K-BUS Project - Why and How

Why

The **Covenant of European Mayors**, signed by over 5100 First Citizens, representing about 172 million inhabitants, commits them to increasing **energy efficiency and use of renewable energy** in their administered territories, to reach and exceed the EU target of a *20% reduction in CO_2 emissions by 2020*.

A report by the International Energy Agency, filed on July 10, 2013, estimated at **54.6 trillion Euro by 2050** the amount of money that could be saved worldwide, if a serious policy to improve the energy efficiency of urban transport systems, which, as of today, alone absorb 8% of the entire world's energy consumption, were implemented. Without such a policy, in addition to a serious economic impact, the environmental damage would be aggravated because the emissions of urban transport could double by 2015 , reaching one billion tons of CO2, with *cars responsible for 90%* of such increase.

IEA suggests three ways to proceed, in order to achieve this purpose:

a) avoid unnecessary travel

b) encourage more efficient and economical travel arrangements

c) improve vehicle and fuel technologies

Being obvious point **a)**, and because public transport is undoubtedly more efficient and economical than individual transport using private cars, an example of excellence in the sense indicated in point **b)** has been given by the capital of Estonia, **Tallinn**, which extended the opportunity - before then reserved only for seniors - to 420,000 residents, from January 2013, to use public transport - ***mainly trolley buses and trams*** - at the almost symbolic price per annum of 2 Euro per person.

This has lead the administration to suffer a 12 million Euro increase in annual costs, which is however considered to be acceptable given the expected benefits, that seem to have been confirmed. In the first quarter of 2013, in fact, traffic congestion in the center of Tallinn has fallen by 15% compared to the last quarter of 2012, the savings in transport achieved by the citizens has increased the propensity to spend, to the benefit of the local economy. Furthermore, the appeal of almost free transport has led 10,000 people (out of a total of 30,000 non-residents) to register as residents, so that the extra revenue from the municipal taxes can almost fully compensate the 12 million extra costs.

A counter-example came from the Belgian city of **Hasselt**, which had granted free public transport to everyone in 1997 and in early 2013 limited this benefit only to those under 19 years, therefore practically revoking it. Even though Hasselt has just about one-sixth of the inhabitants of Tallinn, the service, ***performed by bio-diesel buses*** (whose harmlessness to the environment is at least questionable) in the first 10 years saw the number of passengers carried increase by 13 times and its costs levitate from € 967,000 in 1997 to € 3,453,000 in 2007 (as the price of oil quadrupled in those years from $ 19 to $ 77 a barrel, dragging up the price of bio-diesel). All this caused lengthy discussions in the City Council, which eventually reached the conclusion that this liberality, albeit praiseworthy, was economically unsustainable.

The third way indicated by IEA for an increased energy efficiency of urban transport systems: the improvement of vehicles and technologies, has been implemented successfully by **Sequoia Automation**. Which, on the K-BUS Project, obtained three international patents, granted in **Europe** by the European Patent Organization (EP20691622009), in the **Unites States** by the United States Patent and Trademark Office (US7,984,774,B22011), and in **Canada** by the Canadian Intellectual Property Office. An extensive and significant covering of intellectual properties in protection of the trademark for this industrial invention which makes unique and not repeatable the technological application developed to realize the solution proposed in the present document. This consists in a system of vehicles for collective public transport on wheel, i.e. buses, with an electric motor, therefore an alternative to those systems which use internal combustion engines, but without expensive, bulky or unsightly components, such as rails or overhead power lines. It is also targeted to insure in the long run maximum possible savings both in terms of energy supply and, as will be shown in detail, economically.

How

The main innovation of the K-BUS Project is the accumulation of on-board energy. This does not occur in electrochemical batteries, but in super-condensers - close relatives of conventional condensers and also known as "super-capacitors" - the battery differences of which must be learned in order to appreciate the value of the project. It is in fact very likely that the negative ones can fade to become positive, both thanks to the intense research and experimentation and to volumes of production having a 30% yearly growth trend. These are the major differences:

a) super-capacitors have 5 times less "capacity" (contain less energy) than batteries with the same mass, but can supply, or receive, power almost double than that supplied or received from batteries;

b) their discharge or recharge can be performed in a much shorter time (a few seconds) than that required by electrochemical batteries and, unlike the latter, may be discharged entirely without suffering any damage ;

