the long term allowing the vehicles to be equipped with the right IT infrastructure in the factory to reduce the need for retrofitting. This will simplify

when changing operators and make it possible to use the same vehicles for different public transport authorities.

- An increased focus on the services on board rather than the technology, which will make development and innovation easier. This can also reduce the need for logistics systems, warehouse management and maintenance of technical equipment which is currently a problem for public transport authorities.
- A change in the distribution of responsibility for IT on board, which will allow the public transport operator to take on more responsibility, rather than the public transport authority.
- Allowing the public transport authority to focus on setting requirements for functions and services instead of technologies and on determining how the services should be delivered

Research on the ways of working in ElectriCity

The KIVI project (Collaborative innovation: a path to increased innovative ability) ran from 2017 to 2019. The project studied collaborative innovation processes and ElectriCity was one of two practical examples. It focused on aspects such as the dynamics, the interaction and the challenges involved in the cooperation between the partners.

The study made it clear that ElectriCity is based on a shared vision, dialogue, practical work and trust. The ElectriCity project has no specific project leader, but instead a neutral coordinator who in this context could be described as an intermediary leader. The working method requires discussions between the partners, clear expectations of the results and of each other and a determination to deliver. The role of the intermediary leader is to promote discussion, trust, a sense of responsibility and the determination to deliver. Among other things, the study resulted in a tool for managing projects with a structure similar to that of ElectriCity.

ElectriCity in the city of the future

What happens in a city when the vehicles are electrified and the air is clean? How does life change when vegetables can be grown on walls and roofs in the middle of the city? What opportunities are created by quieter vehicles with less vibration? Which other areas can be electrified to improve the cityscape and the residents' well-being? These are some of the questions that are important to consider when creating a more sustainable city.

Presentation of the city of the future at the Volvo Ocean Race

In the entrance hall to the Volvo Ocean Race 2018, there was a presentation of how the electrification of buses and other heavy vehicles can change the cityscape. Volvo collaborated with the City of Gothenburg, Region Västra Götaland/ Västtrafik and Chalmers University of Technology to create a vision of a quieter,

> "We want to give visitors an understanding of how electrified transport systems can fundamentally change our cities for the better. With cleaner air and less disruptive noise, we can create a more peaceful and healthier environment which will encourage people to adopt a sustainable lifestyle"
>
> Niklas Gustafsson, the Volvo Group chairman of ElectriCity

greener and more people-friendly urban environment, which is not polluted by exhaust gases or noise and which can therefore be used in new ways.

The event included the premier of the new electric articulated buses. Visitors could use them to travel on the Volvo Ocean Race route from Nordstan and the entrance hall to the race area in Frihamnen. The visitors found plants growing from the ground up to the ceiling and everything that was being cultivated was

edible. In addition to the electric articulated buses, an electric delivery truck and an electric refuse truck were also in operation in this environment. A large number of talks were also held in the area on the subject of electrifying heavy traffic in cities. These can be found on YouTube under the title 'ElectriCity talks'.

How should cities with electric vehicles be built?

Benefits for society and new opportunities for urban development

After several years of collaboration on the ElectriCity project, it is clear that the electric buses and the charging systems are working well and that the bus drivers, passengers and people who live and spend time along the bus routes are very satisfied.

In addition to the advantages on an individual level, there is a whole series of potential benefits on a system level and a societal level. Electric buses and other electric vehicles create new opportunities for mobility and for urban development as a whole.

The low noise levels and the absence of exhaust emissions allow the buses to travel to places where it previously was not possible for them to operate. The bus stops can be moved closer to areas where people move about. It is possible to have more bus traffic in noise-sensitive areas and to plan new routes in areas where there are currently high levels of air pollution. This will also give urban planners greater freedom in the future, by reducing the conflict between traffic and areas where people live and spend time. This in turn allow cities to be built more densely. The shift to electric buses and other electric vehicles is therefore an important enabling factor for the future development of Gothenburg into a green and easily accessible city.

