TRAMWAYS
OR BUS RAPID TRANSIT
WHICH IS GREENER?

A study of the lifecycle CO_2 emissions of tramway & BRT systems

A Carbone 4 study, sponsored by Alstom

carbone 4 | ALSTOM *Designing fluidity*

GROUND-BREAKING STUDY TO ASSESS THE ENVIRONMENTAL LIFECYCLE IMPACTS OF TRAMWAY AND BRT SYSTEMS

The global population is set to rise to 9.7 billion by 2050, when 70% of people will live in urban areas. Annual global urban transport emissions are set to double, as a result, to nearly 1 billion annual tonnes of CO_2 equivalent by 2025*.

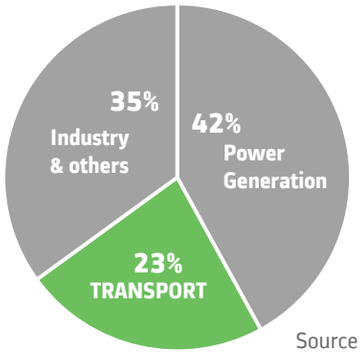
Since transport is responsible for 23% of all energy-related carbon dioxide (CO_2) emissions, curbing transport emissions will be key to reaching the +2 °C target set at COP21, the United Nations Climate Change Conference in Paris.

The local transport policies of cities have a major impact on global warming.

For cities to be truly green, then, they need to be less about cars.

Local and regional governments talk tough on the environment. In Europe, since 2008, through the Covenant of Mayors initiative, some 6,000 cities have voluntarily committed to an average 28% CO_2 reduction.

WORLD ENERGY-RELATED CO_2
emissions per sector



Source : IEA, 2015

But results are slow to materialise. The 2012 LSE green cities survey of 90 world cities found that only 43% of cities reported success in reducing their greenhouse gas emissions**.

"Many cities have not yet been successful in curbing their CO_2 emissions"

Fairly fast to construct, Bus Rapid Transit Systems (BRTs) have enjoyed strong growth in expanding cities worldwide in a bid to meet rising demand in public transport.

But how do they compare to tramways in terms of the system's carbon footprint, over a 30-year lifecycle?

Alstom and Carbone 4 conducted the first analysis to answer this question.

* IEA - A tale of renewed cities.
** LSE Cities - Going green; How cities are leading the next economy.

ALSTOM develops and markets the most complete range of systems, equipment and services in the railway sector. The company is present in 60 countries and employs 31,000 people.

CARBONE 4 is a leading independent consulting firm based in Paris specialised in climate-resilient and low-carbon strategy. Its team has developed strong analytical and field competences to help private and public actors transition to a low-carbon and climate-resilient economy.

ADVANCED STUDY BASED ON INDUSTRY DATA

Until recently, a lack of hard industry data made it difficult to compare the long-term environmental performance of BRTs and tramway systems.

All that changed in 2015 when Alstom shared its data on standard tramway systems and its optimised Attractis integrated tramway system with Carbone 4, which had already designed methodologies and conducted carbon footprint assessment in the field of transport.

The result was one of the world's first studies comparing the end to end carbon footprint of tramways with a range of BRTs.

Carbone 4 began by comparing Alstom's data to BRT data issued by leading French, European and international institutions (see Methodology and Data Sources).

To create a level playing field, Carbone 4 then applied this data to the same 10-kilometre route in Belgium, the reference case.

Each mode of transport was assumed to transport the same number of passengers with a **maximum of 6,400 people per hour per direction** at peak time over the same 30-year period.

It was estimated that, to transport this number of passengers, a city authority would need **90 diesel buses, 98 plug-in hybrid buses, 102 electric buses or 20 trams**.

"One of the world's first studies comparing tramways and BRTs on the same reference case"

The study took into account multiple variables, such as the fact that a fully-electric bus with large batteries would have less room to carry passengers.

It also factored in how often the vehicles would need to be replaced – 30 years for a tram and 15 years for a bus – and wear factors, such as battery lifetime for electric buses.

The study then analysed the CO_2 emitted by the energy used to build, maintain and renew the transport system and power the vehicles.

Regarding electricity, the study took into account the average electricity carbon factor in Belgium, which has a mix of nuclear, hydro and fossil fuel sources. The sensitivity of the results to the emission factor of electricity was also assessed.

Methodology and Data Sources

Carbon impact analysis:
Methodology in line with Bilan Carbone© from ADEME and specific methodologies for infrastructure projects from International Financial Institutions.

Electricity emission factors:
ADEME, EcoInvent and IEA.

BRT life-cycle data from studies:
The Asian Development Bank, The International Journal of Sustainable Development and World Ecology, and Chalmers University.

BRT consumption data:
UNFCCC CDM Registry - BRT Bogota Colombia.