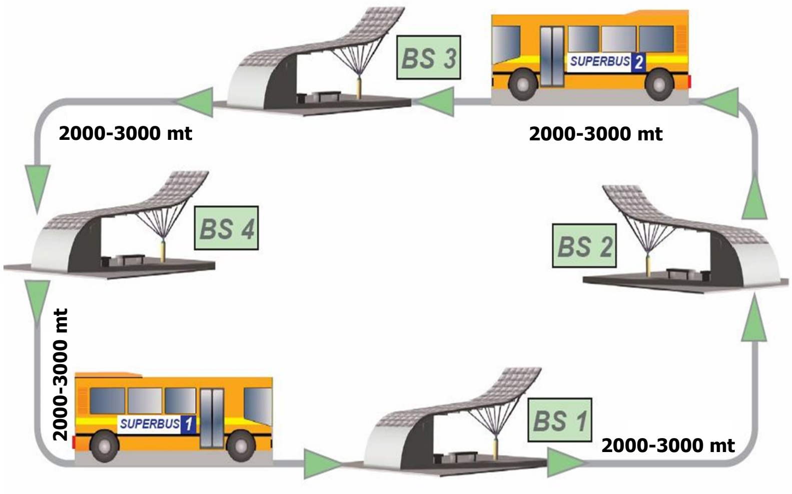
c) the useful life of super-capacitors is at least one million cycles - and when reached their decay is minimal - against a few thousand cycles of electrochemical batteries, at best and if not subjected to deep discharges;

d) super-capacitors, unlike electrochemical batteries, require no maintenance ("install them and forget them", the experts say);

e) super-capacitors today cost 10 times more than electrochemical batteries, but their useful life, many hundreds of times longer (power-wise it is longer than the life of the vehicle), makes them very affordable in the long run .

The high powers which the super-capacitors can supply or receive in a very short time offered Sequoia Automation the solution to the challenge that it had undertaken: the supply of power to the K-BUS vehicles at each stop *in the few seconds during the boarding/descending of passengers*, rather than implementing a partial recharge at the bus terminal, which lasts many minutes, and/or executing a full recharge at night, which lasts many hours, as required for electric vehicles powered by electrochemical batteries.

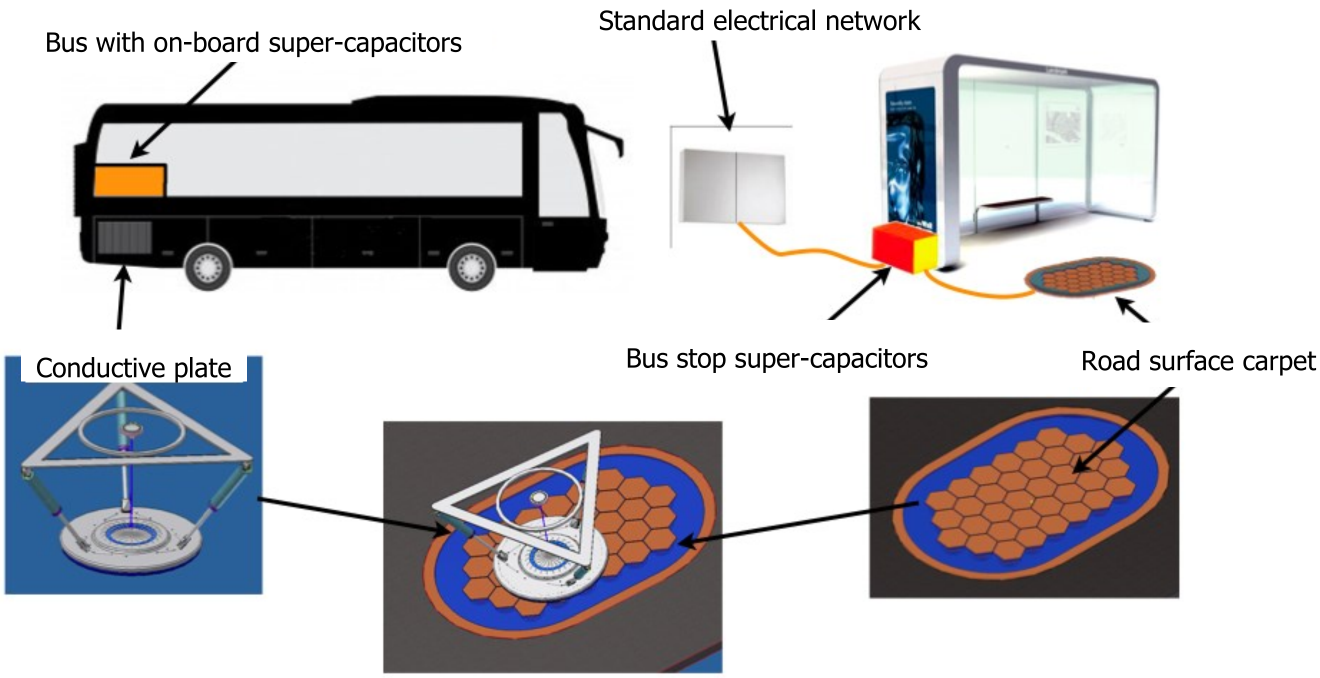
Every K-BUS vehicle has therefore been fitted with a set of super-capacitors, which has a enough capacity to amply cover the route between two stops. And since the normal electricity network is not able to provide adequate power to recharge the set *in a few seconds*, each stop/charging station has been equipped with super-capacitors whose discharge power and total capacity are adequate to recharge at least one and are kept charged from the electricity network during the pauses between the passage of one vehicle and the following. This avoids having to lay large section cables.



