TOWARDS CLEAN, GREEN AND SUSTAINABLE MOBILITY

ELECTRIC BUSES

KEOLIS

1 in every 4 European
citizens is affected by noise levels of more than 55 dB(A) caused by road traffic

5%
of annual deaths across the globe are caused by air pollution
(WHO)

1 out of 2 buses
in the world will be electric in 2030
(ZeEUS)

9.8 billion
people will live in cities in 2050 compared to 4 billion today
(UN, 2017)

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A centre of excellence for electric buses

Keolis is the preferred partner for public transport authorities as they introduce tailored electric bus solutions.

As a pioneer of sustainable mobility, the Group shares its clean energy expertise and its experience in the daily operation of thousands of bus routes with transport authorities. Its key objective? To help them tackle the challenges of public health, the environment and mobility.

A BREATH OF FRESH AIR FOR PUBLIC TRANSPORT

Little by little, electric buses are increasingly visible on the roads of a growing number of cities across the globe.

And for good reason: clean and quiet, they represent an efficient alternative to combustion engine vehicles, thereby enabling transport authorities to address the challenges of climate change and reduce pollution in their communities.

"All-electric solutions are appropriate in reducing local pollution and particularly if they are heavy modes, as is the case for buses."

(ADEME, IFP New Energies 2018, a cross-industry report on the impact of electric solutions by industry.)

ELECTRIC BUSES: CLEAN, GREEN AND VERY QUIET

The main advantage of electromobility is the zero emission of polluting gases (nitrogen oxide and fine particles) which are harmful to health, representing an ideal solution in areas frequented by pedestrians. Whilst their carbon footprint is not entirely neutral (e.g. manufacturing and recycling of batteries, electricity sources), unlike diesel and alternative energy buses, electric buses do not generate any CO_2 emissions when in operation. Electric buses also play a role in reducing the dependency on fossil fuels, thus protecting transport authorities from ongoing fluctuations in fuel costs. And lastly, when running, an electric bus is comparatively very quiet, thereby helping to reduce noise pollution for city dwellers.

THREE OTHER ELECTRIC VEHICLE MODELS USED FOR PUBLIC TRANSPORT

• **City center shuttles**
In French cities such as Dijon, Orléans, Biarritz, Quimper and Caen, electric shuttle services (carrying between 20 and 40 passengers) complement the bus routes of many transport networks operated by Keolis. Providing zero emission short-distance services in city centres, they help reduce congestion in these areas with personal vehicles.

• **Electric coaches**
From the same family as the electric bus, the electric coach provides a transport service for city outskirts and suburban routes. Its operating scope is currently 250km.

• **Autonomous vehicles**
Driverless autonomous electric shuttles already deployed by Keolis in Lyon, Paris La Défense, Rennes, Roissy or Las Vegas, provide a new sustainable mobility solution in areas with few other services, or for the first or last mile to a range of locations including airports and university campuses.

A DEVELOPMENT DRIVEN BY INTERNATIONAL COMMITMENTS AROUND THE WORLD

As demonstrated by Denmark, the Netherlands or Sweden, many countries have embraced proactive policies in favour of electric bus usage. These are in addition to international initiatives such as the ZeEUS programme (UITP and the European Commission), the Transport Decarbonisation Alliance (TDA) or the Initiative for the Transformation of Mobility. Furthermore, 12 of the biggest worldwide municipal authorities gathered at the C40 and 26 major cities who are members of the European Metropolitan Transport Authorities (EMTA), have pledged to reduce their environmental footprint by adopting zero emission bus technologies. Foothill Transit in Southern California intends to be 100% electric by 2030 and the entire state of California has mandated "all electric" fleets by 2040.

Almere, the Netherlands

More than 400,000 electric buses
are currently deployed worldwide and 99% of them are in China
(Bloomberg, September 2018).

0 g/per person/per km.
That's the total amount of greenhouse gas emissions from a 12m **electric bus** over a running cycle, compared to 80 to 120g for a **diesel bus**
(ADEME – French Environment & Energy Management Agency).

(ALMOST) IDENTICAL BUSES

The electric bus is above all, a bus (like any other). It provides the same daily mobility services as a bus, whether it's for regular city, surburban or Bus rapid transit lines.

However, it is powered by an electrical motor and battery which leads to a number of differences in terms of operation, maintenance and driving.