GREENHOUSE GAS: TRAMWAY A CLEAR WINNER

So which transport system has the best environmental performance over the lifecycle?

According to the Carbone 4 study, on the reference case route, and over a 30-year period, the tramway would have a smaller carbon footprint than any type of BRT.

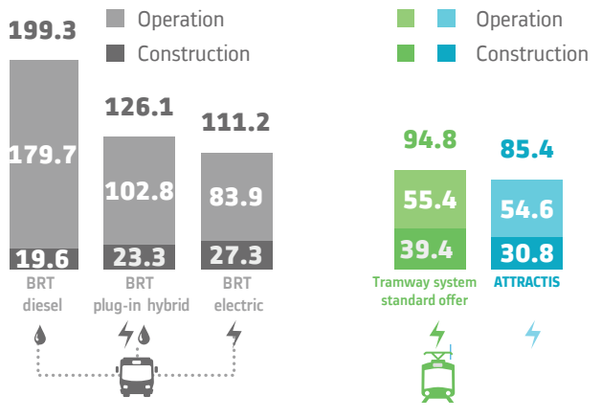
Although BRTs offer short-term advantages during the busway construction and bus manufacturing phases, the tramway system is a clear long-term winner, with much lower overall lifetime emissions, thanks to its better operation and maintenance performance and the longer lifetime of the trams.

Due mainly to the combustion of diesel to power the bus, **a diesel BRT's total lifetime emissions are more than twice as high as the ones of a tramway system**.

For the same reason, a plug-in hybrid BRT system emits about 30% more greenhouse gas (GHG) than a tramway system over its lifetime. The BRT system also uses more electricity than the tramway one with a similar transport capacity.

TOTAL EMISSIONS BY PHASE OVER 30 YEARS

$ktCO_2e$



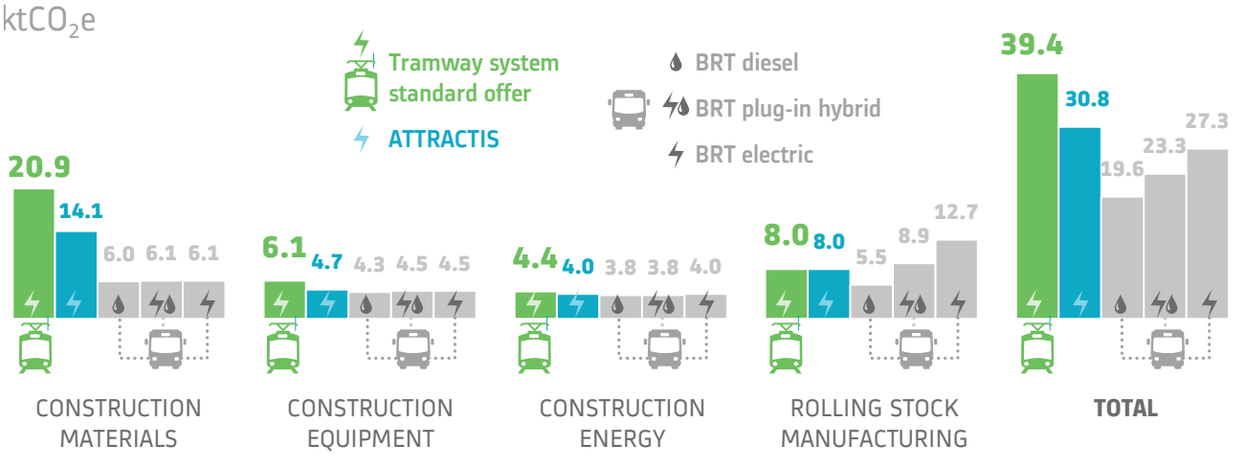
Even a fully-electric BRT system has 17% higher lifetime emissions than a tramway system, since a city would need to operate a large fleet of buses to achieve the same transport capacity as 20 trams, resulting in 3.6 times more annual bus vehicle kilometres travelled.

Construction and manufacturing

Because **BRT** infrastructure is lighter, during the initial **construction** phase, its associated emissions would be **2.2 times lower than for a tramway**. If a city can use existing road infrastructure as a basis to build a BRT system, it would however need to reinforce it for heavy traffic and build stops and other associated elements.

EMISSIONS FROM CONSTRUCTION PHASE

$ktCO_2e$



At the vehicle manufacturing stage, a diesel BRT also enjoys a significant advantage: the manufacturing of a tram emits 400 tons of CO_2e whereas a diesel bus emits only 30 tons of CO_2e.

But a city would need to operate a fleet of 20 trams or 90 buses to provide the same service on this route.

Since a bus only has half the lifetime of a tram, lifetime diesel fleet manufacturing will emit 5,500 tons of CO_2e, compared with 8,000 tons of CO_2e for a tramway, significantly narrowing its lead.