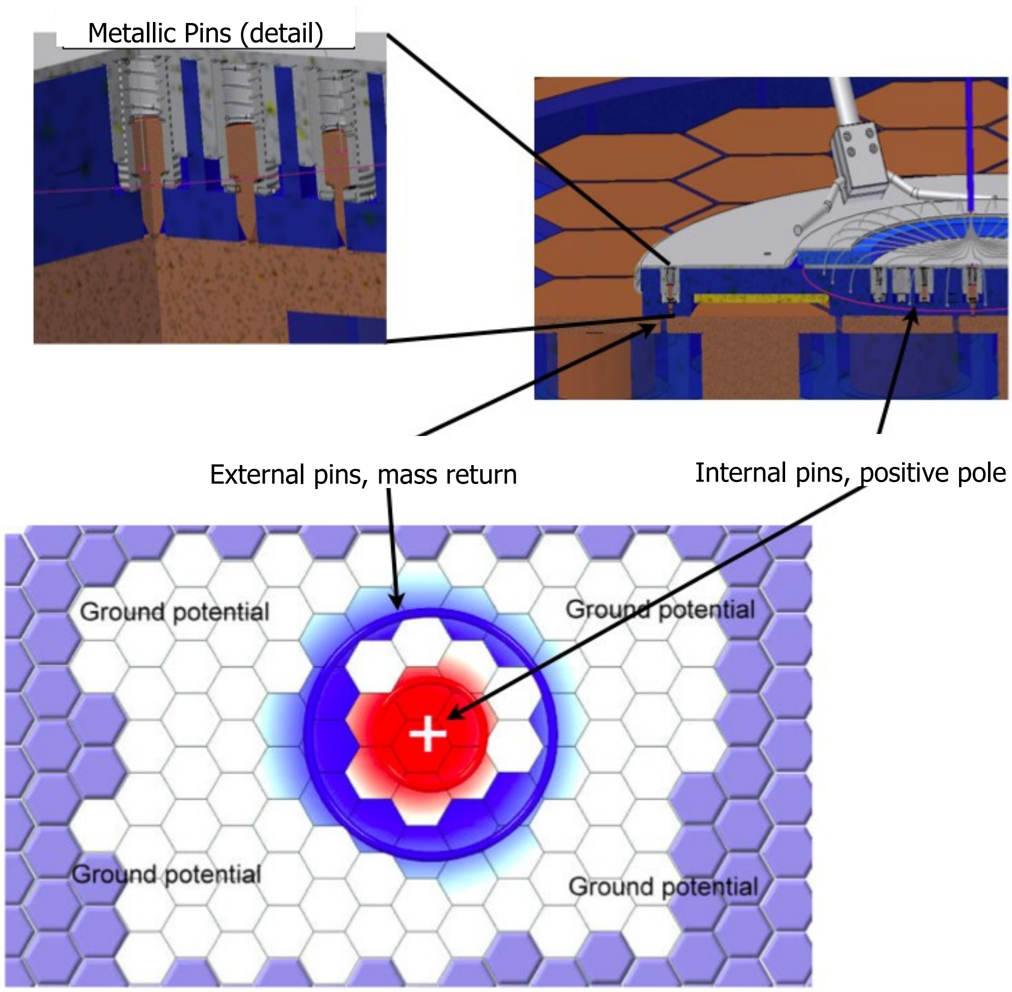
During the recharging phase, contact between the ground super-capacitors and those on board the vehicle is assured by a system structured in two parts: **a) under the floor of the vehicle**, through an electromechanical arm that holds a conductive plate, equipped with a thick cluster of metal pins; **b) on the road surface**, through a "carpet" of metallic hexagons, each one electrically isolated from the others, but each one connected to the electrical and electronic charging system, and made from a material that ensures long-lasting resistance to deterioration, which do not pose limits or constitute danger to the mobility of vehicles or pedestrians. The arm can drop or rise in a few moments and adapt to any change in the vehicle's balance in order for the plate to optimally descend and settle on the "carpet" and maintain a stable electrical contact during the entire charging phase.

