Catenaryless Tram Systems: Sustainable Eco-Friendly Solution for the City Transport

urbos

The technology of the Future...
...that respects the Past

www.caf.net

Index

- CAF
- BACK GROUND
- CAF GROUP
- RAIL SOLUTIONS AND RECORDS
- REGIONAL PRESENCE
- TRAM / URBOS PLATFORM
- ECo CAF SOLUTION
- ENERGY STORAGE SYSTEMS CONTEXT
- ACR SOLUTION
- ACR SYSTEM PROVEN
- SOLUTION TO OPERATORS CONCERNS

CAF Products and Services

ROLLING STOCK

- Design and manufacture of all types of rolling stock

TURNKEY PROJECTS

- Turnkey
- Contract Licenses

FINANCING

- Project Financing
- Leasing/Renting
- Made to measure solutions

SUBSYSTEMS

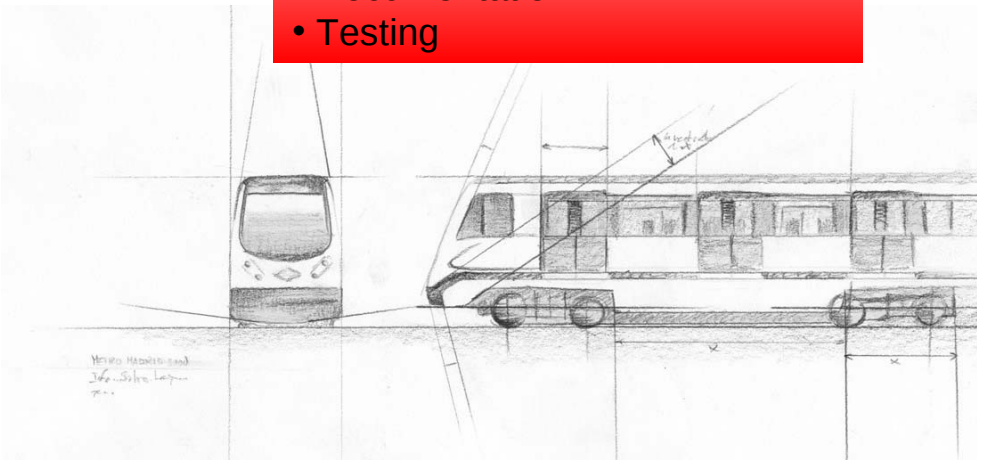
- Component Manufacture (wheels, axles, couplings, etc.)
- Equipment Supply
- (Bogies, Cosmos…)

ENGINEERING SERVICES

- Integration of Systems
- R&D
- Reliability Study
- Simulators
- Documentation
- Testing

AFTER-SALES SERVICES

- Maintenance
- Spare Parts Supply
- Repair



CAF

www.caf.net

WE CREATE

WORLWIDE RAILWAY SOLUTIONS

CAF shares all our GCC customers´ our passion for the design of the latest state-of-the-art technologies for any kind of transport solution, either on turn key or supply basis : metro, commuter trains, high speed trains and catenary free trams.

A new train generation that guarantees maximum power-efficiency and full passenger comfort with latest technology innovations that benefit everyone in order to create a better world.

Rolling stock

Complete Range of Products

High-Speed Trains (350 kph)

Trams (ACR)

Push – Pull Trains

Regional Trains

Suburban Trains

Metro

Airport Shuttles

Articulated Units

Locomotives

CAF Group comprises more than 50 companies that work together to offer global railway solutions such as:

-**BZK Ferroviaria: Transport System Divison**

-**Eliop Seinalia:** energy remote control and signaling

-**CETEST:** comprehensive testing and test management

-**Lander:** simulation systems

-**Danobat Rail:** depot equipment

-**Trainelec:** design and manufacture of electrical traction equipment for all types of trains

-**Traintic**: information and communication systems in the railway sector

-**Geminys:** integrated document management

-**NEM:** intelligent maintenance management systems.