In fact, the diesel BRT system is the only one to offer these advantages: manufacturing emissions for a plug-in hybrid bus fleet are 11% higher than for a tram fleet, while the **emissions of a fully-electric bus fleet are 58% higher**.

This is because batteries are carbon intensive to produce, heavy and take up space, reducing the number of passengers a hybrid or fully-electric bus can carry.

Operation and maintenance

Following the initial construction and manufacturing phase, the carbon emissions advantages of a tramway system rapidly outpace all BRT systems.

A diesel BRT system generates 3.3 times more operation GHG emissions over 30 years than a tram, a plug-in hybrid system 86%, and a fully-electric system 51% more.

To calculate these figures, the Carbone 4 study broke down operation emissions into four main sources: traction energy, energy used for depots, gas leakages and maintenance.

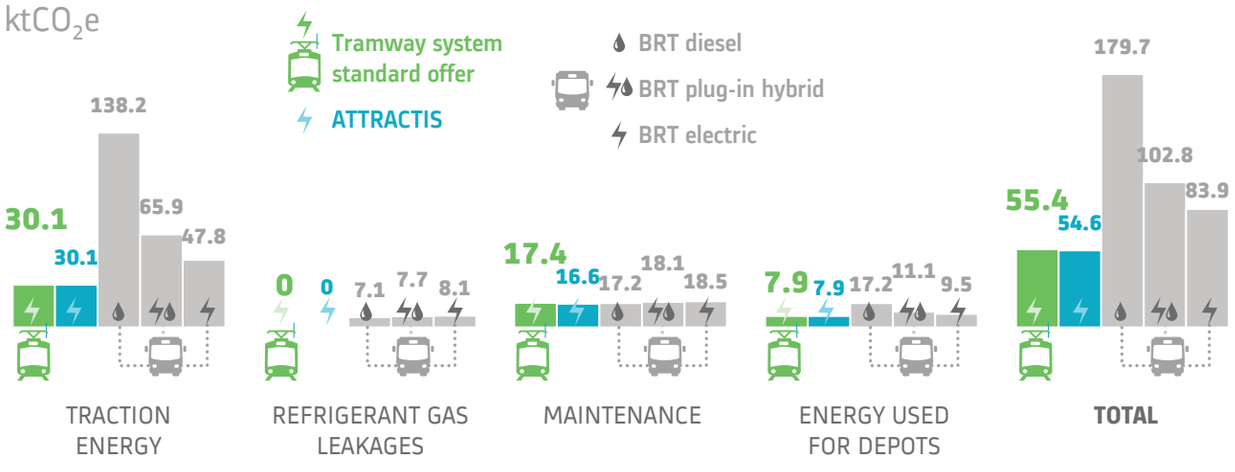
A tram emits roughly four times less CO_2 from traction energy than a diesel bus. Since the energy used for depots is due mainly to traction energy between line and depot, the same figures apply.

"Tramway systems have the lowest operation and maintenance emissions"

Although plug-in hybrid and electric traction energy emissions are lower than for diesel, since a bus fleet needs to travel four times more vehicle kilometers than a tram fleet to transport the same number of people over the same route, even the fleet of fully electric buses will use 1.6 times more electricity than a tram.

Tramway systems also have significantly lower air conditioning-system gas leakages – another source of GHG emissions. Legislation applying to tramways in this field is much more stringent than for road vehicles.