For safety purposes, the charging phase is compliant with the following procedure: **a)** a radio signal allows the vehicle's electronic system to perceive the approach to a charging point and starts the descent of the supply arm; **b)** the plate, which is also equipped with a brush to clean the carpet from any possible debris, is pressed against the carpet to ensure an optimal electrical contact; **c)** the contact between each tip and the hexagonal metal of the carpet is verified by an electronic device capable of identifying the socket and bus code number, the exact position of the vehicle with respect to the carpet, the number of pins in touch with every single hexagon and the absence of "bridges" or conductive contact interruptions due to external causes; **d)** only after verifying that there are no obstacles to a safe energy transfer the electronic system supplies power ***only*** to the hexagons in contact with the positive pole pins, and the charging phase takes place.

K- BUS Fast-Charging System Operating Diagram



Details of the Vehicle's On-Board Conductive Plate And Its Power Supply



In case an unforeseen event should hinder the recharge of the K-BUS at a certain station, each vehicle is equipped with an electrochemical battery having a capacity which allows the vehicle to safely cover twice the maximum distance between two stations.

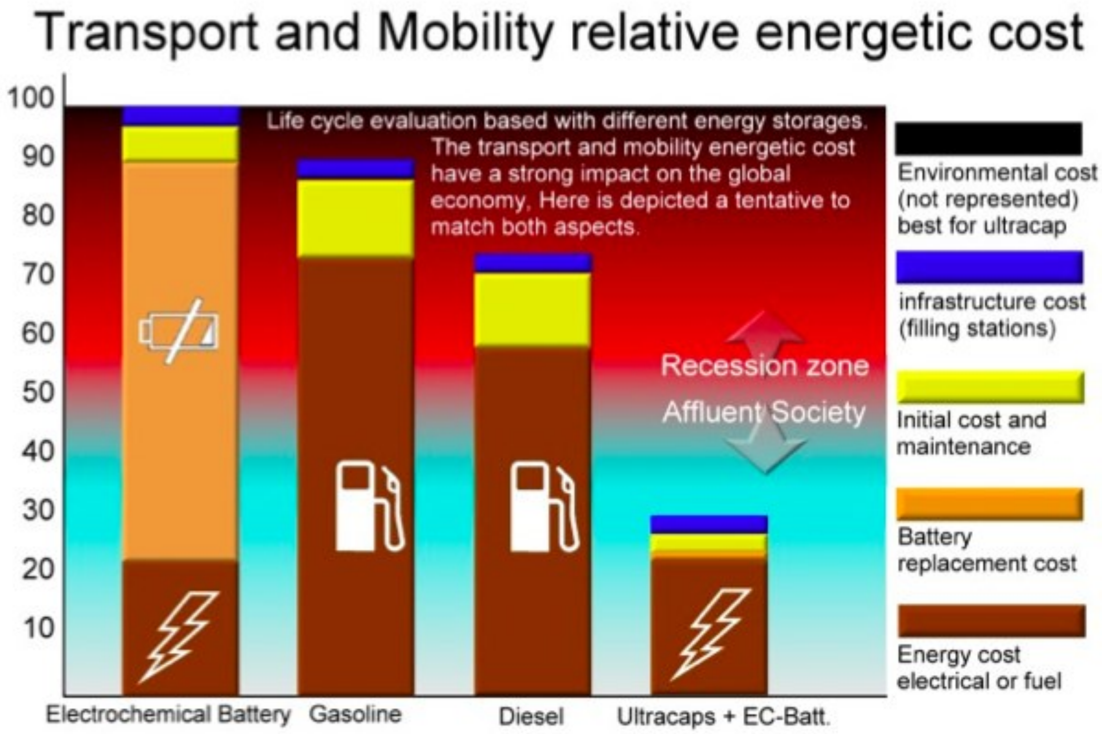
The nearly infinite longevity of the super-capacitors, their indifference to deep discharge procedures and the fact they are maintenance free make them today, as mentioned above, much more convenient than electrochemical batteries in the long run, even if their initial purchase price is still 10 times higher.