bzk

LANDER
SIMULATION & TRAINING SOLUTIONS

eliop seinalia

Geminys
gestión de manuales industriales e ingeniería

cetest CENTRO DE ENSAYOS Y ANÁLISIS

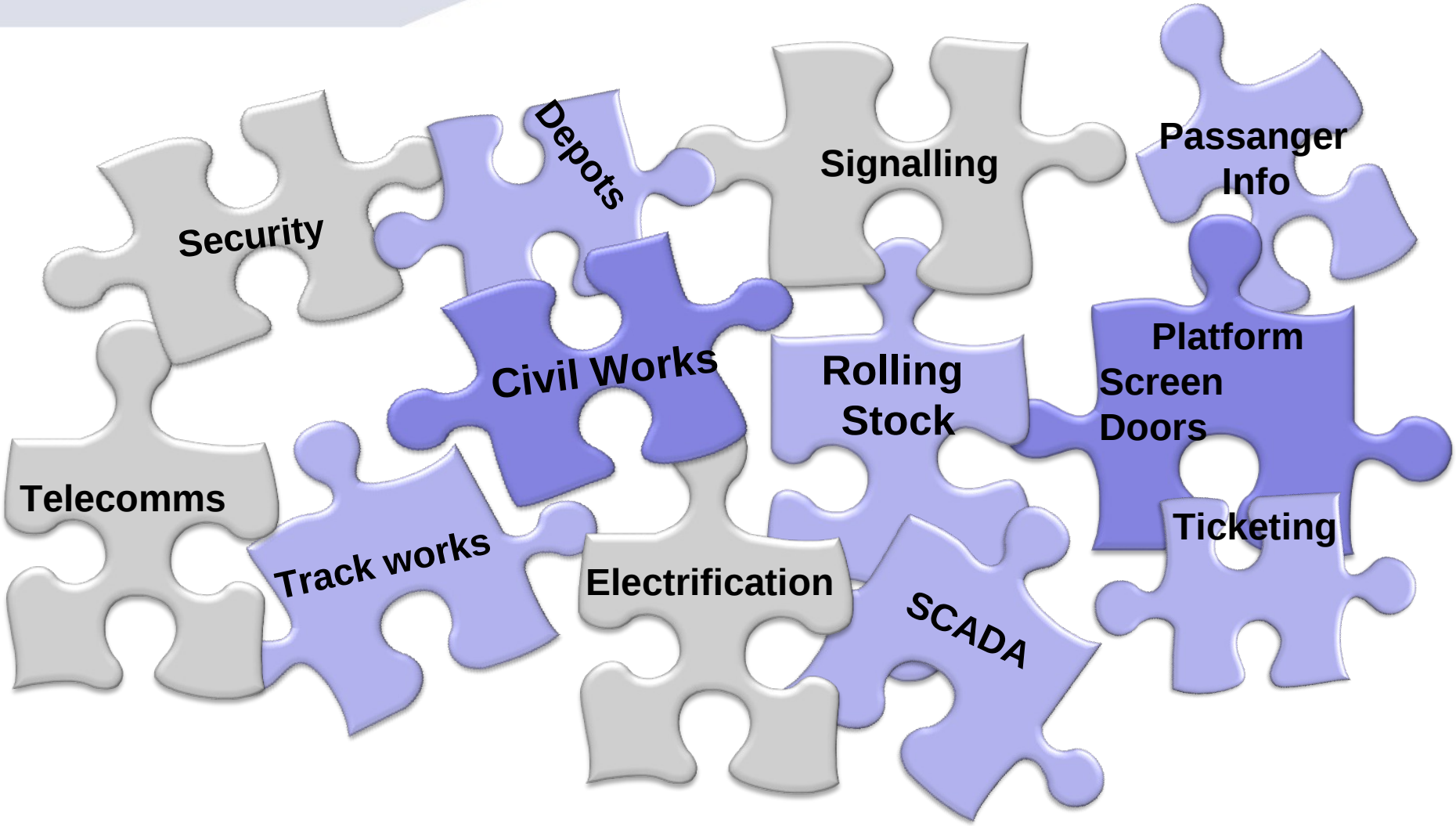
NEM solutions

traintic

trainelec
Traction solutions for the railway industry

ennera
energy for a new era

CAF Transport Systems Division provides a fully customised Turn Key Solution



CAF Group guarantees the integration and compatibility of all the required subsystems (Turn Key Solution)

