ELECTRICITY
Cooperation for sustainable and attractive public transport
STATUS REPORT JUNE 2016
ELECTRICITY STATUS REPORT

[Image of an electric bus]
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Image copyright: Volvo, Riksbyggen, Business Region Göteborg
Introduction

The ElectriCity partnership has been underway in Gothenburg, Sweden, since the spring of 2013. It is a collaborative, cross-functional cooperation with partners from industry, the academic world and the society. ElectriCity involves developing, testing, demonstrating and evaluating solutions which will contribute to the establishment of new, sustainable, attractive public transport systems and open up new opportunities for travel and urban planning in the future. Using electric power in public transport systems helps to resolve the problems in the future caused by noise and poor air quality and significantly reduces energy consumption and the impact of transport on the climate. It creates new opportunities for travelling, building and living in the cities of the future. This is an area in which western Sweden is leading the way.

ElectriCity consists of:
- A new bus route – route 55 – with electric buses operating in central Gothenburg.
- A demo arena for new bus stop solutions, transport management systems, safety concepts and networked technology and systems for energy supplies and storage, for example.
- A platform for research into urban planning and building, technological development and behaviour patterns.
- A source of inspiration and motivation for future urban development.

The current cooperation period will last until 2018, but the intention is for the partnership to continue into the 2020s. This report describes the project content and status at the end of the first half of 2016. The most important results already achieved are as follows:

- A test route for electric and electric hybrid buses in the city of Gothenburg with around 100,000 passengers per month. The test bus stops are both outdoors and indoors. The service is very punctual with few cancellations.
- During the first year, the electric hybrid buses operated for 77 percent of the time on electricity and otherwise on renewable HVO fuel. This led to high levels of energy efficiency and low emissions.
- It has been possible to run the service on a high percentage of electricity even during periods when only one of the two charging stations was in operation. The predicted charging time was 6 minutes, but it has become clear that 3–4 minutes is adequate for a 7.6 km route.
- The passengers are much more satisfied with route 55 than with other public transport systems in the city. They responded particularly positively to the access to free WiFi, the option of charging their mobile phones on board and the low noise level in the buses.
- The drivers enjoy operating the buses on route 55 and work well with the staff in the workshop and the depot. The zone management system is functioning effectively. This ensures that the buses automatically travel at slow speeds in...
areas where there are pedestrians and cyclists. It also controls when the electric hybrid buses run on electricity.

- The indoor bus stop is working well in technical terms and receives a positive response from 78 percent of passengers. However, it is not clear how the bus stop area should be used by passengers. Property owners who are planning to install bus stops in future are considering the option of creating indoor bus stops and of enabling buses to drive close to a building and dock with it. When bus stops are integrated into buildings, new questions arise about the boundaries between private and public spaces.
- The experiences from the ElectriCity partnership show that a city, region or bus operator that intends to set up an electric bus service needs to discuss with stakeholders about the project management of the start-up phase and about charging, among other things.
- A digital platform has been established and used in an innovation competition which involved developing initial ideas for services and products. The partners have identified that the process of accepting ideas for the demo arena needs to be developed further in the future.
- ElectriCity has also attracted a great deal of international attention. Nine out of every ten residents of Gothenburg have heard of ElectriCity and route 55. During the first year around 100 delegations consisting of approximately 5500 visitors came to Gothenburg to find out about ElectriCity. This included a large number of visitors from foreign cities and regions.

Organisation

The partners in ElectriCity are the Volvo Group, Keolis, Chalmers University of Technology, Chalmersfastigheter, Akademiska Hus, the Swedish Energy Agency, Lindholmen Science Park, Johanneberg Science Park, Region Västra Götaland and Västrafrik (the regional public transport company), the City of Gothenburg and Trafikkontoret (City of Gothenburg, Urban Transport Administration), Business Region Göteborg, Göteborg Energi and Älvstranden Utveckling. Ericsson joined ElectriCity in June 2016. For a presentation of each partner’s role, visit www.goteborgelectricity.se