Indoor bus stops

On route 55 an indoor bus stop is being tested at Teknikgatan in Lindholmen. The experience gained so far has been positive. However, this is an end bus stop where there is often a bus waiting that passengers can get on. Passengers would probably benefit more from indoor bus stops along the rest of the route. This would give them a comfortable place to wait and allow them to shop, run errands or work while they are waiting, because an indoor bus stop can be located closer to shops, parcel collection points and other services.

A number of factors need to be investigated before indoor bus stops of this kind can be created: How will the buses drive into and out of the building? Will they have to cross pavements and bike lanes? How far can the buses travel indoors and what speed can they operate at? How can safety be guaranteed at indoor bus stops?

These questions were considered during a project run by Älvstranden Utveckling in Frihamnen where an indoor bus stop was planned in one district. Various options for the design and location of the indoor bus stop were produced, each of which had advantages and disadvantages. However, the challenges that were identified in the different scenarios can all be overcome. The project concluded that there is no standard template for indoor bus stops which can be used everywhere. Instead the unique circumstances of each location need to be taken into account.

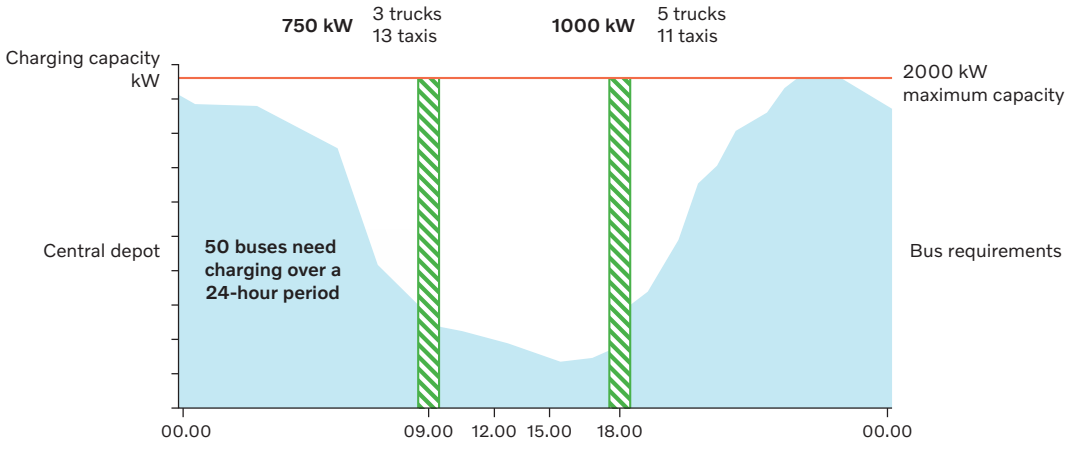
Low noise levels and the absence of exhaust emissions open up new possibilities for the location of bus stops and depots.

One potential site for an indoor bus stop is on Per Dubbsgatan at the entrance to Sahlgrenska hospital. Moving the bus stop into the entrance would free up valuable space to develop. It would also be a more convenient solution for passengers. However, it will involve several operational challenges.

Central bus depots improve the conditions for electrified public transport

The fact that electric buses produce less vibration and noise and no exhaust emissions makes it possible to think outside the box when deciding on the design and location of bus depots. This can change the urban planning requirements and also allow other vehicles to use the charging stations in central locations. On the basis of the experience of the ElectriCity project, Volvo, Göteborg Energi and Skanska have investigated the usefulness of centrally located electric bus depots. Depots and charging stations close to the bus routes are essential for the efficiency of electrified public transport systems. They open up new opportunities for services in local areas which can reduce the need for charging at bus stops. The specific improvements include:

- A reduction in the number of empty journeys to and from the depots
- Lower driver and fuel costs
- Optimised battery size
- Lower environmental impact
- Fewer buses needed
- The flexibility for buses to change to different routes. Provided that they have sufficient battery capacity, the buses do not need to travel to charging stations that are not on their route



If other modes of transport, such as taxis and trucks, can use the available capacity during the daytime, this will reduce the total installed power requirement.

However, because of their energy usage, high-capacity buses will need more frequent top-up charging at end bus stops and/or at central hubs.