ONBOARD STORAGES

Integration of storages into the vehicles

Energy storage control unit for optimization of energy savings

VEHICLES

OPERATION CONCEPT

Charging Strategy

Localisation of vehicles

Charging units, safe & reliable power supply

CAF SYSTEM INTEGRATOR

Right of way with pedestriams and vehicles

ELECTRIFICATION

SIGNALLING SOLUTIONS

RAIL AUTOMATION

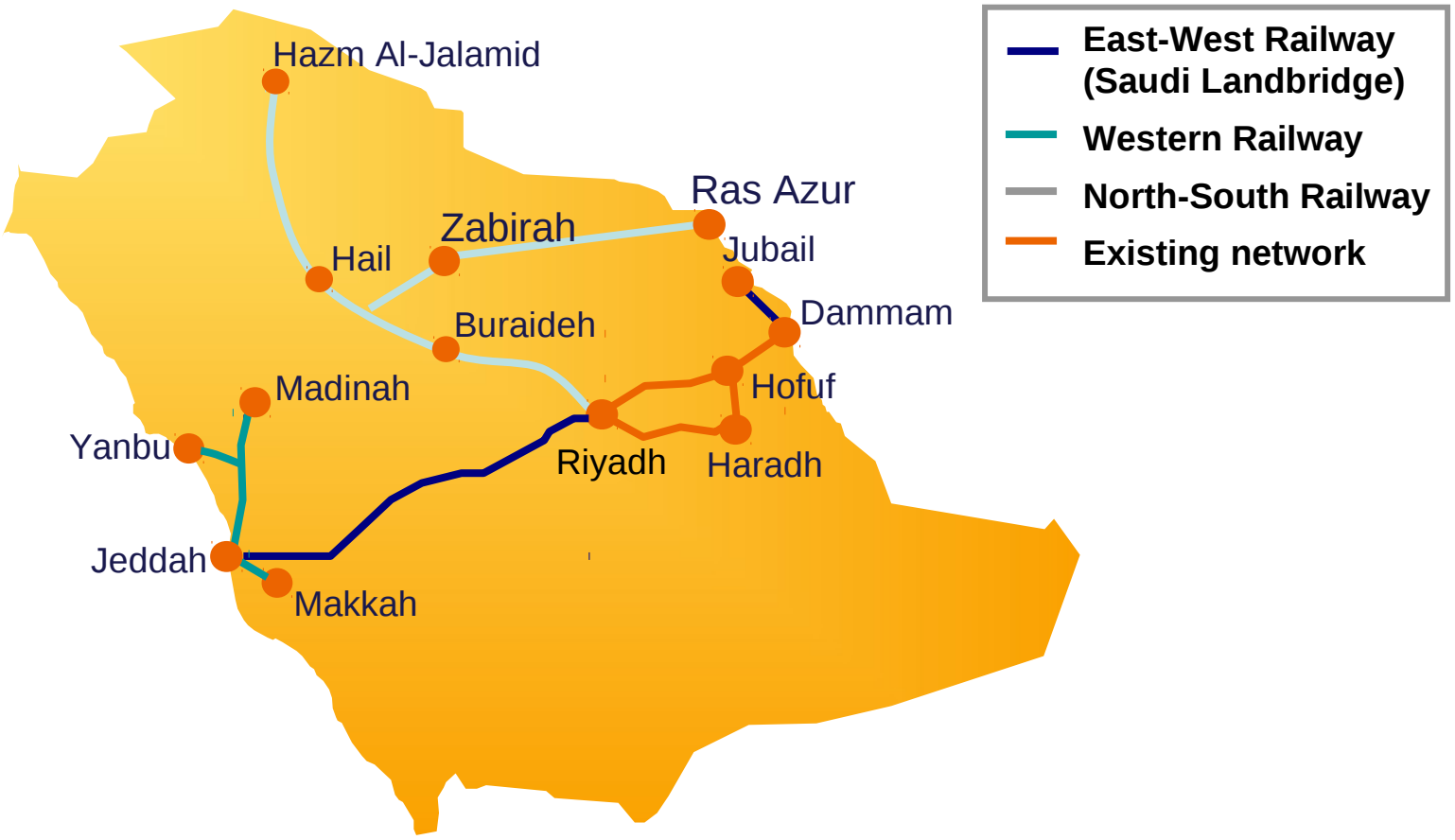
Charging Points Design at Stations

International Records

- **28 COUNTRIES**
- **60 PROJECTS**
- **Over 15,000 M €**

The Railway Expansion Program

Railway Expansion Program will add 3,200 km of track to the existing network …



… connecting all major cities in the Kingdom

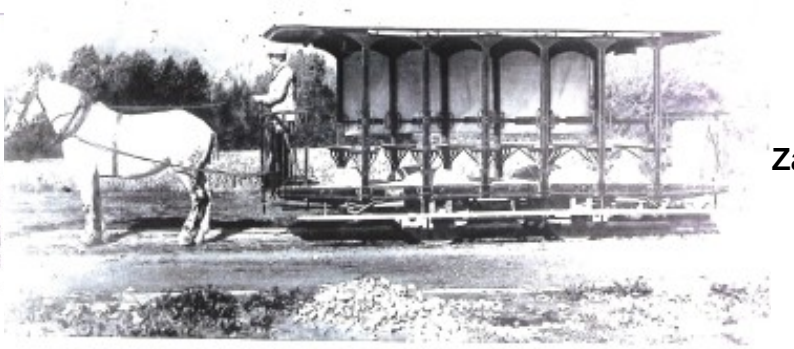
قطارات حديثة تقطع المسافة بين الدمام والرياض في 3 ساعات

8 قطارات إسبانية تدخل الخدمة بعد 8 أشهر

القطار الجديد (اليوم)

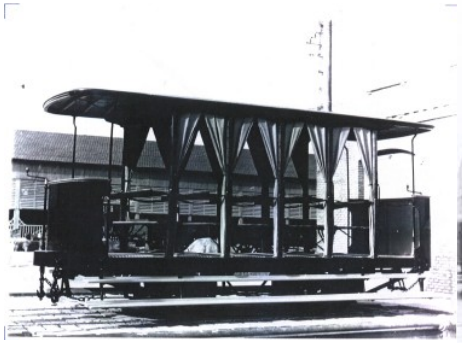
Start of the 20th century. The beginnings of our current URBOS Trams

Zaragoza trams 1902