ElectriCity is based on a shared vision of sustainable transport in which cities, regions, businesses and academic institutions develop working methods for research and demonstration projects involving private and public sector players and the academic world and produce new scalable business models for sustainable transport in cities. The aim of ElectriCity is to make use of electric buses and new connected services and products to create attractive public transport solutions and urban developments. All the partners are expected to take part in activities in these areas and in many cases the activities involve mutual dependencies between the different partners. At the same time, none of the partners can tell the others what to do. The ElectriCity organisation consists of a partner group where all the partners are represented and a steering group with representatives from Volvo, the City of Gothenburg, Region Västra Götaland and Chalmers. There are also project coordinators. The practical work relating to the different activities is carried out in project groups.
Route 55 – electric buses operating in the centre of Gothenburg

The most visible part of ElectriCity is the electric bus route 55 between the two campuses of Chalmers University of Technology in Johanneberg and Lindholmen. The route came into operation in mid June 2015.

Route 55 has three electric buses and seven electric hybrid buses supplied by Volvo. The electric hybrid buses operate for around 77 percent of the time on electricity and for the rest of the time on renewable fuel (HVO). The buses’ batteries are charged at the end stops using a process called opportunity charging (see page 19). The charging process takes 3 to 4 minutes and is more than adequate for the entire route. The route is 7.6 km in length in each direction. The journey takes around 25 minutes at an average speed of 18 km/h. The electric hybrid buses are commercial products, while the electric buses are concept vehicles with a centrally positioned seat for the driver and an extra-wide door with a low entry step in the middle of the bus. Passengers on the buses can charge their mobile phones using USB ports. All the buses and some bus stops have free WiFi, which gives passengers a seamless WiFi experience. On board the buses, passengers are also provided with information about the route and estimated arrival times, plus news and weather reports.

From the start of operations through to May 2016, around 35,000 journeys were made by buses on route 55, while only around 120 journeys had to be cancelled. This means that the service provision level of route 55 is 99.68 percent, which is very close to Västrafik’s target of 99.85 percent.

Bus stops with innovative technology and a modern design

Five of the bus stops on route 55 have been modified for ElectriCity. They have a new design, screens showing Västrafik TV of the same type that are installed on commuter trains and access to free WiFi. At the bus stop in Sven Hultins plats, a shelter for protecting passengers from the weather which includes noise insulation technology is being tested as part of the Controllable Urban Soundscapes innovation project. At bus stops at Chalmersplatsen, Götaplatsen and Teknikgatan, different types of touch screens are being evaluated. These allow passengers to search for routes and timetables, among other things. There is also the option of interacting with the screen in a map view, obtaining information about ElectriCity and finding bicycles that are available to hire (Styr&Ställ – a bike rental and share scheme).
The end bus stop in Teknikgatan in Lindholmen is indoors in an annex to an existing building. The annex has a glass facade and a sedum roof. Next door there is a café which helps to create a pleasant environment for passengers waiting for buses. The bus stop also has a USB port for charging mobile phones and there is a collection point for DHL parcels.

At the Lindholmsplatsen stop next to the main building in Lindholmen Science Park, there is a lounge for passengers who are waiting. Traffic information and real-time screens are available in the lounge. A roofed area connects the building with the bus stop, which helps passengers to reach the buses without getting wet. A "go to gate" sign that indicates when bus 55 is departing is shown on a screen above the exit to the path from the main building.

Several research projects have links to the indoor bus stop at Teknikgatan. Among other things, the indoor environment is being evaluated from the perspective of energy. This is the first time that indoor charging of buses has been tested and it will lead to new experiences which can be incorporated into future urban development projects. The charging process allows heat to be recovered from a transformer in the basement. The doors which are opened by the buses' signal priority systems have been tested and are working well. At the exit, the illuminated
and audible warning systems which alert passengers and cyclists to the arrival of a quiet bus are being tested.