"Our decision to have a 100% electric bus fleet by 2030 was a natural continuation of our commitment to pushing the envelope. The Keolis team has been working hard to keep things running smoothly."

Kevin Parks McDonald, Foothill's Deputy Executive Director, USA.

SAFETY FIRST

The electric vehicle's main characteristic is its **high voltage electric design** which requires a clear understanding of the risks involved and experience in dealing with them.

This imperative demands strong expertise in the following areas:

- Knowledge of, and compliance to existing national and local safety regulations;
- Organization, operation and maintenance procedures;
- Definition and installation of charging infrastructure and depot conversions;
- Specialist training for drivers and maintenance staff (qualification and accreditation).

BUS RANGE, A KEY CHALLENGE

In an electric bus, the battery replaces the fuel reservoir. This provides the necessary energy to drive the vehicle as well as power many auxiliary vehicle functions (e.g. suspension, steering, heating and air conditioning). The battery's limited storage capacity therefore has an impact on the distance and running time of the vehicle between two charges making the daily operating of an electric bus more complex than a conventional bus. There are a number of key factors to take into account for the deployment of electric buses, including the number of passengers, network topography, the number of bus stops and outside temperatures. This analysis stage is essential in finding the solution best suited to the needs of each network regarding its choice of vehicle/battery/charging infrastructure, as well as its operating and recharging (smart charging) strategy.

SPECIFIC, BUT LESS COMPLEX MAINTENANCE

The absence of a combustion engine, sophisticated pollution control system and a gear box and clutch (depending on manufacturer) makes maintenance easier. There are less risks of wear-out and breakdown especially due to reduced braking (energy recovery during the deceleration phase). Another advantage is a decrease in the consumption of fluids (oil for example). On the other hand, electric bus maintenance does require greater expertise in electrical systems, and this needs to be considered in the initial stages of a project.

→ **Heating and air conditioning can account for 30 to 40% of an electric bus' energy consumption.**

→ **Energy recovered during braking can reduce up to 30% of the vehicle's electricity consumption.**

Montreal, Canada

ELECTRIC BUSES AS AN IMAGE DRIVER

Electric buses are a strong image driver for promoting the environmental ambitions and innovation policies of a transportation authority. Some manufacturers are coming up with disruptive designs which make them stand out immediately from conventional buses. However, regardless of the model chosen, the visual identity and bus livery (covering) will highlight its environmental attributes. As with high frequency buses, the different look of a vehicle encourages residents to try a new travel experience (e.g. a smoother ride and reduced noise) and helps persuade new customers to opt for public transport.

4 COMPLEMENTARY TECHNOLOGIES FOR A DIVERSE RANGE OF NEEDS

With its finely-tuned knowledge of local communities, its expertise in different types of electric vehicles and the feedback obtained from experience across many projects, Keolis is capable of supporting every transport authority in their choice. With the ultimate guarantee of providing them with the technology best suited to their needs.

01 CHARGING BUSES AT THE DEPOT

This solution is suitable for operating conditions that do not require a large degree of bus range. Charging takes place at the end of service for 6 to 8 hours. It requires the installation of a charging station and a high voltage supply in the depot.

It is the technology of the future given the growth of battery capacities which increase vehicle range year after year.

02 CHARGING BUSES ON THE LINE

The main solution when battery autonomy is not sufficient to power a whole service on one depot charge (bus size, route distance and running time, high passenger frequency, difficult weather conditions, all play a role). Depending on the battery type, recharging takes place during the day with a pantographic overhead system at the station or at the end of the line. It takes between 5 and 45 minutes, and the bus is stationary during this time.

The infrastructure is expensive, and operations are hindered by the fact vehicles must be stationary.

03 TROLLEYBUS IMC (IN MOTION CHARGING)

A new generation of trolleybuses equipped with a battery that replaces the combustion engine. The battery can supply the required energy for 30 to 40% of the service, during which time the vehicle does not need to be connected to an overhead contact line.

This innovation means that overhead electric lines in town centres can be removed.

04 FUEL CELL BUSES (HYDROGEN)

This is the most favourable solution in environmental terms provided the energy required to produce hydrogen is obtained from renewable sources.

This is a technology of the future but is still very costly. The economic model should be consolidated in the next five years.