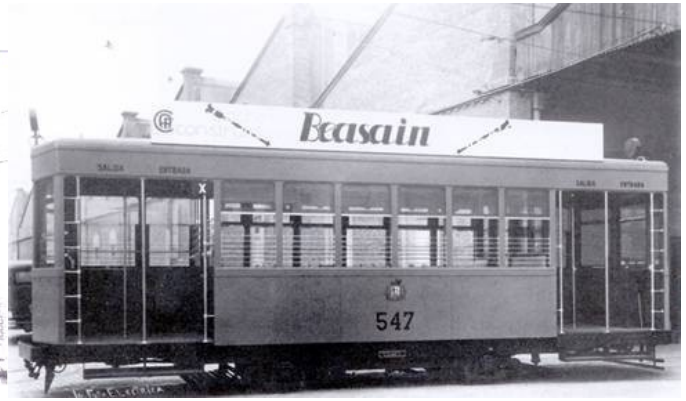


Zaragoza trams 1895

Cádiz trams 1903



Irún – Fuenterrabía trams 1919



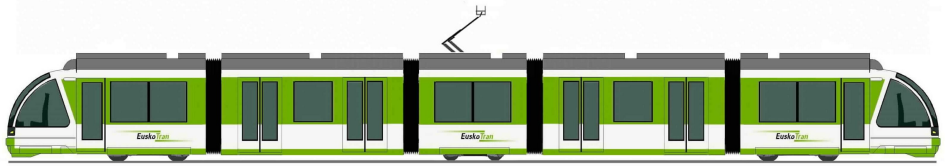
Madrid trams in the 30s

URBOS Platform by CAF

URBOS platform includes the followIng vehicle families:

- **URBOS - 70%**

- **URBOS 3 - 100%**



- **URBOS AXL**

All of them are compatible with the energy storge system

ACR evoDRIVE and ACR freeDRIVE

URBOS 100% LOW FLOOR

- **Modularity**
  - Length: **21m / 32m / 43m / 54m**
  - Width: 2.300mm / 2.400mm / 2.650mm
  - Track gauge: 1.000mm / 1.435mm

21 m

M M

32 m

M R M

43 m

M M R M

54 m

M M M R M

URBOS * Trams with ACR technology

PROJECT	Low Floor	Gauge	Nº LRV	Length/width (m)
Seville Metro	URBOS 2	1.435	17	31,26 / 2,650
Velez-Malaga	URBOS 2	1.435	3	31,26 / 2,650
Vitoria-Gasteiz	URBOS 2	1.000	11	31,26 / 2,400
Antalya	URBOS 2	1.435	14	35,00 / 2,650
Edinburgh	URBOS 2	1.435	27	42,26 / 2,650
Malaga	URBOS 3	1.435	14	32,366 / 2,650
Seville Downtown*	URBOS 3	1.435	5	32,366 / 2,400