Depots close to the routes also allow for top-up charging during off-peak hours which leads to greater use of the buses, a reduction in the need for large batteries, sharing the cost of grid connections and the possibility of a lower or shared investment in and a higher usage rate of the charging facilities. This last benefit can be achieved if other modes of transport, such as taxis and trucks, can use the available capacity during the daytime and therefore reduce the total installed power requirement.

> ”Building the Gothenburg of the future, with sustainable mobility and a high-quality city environment, requires innovative solutions and strong partnerships. ElectriCity is an excellent example of what we can achieve together in the city.”
>
> Malin Andersson, Head of Department at the Urban Transport Administration of the City of Gothenburg

Depots close to the bus routes can also be integrated into the urban environment and the value of the land can be exploited to the full by building commercial premises and homes above the depot, which is currently difficult because of exhaust fumes, vibration and noise.

Work on developing these benefits further is already underway. The City of Gothenburg and Region Västra Götaland have signed a letter of intent covering the infrastructure needed for electric vehicles, including depots. The region, the city, Västtrafik and Västfastigheter are also collaborating to develop depots with the capacity for charging, servicing, maintaining and repairing electric buses. This work will accompany a project focusing on options for charging buses at bus end stops.

In addition, a project is taking place in the south-western part of the city. The goal of the Radiomasten project is to create a depot with the capacity for 110–120 electric buses. The plan is for the depot to be completed by 2024 at the latest. In the short term, before the Radiomasten depot is finished, temporary charging capacity for around 60 electric buses will be provided at the Kville depot north of Backaplan. Investigations into where new electric bus depots with a capacity for 60–80 buses can be located are also taking place in the north-east of Gothenburg and in Hisingen north-west of the city.

In the city centre, attempts are being made together with the City of Gothenburg to find a site for a new electric bus depot that can accommodate around 100 buses. Projects are already underway in Partille and Mölndal to ensure that sufficient capacity is avaliable for electric buses in existing depots.

Electrified machines and vehicles in construction workplaces

The partners in the ElectriCity project intend to develop a new demonstration arena for electrified construction machines. Volvo Construction Equipment, the City of Gothenburg, NCC, Chalmers University of Technology, Lindholmen Science Park and Göteborg Energi have been granted funding to carry out a feasibility study by the Swedish Energy Agency. The study will investigate the possibility of setting up a demonstration arena with different types of electrified construction equipment.

There is a great deal of potential in this area and the partners in ElectriCity have the right skills and network to demonstrate under real-life conditions how electrification can benefit the local environment and the working environment.

Marine demonstration arena

The project also aims to establish a demonstration arena for electrified, fast-charging ferries. The plan is for the Älvsnabben 4 ferry, which currently operates on the Göta river between Lilla Bommen and Klippan, to be converted to electric operation by Volvo Penta in collaboration with Västtrafik's operator Styrsöbolaget, which is part of Transdev.

The project will be implemented in two phases. Phase one involves converting the existing powertrain into an electric system which is charged by a generator on board that runs on fossil-free fuel (HVO). Fast charging will be introduced in phase two, which means that the ferry will be fully electric.

Volvo Penta, ABB and Chalmers University of Technology are currently carrying out a preliminary study to evaluate various technical solutions that can overcome the challenges involved in the fast charging of electric ferries. Among other things, the study will investigate whether the fast charging technology used on bus routes 50 and EL16 can be adapted to a marine environment. The study is supported by the Swedish Energy Agency.

An award-winning project

Researchers, companies, politicians, public authorities and private individuals from all over the world have shown interest in both the ElectriCity partnership and collaboration in itself, as well as in the results that has been achieved. More than 10,000 people have so far visited ElectriCity and routes 55 and EL16.

The project has been recognised on the international level and has received the following awards: The Polis network "Thinking Cities Award 2018", the UITP Award for "Operational and Technical Excellence" 2017, the "Euro¬China Green & Smart Cities Award 2016" and the "European Solar Prize – the best example of sustainable public transport using renewable energy" 2015.

"One of the strengths of the ElectriCity project is that we have been able to demonstrate all the benefits which electric bus services can bring for the climate, for the urban environment and for our drivers and customers."

Hanna Björk, Head of Sustainability, Västtrafik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