SUCCESSFUL ELECTRIC BUS DEPLOYMENT: THE KEOLIS METHOD IN 4 STEPS

STEP 1

UNDERSTANDING THE CHALLENGES

Keolis offers tailored solutions to transport authorities wanting to deploy electric buses in their community. The Group's experience in understanding the ambitions and specific challenges of each transport authority, means it is able to accompany them during every stage of the process.

→ **The battery can represent up to 35% of the cost of an electric vehicle.**

→ **In 2026, the forecast decrease in battery costs should see an alignment of certain electric models with diesel costs** (BNEF).

Although many cities are planning to introduce electric bus fleets, each local context is very different.
A tailor-made response needs to be developed to meet these specific local factors. Keolis teams work hand in hand with each transport authority to fully understand their objectives and define the issues at stake.

PRELIMINARY ANALYSIS IS AN ESSENTIAL FIRST STEP

To fully comprehend the transport authority's objectives, Keolis teams share and discuss information regarding the context of electric bus deployment.

This includes:
- Environmental policy ambitions;
- Potential for replacing the authority's bus fleet in the coming years;
- Network topography;
- Number of passengers transported daily;
- Possibility of converting the existing depot(s) for the installation of charging infrastructure.

An in-depth analysis based on these factors provides the best suited options for investment and transition, considering the impact these will have on operating and service quality.

NEOLIS, OR HOW TO INTEGRATE ELECTRIC BUSES IN AN IDEAL NETWORK

The introduction of electric buses may require a redesign of the network by adapting existing lines or creating new ones. To ensure the transformation is a success, Keolis has developed an innovative method for network design known as Neolis. Thanks to a number of analytical tools and highly-detailed marketing surveys, Neolis can create the 'ideal' network on a tailor-made basis, adapted to each city, thus providing valuable data for the design of electric bus lines (services, stops, timetables, frequency) that meet passenger needs and take into account all the specificities of this electric mode.

Orléans, France

WORKING CLOSELY TO MAKE ORLÉANS AN 'ALL-ELECTRIC' TOWN

Orléans Métropole (France), the local transport authority, has renewed its contract with Keolis, who has been its mobility partner since 2012, to support the city in its ambitions to make Tao the transport network with the lowest level of carbon emissions in France. Indeed, the real challenge for the Group is to convert the city's 150 buses to electric models by 2024.
To make this transformation successful and start the first replacements in 2019, Keolis and the local transport authority worked closely to understand local challenges and begin trialling different bus models. These tests provided valuable information on key issues such as autonomy and charging times, thus anticipating the problems which need to be resolved when deployment is extended to a larger scale.

STEP 2

ANALYSIS AND MODELLING

Based on the feedback communicated by the transport authority, Keolis draws up several financing and operating strategies and evaluates the associated costs, risks and performances.

The systems approach developed by the Group and its finely-tuned modelling enables Keolis to support elected representatives in their decision-making.

→ The weight of a battery for a **40 ft** long bus is up to **3 tons.**

When evaluating the feasibility of electric bus deployment, the choice of vehicle should not prevail over other elements of the system. It is crucial that it is considered as part of the overall scope of the project.

THE IMPORTANCE OF A SYSTEMS APPROACH

To take account of all parameters, Keolis conducts research for each project based on a systems approach in which autonomy is the key parameter. It is important to understand the complexity of local specificities and how these factors interact.

For example:
- Lines to be operated (e.g. distance, number of stops, duration of service, topography);
- Configuration of the existing depot;
- Solutions available on the market:
  - battery technology (energy/power);
  - vehicle model (in particular, passenger capacity);
  - charging infrastructure mode (line or depot);
  - energy supply options.

Keolis experts work on an in-depth analysis of network data and the relevant lines in order to anticipate the autonomy required. This will determine the choice of vehicle, battery and charging system.

CALCULATIONS AND SIMULATIONS

With this goal in mind, Keolis teams have various tools at their disposal for vehicle scheduling configured for electric modes, energy consumption simulations, or analysing climatic conditions in the region over the past few years. This kind of approach enables us to challenge the manufacturers' offer. It also aims to assess vehicle autonomy in a way that resembles the reality of operating conditions more accurately than data used for tests by manufacturers.

In parallel, research is carried out to model and budget all the other system components (e.g. installation of charging systems, works and electrical supply in the depots, energy purchasing, staff training) in order to offer the transport authority several economic options and a risk/performance assessment for each scenario.