For example, though limiting to one million cycles the life - in fact much longer - of a super-capacitor and calculating the cost per kWh accumulated in the course of its life and that of a Lithium-Ion battery, they were found to be, respectively, of 0.01 and 1.25 €/kWh. Therefore the super-capacitor's cost was found to be **125 times lower than that of a Lithium-Ion battery**.

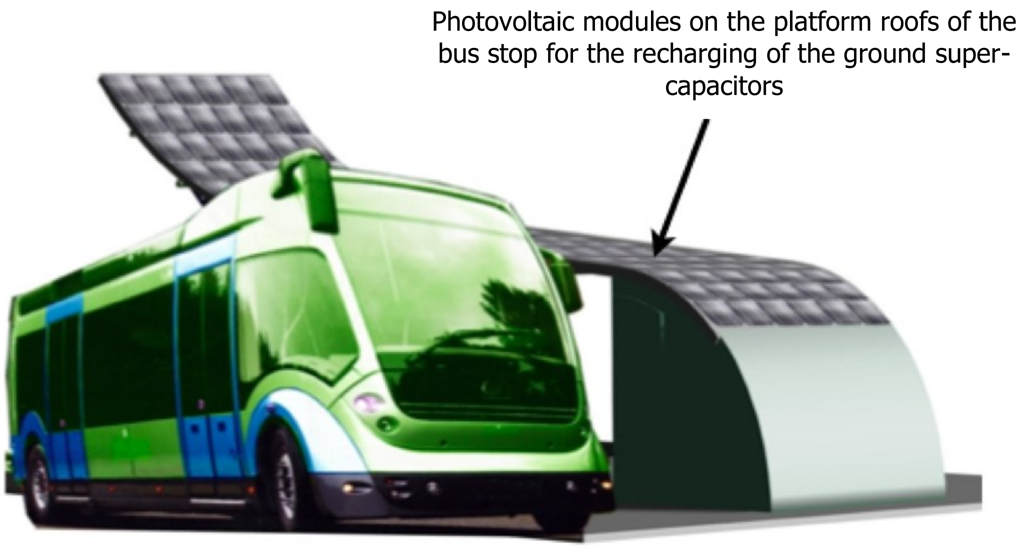
A comparison of data was carried out between a current urban electric bus line in Turin - served by electric battery-powered buses, which cover a distance of nearly 12 km and that undergo partial recharges at the terminal stations and a total recharge during night - with those of a hypothetical similar line, equipped with K-BUS vehicles.

The resulting data showed that if the current system were replaced with one built according to the K-BUS protocol, the initial investment costs would amount to little over half the sum which had been spent at the time the current system was implemented. Moreover, the revenue account at 12 years (including maintenance material substitution costs) would amount to less than half of what the current system requires, due to the frequent replacement of batteries that it entails.

Very eloquent, to this regard, is the following graphic comparison between the costs of various power systems for city buses, where "ultracap" means "super-capacitors".



Perhaps even more convenient from the economic point of view, and certainly more “green”, is the opportunity to aid the recharge of the K-BUS system using photovoltaic platform roofs that equips the charging stations .



Given the amount of energy that needs to be produced and transferred, and the type of power involved, in most cases this type of recharge system would be supplementary to the electrical supply provided by the network. It would however be the ideal solution - adequately sizing both the solar generator and the ground super-capacitors - for extra-urban stations with a limited daily vehicle passage, especially if there were no possibility to easily charge the K-BUS vehicles through the normal electrical supply network.

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Show Room & Area Demo K-BUS in allestimento