The current results indicate that the indoor bus stop is functioning effectively from a technical and an energy perspective. It receives a positive response from 78 percent of passengers, but it is not clear how they should use the bus stop area. Property owners who are planning to install bus stops in future are considering the option of creating indoor bus stops and of enabling buses to drive close to a building and dock with it, to ensure that passengers have a pleasant journey.
Zone management system controls operation and speed

The buses on route 55 are equipped with a zone management system which automatically controls the buses’ operation and speed in different areas. For example, the system ensures that the electric hybrid buses cannot enter the indoor bus stop with their diesel engines running and restricts their speed as they enter and leave. The zone management system also covers other environments which the buses share with pedestrians and cyclists. In these areas, the buses have to operate at a low speed. For example, the system ensures a high level of road safety in the square between Teknikgatan and Lindholmsallén where there are a lot of pedestrians and cyclists. In the electric hybrid buses, zone management is used to specify the zero-emission areas where the buses have to operate quietly using electricity. In all the buses on route 55, the system is used to limit the buses’ speed in areas where there are large numbers of vulnerable road users.

The zone management system has been developed, implemented and tested on route 55. The drivers feel that the system supports them and helps them to focus on driving, which reduces the risk of stress and accidents.

ElectriCity has made it possible to demonstrate the potential of the system to a large number of interested external parties.

Volvo Bus Experience Centre – workshop, depot and control centre

The electric buses used on route 55 are maintained at the Volvo Bus Experience Centre in Arendal where there is a workshop, a depot and a control centre. The premises are designed to allow technicians and drivers to meet and share information and experiences. The facilities are also used for training technicians, suppliers and customers. To ensure that the technicians can work efficiently and safely with the electric buses, which have a number of roof-mounted components, a special work platform has been developed. This also reduces the amount of time that the buses have to spend in the workshop. A number of diagnostic and troubleshooting systems also help to keep the buses on the road.

In the control centre, there are functions for planning and monitoring traffic in real time and for workshop planning. Visitors can experience for themselves what
an advanced public transport control centre is like. This includes functions for controlling and monitoring the buses’ use of electricity. However, the day-to-day operation of route 55 is handled by Keolis’ standard management system, because it has to be synchronised with all the other public transport services.

**Digital innovation platform for development**

To enable ElectriCity to function as a modern test and demo arena for innovative development projects, a digital innovation platform has been created for information sharing and communication. This is the virtual part of the demo arena. The physical parts of the arena are linked to route 55.

The innovation platform allows new services and products to be developed internally and externally, by collecting and sharing information from several of the partners in ElectriCity. The aim of these products and services is to make public transport more attractive and the intention is to test, demonstrate and evaluate them as part of the ElectriCity partnership. In addition, the innovation platform will simplify research, cooperation and the development of knowledge by opening up opportunities for storing and sharing data.

The platform formed the basis for ElectriCity’s innovation competition and will be developed further in future.

The innovation platform collects and shares real-time data and other information from the partners in the ElectriCity partnership to enable new services and products to be developed internally and externally and to make this process easier.
In the autumn of 2015, Zara Larsson appeared on route 55 as part of the Silent Bus Sessions campaign.
Positive response from passengers to route 55
Surveys by Västtrafik show that passengers on route 55 are without exception more satisfied with the service than passengers on other comparable routes. A total of 80 percent of passengers valued the access to free WiFi on board. As many as 66 percent liked the availability of USB ports on the buses for charging mobile phones. As a result, Västtrafik is planning to introduce the option of charging mobile phones as standard on all new buses.

How satisfied are you with this journey overall? (%)

The passengers on route 55 are more satisfied than passengers on comparable routes. Source: Västtrafik.

A small group of drivers makes training and communication easier
The buses on route 55 are driven by a group of just over 20 drivers. Because Keolis has chosen to restrict the number of drivers, it has been easier to give them training and to keep them up-to-date with the latest developments. Providing information about new features has worked well in such a small group. In the annual employee survey carried out by Keolis Sverige AB, the drivers who work on route 55 gave higher marks to almost all the questions than Keolis’ other drivers.
Environmental impact – noise, energy, climate and air quality

Compared with conventional diesel buses, the electric buses on route 55 make less noise, are more energy-efficient, have a lower impact on the climate and produce less air pollution.

Less engine noise from electric vehicles
Traffic noise is a major environmental problem in cities. At low speeds, the majority of the noise comes from the vehicles’ engines. Heavy vehicles that use traditional fuels produce low-frequency noise and are therefore a significant source of noise pollution even inside buildings.