EMISSIONS FROM OPERATION PHASE



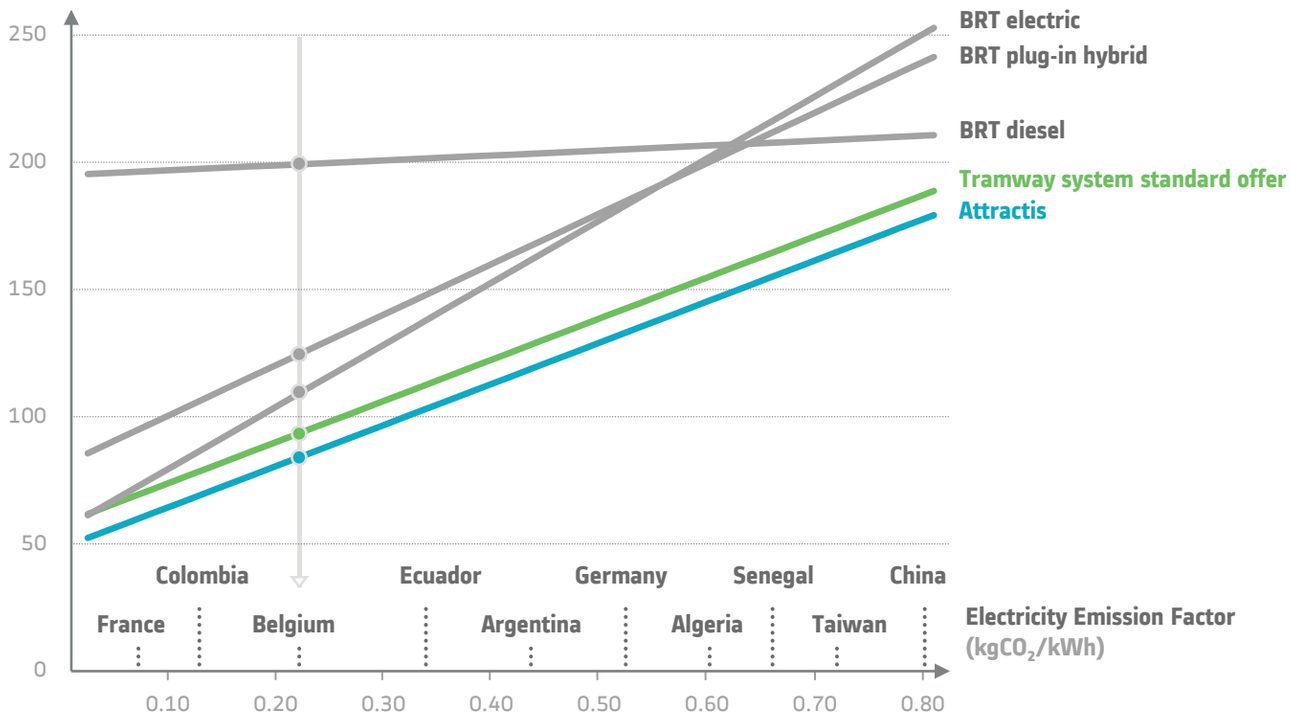
Impact of energy mix

Electricity production accounts for more than 40% of global fossil CO_2 emissions. Since tramways are powered solely by electricity, how does the electricity mix influence the carbon footprint advantage of tramway systems?

Even in a worst case scenario in which the electricity emission factor is around 0.800 kg CO_2e per kWh, as in China, all other assumptions remaining the same, the tramway's carbon footprint remains lower on a 30-year lifetime than a diesel, hybrid or electric BRT system.

SENSITIVITY TEST ON ELECTRICITY EMISSION FACTOR

Total emissions on a 30-year lifetime $ktCO_2e$



"Tramway systems have a lower carbon footprint than BRTs even with high carbon content electricity"

What's more, the electricity emission factors are expected to significantly decrease in the coming years, thanks to the current development of renewable energy, which will reduce further the footprint of electrical modes.

ALSTOM ATTRACTIS: AN OPTIMISED TRAMWAY SYSTEM

Eager to reduce costs and minimise disruption while maximising environmental performance, many city authorities are opting to develop tramway systems in a turnkey mode.

Attractis, an integrated tramway system developed by Alstom, is one such alternative.

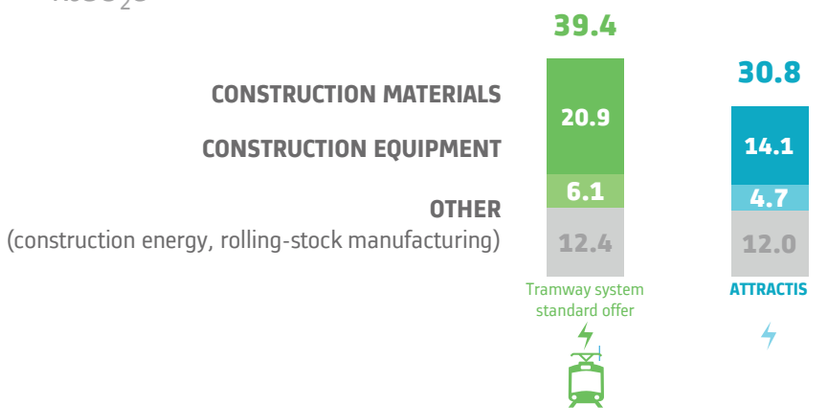
A 12km long Attractis tram system can be fully operational within 30 months: this is a much quicker deployment time than available up until now. Attractis aims at offering up to 20% savings in investment from a classical tramway line.

When compared against each of the study's criteria, Attractis almost always gives the best carbon performance compared with rival systems.

In terms of carbon footprint, the construction phase offers the greatest potential for tramway system improvements. Since the optimised Attractis system uses fewer materials, such as concrete, steel and cables in construction, it can cut GHG emissions by more than 20%.

CONSTRUCTION EMISSIONS FROM TRAMWAY SYSTEMS

$ktCO_2e$



Altogether, over a 30-year lifetime, the Attractis tramway system emits 57% less GHG than a diesel BRT, 32% less than plug-in hybrid, and 23% less than fully-electric.

In terms of sensitivity to electricity mix, Attractis delivers a performance equal to a standard tramway.

"Attractis cuts tramway construction GHG emissions by more than 20%"

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