ASSESSING TOTAL COSTS FOR THE TOTAL LIFE CYCLE

The cost of an electric bus is not comparable to the cost of a diesel bus – it cannot be calculated in the same way and cannot be limited to its acquisition cost. Total operating costs over the totality of the life cycle need to be considered. Keolis therefore works on a TCO approach (Total Cost Ownership) including:
- **Investment costs** e.g. charging infrastructure and depot conversion, vehicles/batteries, battery replacement – on average half way through the vehicle's life cycle;
- **Operating costs** e.g. maintenance, training, energy consumption.

This approach, which allows the budgeting and comparison of the different solutions proposed by Keolis, represents a very useful tool to aid the decision-making process for the transport authority.

Rennes, France

RENNES: 30 MONTHS OF TESTING IN REAL OPERATING CONDITIONS

A successful launch. In May 2018, the first electric buses began running on the STAR network in Rennes (France). Key to the success, based on a new vehicle model using highly innovative batteries, was the bid from the Keolis project team involving a large number of teams from the outset (e.g. maintenance, operating, safety, high voltage). The 30-month trial will facilitate the choice of the electromobility system and allow the drawing up of acquisition conditions for the whole system (the first stage of deployment includes the launch of 72 buses between 2021 and 2024).

Every time **1,000 electric buses** go out on the road, the daily demand for fuel decreases by **500 barrels** across the globe. (Bloomberg New Energy Finance).

STEP 3

DECISION-CLARIFYING RECOMMEND-ATIONS

→ Replacing all of America's diesel buses with electric buses would avoid **7.3 million tons** of greenhouse gas emissions annually. (Argonne National Laboratory, 2017)

To help the transport authority decide on the most appropriate solution for the electric bus system to be deployed in their network, Keolis has developed a tailor-made approach based on a very thorough technical-economic analysis.

Following the identification of several options, Keolis works alongside the transport authority to determine the choice of the optimum electric bus solution on all levels: technical (bus, batteries, charging infrastructure), operational (operating, charging, storage concepts), migration strategy and financial (purchase or lease).

FINDING THE BEST COMPROMISE

The objective of this consultative approach, based on the assessment of different scenarios and potential suppliers' offers (price, availability, etc.), is to determine the best possible compromise between system performance, and costs and risks for the duration of the life cycle. Checks are run to ensure that each scenario corresponds to the goals and priorities initially set out by the authority. The consultation is carried out with support from the Group's Centre of Excellence for Buses and New Energies (see p.18). This group is responsible in particular for follow-up with manufacturers, technical monitoring, tests carried out in other networks and collecting feedback. Risk mapping and plans for risk management are drawn up for each scenario, ensuring that all conditions for successful deployment come together. Special attention is also given to the conversion of the existing network (e.g. depot refurb, integrating new buses into daily operations, scaling and training of teams).

ANTICIPATING TECHNOLOGICAL ADVANCES

The Keolis recommendation process also looks very closely at next generation technology evolutions, and in particular, battery performance. This approach may lead to advising the transport authority to rethink or postpone its initial investment decisions, if for instance, the purchase of an additional bus is not an efficient solution for the line in the medium term because of forecasted autonomy improvements.

> "Battery technology for electric buses is advancing in leaps and bounds. Thanks to this progress their price decreases every year, on average by 5% with a similar proportional capacity increase. In the medium term the autonomy issue should disappear, and we will see a significant reduction in the cost of replacing them."
>
> Jean-Marc Ducros, Alternative Energies, Director, Keolis Group.

PRECAUTIONS TO BE TAKEN FOR CHARGING INFRASTRUCTURE

The operating of the charging system, whether it is in depot charge or overhead in line, requires a connection to the public electrical supply, a high voltage supply, transformer stations and major building works. All these elements are subject to very strict security norms which are of course respected by Keolis in its choice of equipment.

Group recommendations also consider inter-operating factors, i.e. the possibility of investing in charging systems which can be used by different operators on one installation. This precaution avoids re-investment in additional material when the time comes to invest in new buses further down the line.

Los Angeles, United States of America

KEOLIS ELECTRIFIES THE UNITED STATES

Keolis electric bus expertise is highly exportable across the Atlantic. In 2017, Keolis Transit America (KTA) was chosen by Foothill Transit to operate their bus network for the Los Angeles region (that's 139 buses and 14 electric buses) and to support them in their transition to all-electric by 2030. And in North Carolina, the Greensboro Transit Authority also chose Keolis to bring in 14 electric buses into the network as of March 2019, the first stage of a progressive conversion of the whole fleet of 43 vehicles to electric.