The motors in electric buses generate much less noise and it is not of the same low frequency as that produced by diesel- or gas-engined vehicles. The zone management system allows the operation of hybrid buses to be controlled in such a way that they only use their diesel engines in less noise-sensitive areas.

Electric public transport systems are likely to bring significant benefits in terms of the social and environmental sustainability of cities. In Göteborg, Trafikkontoret (City of Gothenburg, Urban Transport Administration), together with Miljöförvaltningen (the Environmental Authority), Västrafik and Region Västra Götaland, has launched a joint project to investigate the benefits of electric buses and electric hybrid buses on the city’s bus network.

Much less noise from electric vehicles
Noise measurements made outdoors show a significant difference between electric and diesel buses. This relates not just to the noise level but also to the frequency. Both factors have an impact on the perception of the noise, but the frequency in particular makes a significant effect on indoor noise levels.

Outdoor measurements of noise levels from diesel and electric buses at constant speeds indicate a difference of 5–9 dBA at normal operating speeds in a city environment. See the diagram on the next page. Because the scale is logarithmic, the perceived difference is very large. A noise level difference of 5–9 dBA can be regarded as being between "a clear difference" and "a perceived doubling" of the noise level. The differences in noise levels between electric and diesel operation reduce as the speed of the bus increases. This is because tyre noise becomes dominant from around 50 km/h. The noise levels inside an electric bus are also much lower than in a diesel bus. At low speed, the noise level is reduced to half. As the speed increases, the difference between the two types of bus reduces.
A comparison between the noise levels of a diesel bus and an electric bus (from route 55) showing external noise at a constant speed. The measurements were made at a distance of 7.5 m on a certified test track. The diesel bus used in the comparison above is certified to have a noise level 5 dBA below legal requirements. Source: Volvo.

Comparison of the noise levels measured inside an electric hybrid bus during diesel and electric operation at different speeds. The measurements were made in the rearmost seats at ear height. Source: Volvo.
While the measurements were being made, it was noticed that the difference in the noise level was perceived to be much greater than the results on the previous page indicated. Studies have shown that the dBA filter can be misleading. When diesel buses and electric buses are compared, the perceived difference is larger than that indicated by the measurements. This is confirmed by the fact that route 55 was rated very highly for its low noise levels in Västrafik’s passenger survey. A total of 74 percent of passengers agreed fully with the statement "I find the noise level on board comfortable", compared with 29 percent on route 16 in Gothenburg.

**Electric buses – up to 80 percent more energy-efficient**

The electric buses operating on route 55 are approximately 80 percent more energy-efficient than equivalent diesel buses. The amount of energy used by electric hybrid buses is around 50–65 percent lower than diesel buses.

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**Energy consumption**

![Energy consumption chart](image)

Energy consumption of electric hybrid buses on route 55 compared with a diesel bus on a similar route. Figures from 2015–2016. Source: Volvo.

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**Electric hybrid buses operated using electricity for 77 percent of the time**

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<th>36%</th>
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<tr>
<td>Electric at stop</td>
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<td>Electric when driving</td>
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The figure shows the average proportion of time spent in electric and diesel operation by the electric hybrid buses on route 55 during the period 1 June 2015 to 27 March 2016. Source: Volvo.
It takes 3–4 minutes to charge the electric buses.
Charging
The energy supplied to the buses consists of:

- High power charging at the end bus stops
- Low power charging overnight
- Consumption of liquid fuel (electric hybrids)

In addition, energy is recovered during braking and returned to the battery.

The buses on route 55 have a lower energy consumption than was originally predicted. The consumption is relatively constant and there are no major differences between electric buses and electric hybrids.

The buses’ batteries are charged using the opportunity charging process. This means that the batteries are charged several times during daily use, which allows for more continuous operation. The batteries are charged at charging stations at each end of the route by a pantograph which is lowered onto the roof of the bus. The driver simply has to stop the bus in the correct position and apply the handbrake. Then the charging process begins automatically.

There are two charging stations for route 55. One is outdoors (Sven Hultins plats) and one indoors (Teknikgatan).

The buses are charged around four hours a night in the depot in order to balance the batteries.