STEP 4

ACHIEVING SUCCESSFUL DEPLOYMENT

Thanks to the extensive expertise Keolis has gained from transforming and launching public transport networks, transport authorities benefit from the Group's know-how, helping them successfully introduce electric bus lines.

The roll-out of a new transport system is a complex and delicate exercise. Upfront, the risks associated with operating and maintenance need to be identified and minimised. Along the way, the transition with existing transport services needs to be smooth if future success is to be guaranteed.

EXPERTISE AND METHODOLOGY INSPIRED BY TRAMS

Electric buses have a lot of things in common with the tram: electric modes, dedicated infrastructure, a systems approach and so forth. That's why Keolis is building on the expertise it has acquired as the world leader in operating tram systems, to develop a methodology guaranteeing the successful launch of a new bus line. Working alongside Group engineering experts, the project team checks running capacity, maintenance capacity and systems performance, at the earliest stages, with the aid of a design review.

ACTIVELY UPFRONT

A very precise schedule including key milestones for the validation of the system is established at a very early stage. The objective being to guarantee flawless implementation of the project and ensure positive collaboration between all actors and suppliers.
In parallel, the local subsidiary is trained to on-board the new system: instigating organisational procedures, writing-up of operational procedures, team sizing, staff training (e.g. driving, maintenance, control center) and updating of the risk register.

TRIALS IN REAL CONDITIONS

As soon as the new vehicles and different recharging equipment arrives, unit testing, followed by overall tests, are carried out. Their objective is to check system performances (e.g. autonomy, recharging time in depot and in line, time recording for maintenance) and to begin to train the teams on-site. Next, a dummy run is carried out in real operating conditions to test and validate process reliability, in the event of operational incidents.

SUCCESSFUL MIGRATION

As in any network transformation, the launch of an electric bus line can have an impact on service continuity and cause disturbances for passengers and local citizens. Keolis therefore pays great attention to all the strategies that ensure a smooth transition into passenger service:

- Minimising the impact of works on the highway and existing bus traffic;
- Temporary changes in traffic routes;
- Passenger information;
- Communication campaigns for customers.

To this end a migration plan is developed at an early stage. This is accompanied by an ongoing operations plan which aims to provide for all contingencies should a malfunction occur.

GREEN DRIVING, TWICE AS BENEFICIAL

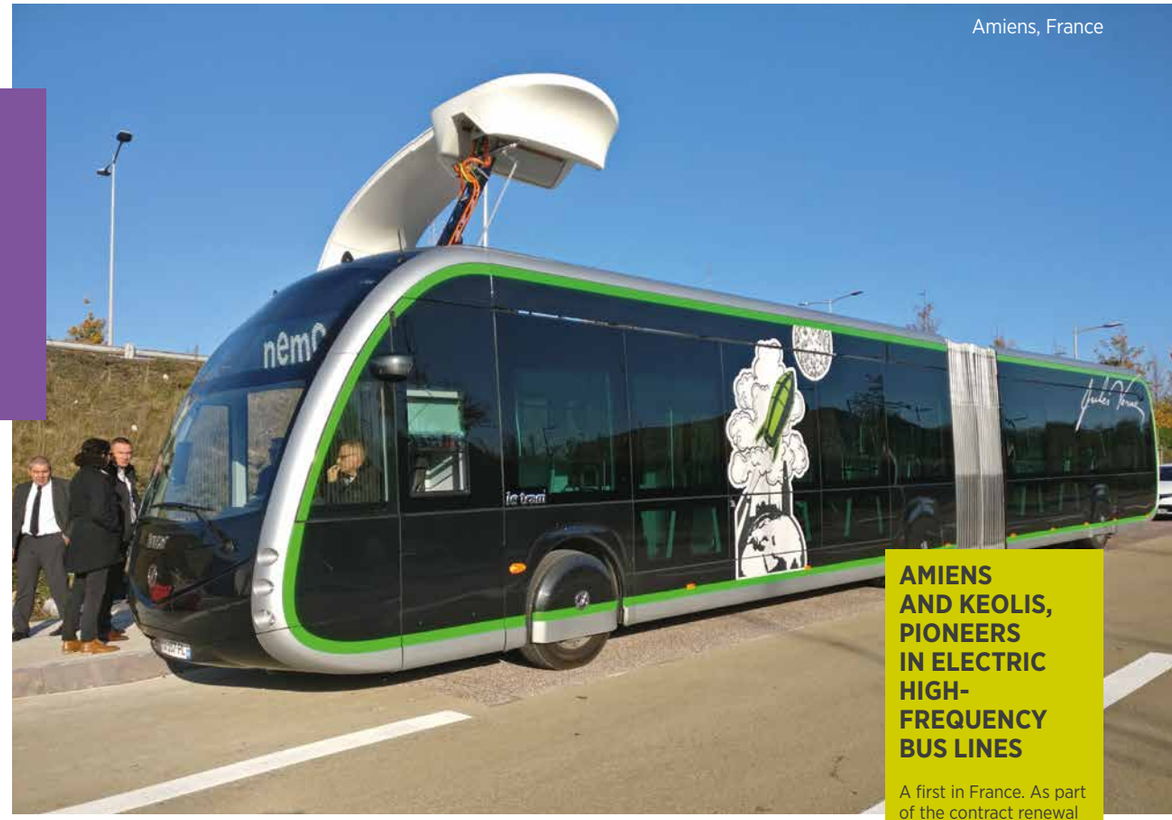
One of the differences of an electric bus is that drivers must be trained in eco-driving i.e. smooth driving, without any sudden stops or starts. This saves on electricity consumption thanks to the energy recovery system during braking. It also maximises battery performance and ensures passengers enjoy a more comfortable ride.