The charging time is set to 6 minutes at each end stop, but in actual operation it is generally 3–4 minutes. The buses can travel around 20 kilometres on one charge. This means that an electric bus should in theory be able to miss two charges and still provide a normal service.

The seven electric hybrid buses also have a diesel engine that runs on renewable fuel (HVO).

The experiences from the ElectriCity partnership show that a city, region or bus operator that intends to set up an electric bus service need to involve all stakeholders about the project management of the start-up phase and about charging, among other things.

A significant reduction in the climate impact
The reduction in the use of fuel in electric hybrids compared with conventional diesel buses has a considerable effect on CO₂ emissions. The well-to-wheel carbon dioxide emissions from electric hybrids running on HVO fuel on route 55 are 97 percent lower than those from conventional diesel buses running on fossil diesel.
The diagram below shows the total CO₂ emissions from electric hybrid buses on route 55 during the period from 1 June 2015 to 27 March 2016. The figures represent well-to-wheel CO₂ emissions with green electricity. The electricity contracts for all the charging stations are for green electricity.¹

![CO₂ emissions diagram]

Comparison of carbon dioxide emissions from electric hybrids on route 55 (far right) running on HVO fuel and electric hybrids on the same route operating on fossil diesel (middle bar) and conventional diesel buses (EURO VI) (far left). Source: Volvo.

**The possibility of zero exhaust emissions**

From the perspective of emissions, the major benefit of electric hybrid buses is the zero-emission function. This is full electric operation which does not generate any emissions at all. The zone management system controls the zero-emission function. The area around the indoor bus stop on Teknikgatan is an example of a zero-emission zone.

The amount of exhaust emissions from electric hybrid buses is determined by how long they run on electricity. This in turn depends on the length of the vehicle’s route before it can be charged. The drive train is still under development, but the emissions from diesel operation have been measured. The emphasis was on nitrogen oxides (NOₓ) and carbon dioxide (CO₂).

¹ All the energy used to charge the ElectriCity buses comes from renewable energy sources, such as wind and hydroelectric power. This is ensured by means of a statutory guarantee of origin for electricity, which 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 Energy Agency.
One reservation concerning the results is that they are based on a limited number of measurements. Other measurements have been made in Great Britain when the same electric hybrid model was certified as an LEB (low emission bus). The equivalent NO\textsubscript{x} figure in the measurements from the certification process was significantly lower than the measurement below (0.22 g NO\textsubscript{x}/km). The certification cycle is quite similar to route 55 and includes commuter and urban traffic.

Accumulated NO\textsubscript{x} in grams during two round trips on route 55, in other words, two journeys from Lindholmen to Lindholmen with charging at both end stops, calculated in grams per kilometre and compared with a diesel bus on a similar route (EURO VI, Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles. The measurement was made using an electric hybrid bus on 3 February 2016. Source: Volvo.

Can you drive a bus into a library? With the support of Volvo Ocean Race in Gothenburg, one of the bus stops has been transformed into a proper library. The aim was to demonstrate that quiet, zero-emission buses can establish completely new conditions for traffic and for urban development.
Research linked to ElectriCity

Several research projects with links to ElectriCity are underway and more are planned. The research is being carried out by the partners and coordinated by Chalmers. Both the physical arena and the cooperation between the partners form the basis for the research projects.

Ongoing research

1. **Research from a user’s perspective.** How passengers, drivers and local residents perceive and interact with the new solutions, plus proposals for developing them further. Part of the European Bus System of the Future 2 project which was launched in 2015.

2. **Indoor bus stop.** This project focuses on maintaining a comfortable indoor environment and minimising the energy needed by the bus and the indoor bus stop, with the help of new control technology and interaction (the exchange of information) between the bus stop and the bus that is arriving. The project is based primarily on existing designs for indoor bus stops and the technical systems they use. The potential for improvements brought about by predictive control technology is being studied by means of simulations and measurements which are mainly made in the real-life environment. The next step is to continue investigating potential alternative technical solutions and building designs. These studies will to a large extent take the form of simulations which in some cases will be combined with lab measurements.

3. **Controllable Public Soundscapes.** One of the stops on the Johanneberg campus is being used as a test site for the Controllable Public Soundscapes concept.

4. **Innovation leadership.** The ground-breaking way of working within ElectriCity has aroused a great deal of interest. It is cross-functional project involving several organisations grouped around a core concept which brings them together with the aim of achieving joint success. A project is underway which intends to systematise and package selected experiences and knowledge resulting from innovation activities, including experiences from ElectriCity.

5. **Innovation platform.** Access to digital data for research and for developing IT services. Customer-specific IT services on buses and at bus stops have been identified as an area with research potential. A project which will enable potential service providers to begin developing services and carrying out research has been launched with the aim of creating an innovation platform with digital
data (public and customised). This will be made available by the project and its subprojects. The project has links to the innovation competition and to research into indoor bus stops.

6. **Connecting charging stations to the electricity grid.** Investigations are being carried out into connecting high power charging stations to the electricity grid. Alternatives will be analysed with the aim of reducing the impact on the grid. These include the use of energy storage, user flexibility and reactive power compensation.

7. **Second-life batteries.** Batteries from the electric buses will be used for storing electricity as part of the Riksbyggen project known as Positive Footprint Housing which involves the Viva housing cooperative. The buildings will be occupied in 2018. The 132 housing cooperative apartments, which have a large number of solar panels on their roofs, will generate excess electricity over the course of a year and the bus batteries will be used to store this in order to extend the "solar day”.

8. **System study.** A life cycle analysis study of the new transport solution has been started by the Environmental Systems Analysis division, the Energy and Environment department and the Applied Acoustics division at Chalmers University of Technology. A unique feature of the study is the plan to include noise.

9. **ElectriCity cooperation.** The way in which the cooperation within ElectriCity functions is in itself the subject of a research project in the Technology Management and Economics department at Chalmers. A social anthropologist has been studying the partnership since the spring of 2016. She takes part in meetings, observes the people working on ElectriCity and helps them to reflect on what has happened during the joint creation process.

### Completed projects

1. **A preliminary study** which investigated the requirements for combining community planning, transport and housing was carried out in 2015 and included an analysis of the surroundings and the interested parties. The possibility of continuing the project is being investigated. Among other things, the challenges involved in a potential shared-space solution have been identified, before offices are built in Johanneberg Science Park right alongside route 55.

2. **Innovation competition.** There is a research project in the field of open digital innovation in which ElectriCity was used as a practical platform for an innovation competition in 2015.
Planned projects

1. **Road safety.** This project, which is still in its application phase, is called MeBeSafe and forms part of the EU MG 3.5 call "Behavioural aspects for safer transport". The aim of the project is study how the behaviour of vulnerable road users and, in particular, cyclists can be influenced. The plan is to set up a test environment in a shared space, possibly in Lindholmen, with interfaces to ElectriCity. The applicants include SAFER, the Design and Human Factors department and the Product and Production Development department at Chalmers and Trafikkontoret.

2. **Challenge Lab.** ElectriCity took part in the 2014 C-Lab. One project involved developing an app for augmented reality at bus stops. The participants established a company on this basis called Devkittens AB. Discussions are underway about using the technology in the visualisation project which forms part of the "Energy on Campus" program managed by the Energy Area of Advance at Chalmers.

Batteries from the electric buses start a new life as energy storage in apartment buildings.
Major interest in ElectriCity

ElectriCity and route 55 have demonstrated that there is significant interest in future urban planning and electric public transport systems both in Sweden and elsewhere in the world. Nine out of ten residents of Gothenburg know about ElectriCity and associate it with an environmentally friendly approach, a new electric bus route and free WiFi.

The project has attracted attention from the international media and has received a large number of requests to take part in seminars and conferences. Around 100 delegations consisting of a total of 5500 people from all over the world have visited Gothenburg to find out more about ElectriCity.

The visitors include customers, politicians, representatives of city authorities, ambassadors, ministers, members of royal families, research groups, students and public officials. The majority of the delegations came from outside Sweden and the size of the groups ranged from 5 to 20 people. The project has also been promoted at Volvo Ocean Race, COP 21 (the UN climate change conference) and Mipim (the property trade fair).
In the mood for Christmas with lights and music on route 55 in December 2015.