TRAINING TO ENSURE SAFETY FOR TECHNICIANS

All maintenance personnel working on electric buses has to undergo specific training and follow specific prevention measures. Off-tension work needs to be a priority which requires the consignment of the vehicle following the manufacturer's recommendations.

→ **The "learning rate" for electric batteries, i.e. the decrease in price for every two-fold capacity increase, is**

19%.



Amiens, France

AMIENS AND KEOLIS, PIONEERS IN ELECTRIC HIGH-FREQUENCY BUS LINES

A first in France. As part of the contract renewal for the Amiens transport network, Keolis will operate a fleet of 43 electric 18m buses on three new high-frequency bus lines. To make this launch successful without having run a trial previously, Keolis Amiens teams and experts from the Centre of Excellence for Bus and New Energies spent several months on a wide range of projects including operation modelling, vehicle delivery, unit and fleet tests, month-long dummy runs, and the training of 330 employees (including drivers, central command operators and maintenance staff).

A CENTRE OF EXCELLENCE, EXPERT IN ELECTRIC BUS SYSTEMS

To provide expertise to transport authorities and Group subsidiaries, Keolis has created a Centre of Excellence dedicated to Buses and New Energies.

Based in Lyon, it channels all the Group's expertise in electromobility systems and works very closely with other Centres of Excellence (Metro, Tram, Rail and Intelligent transport systems).

This specialist pole, with its specific business knowledge and systems know-how, has the following support systems at its disposal:

- **Group experts,** in charge of technical aspects and consolidating areas of knowledge for electric buses, are responsible for:
  - Capitalising on Keolis' best practices;
  - Technological monitoring working closely with bus manufacturers;
  - Following changes in industry regulations;
  - Organising technical support at all stages of new projects e.g. technical design reviews, mobilisation, initial operations, performance improvement.
- **Reference networks operated by Keolis** who have developed specialist expertise in electric buses (Rennes, Orléans, Amiens, Bayonne, Foothill, Almere, Utrecht, Karlstad, Gothenburg).
- **A group of experienced employees** based in subsidiaries running electric buses, who meet at regular intervals to share their experience and best practices.
- **A collaborative platform** and **online library** archiving all reference documents.

KCP, UNIQUE EXPERTISE AVAILABLE FOR EACH PROJECT

Support available to the transport authorities to help them in the deployment of their electric bus systems also comes from the experience acquired by the Keolis KCP subsidiary (Keolis Consulting and Projects) in many energy transition projects. With their in-depth knowledge of industry operational skills and maintenance, and their expertise in handling sophisticated modelling tools, these specialists participate in all project stages: feasibility study and transition strategy, functional and technical assistance in the purchasing and contractual stage, providing support to the networks for the preparation of operating systems, assistance in the implementation and completion phase, advice and analysis.

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