URBOS

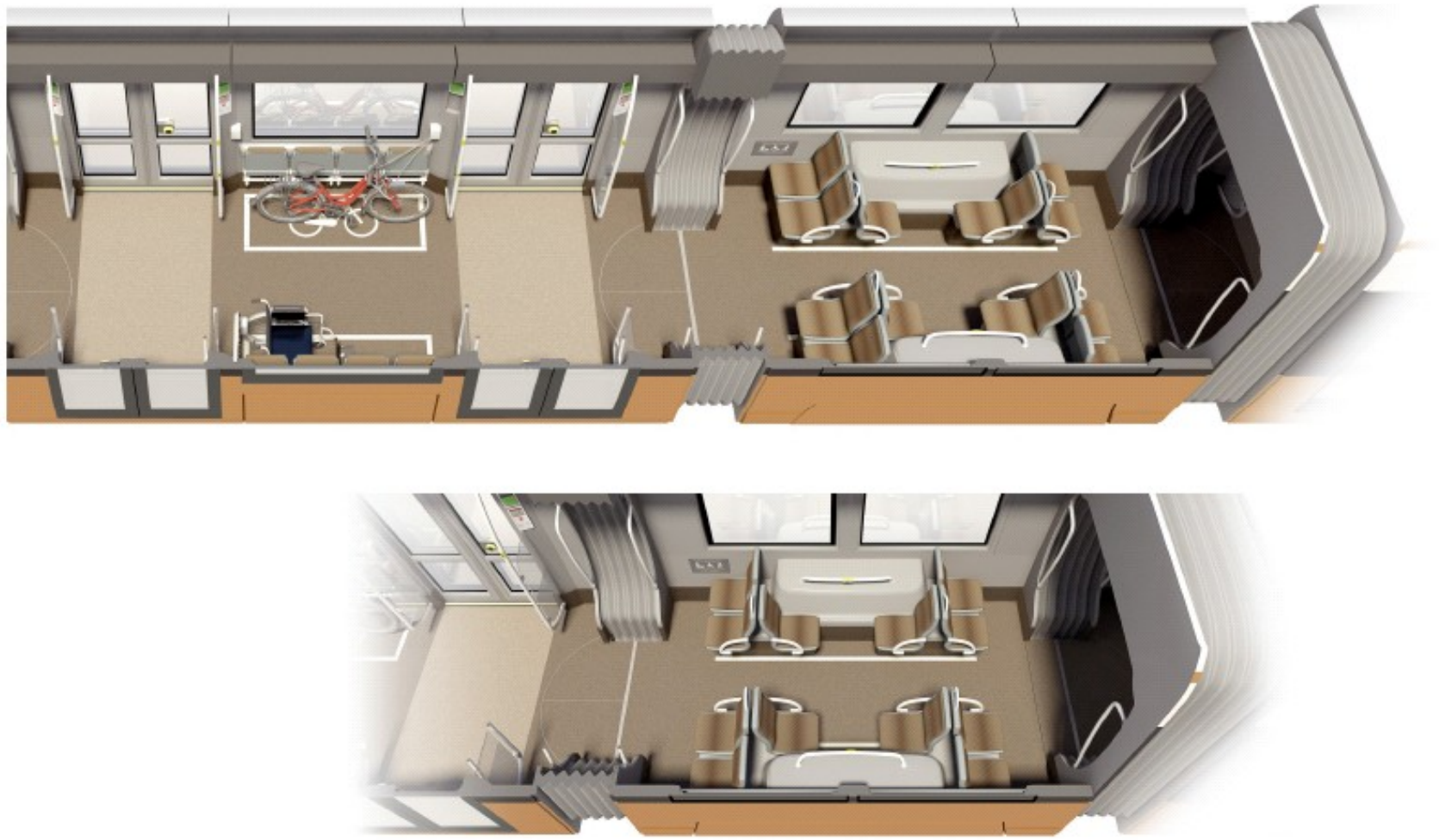
*** Trams with ACR technology**

PROJECT	Low Floor	Gauge	Nº LRV	Length/width (m)
Belgrade	URBOS 3	1.000	30	32,36 / 2,30
Granada*	URBOS 3	1.435	13	32,36 / 2,65
Saragossa*	URBOS 3	1.435	21	32,36 / 2,65
Nantes	URBOS 3	1.435	12	37,96 / 2,40
Besançon	URBOS 3	1.435	19	23,02 / 2,40
Stockholm	URBOS AXL	1.435	22	30,80 / 2,65
Birmingham	URBOS AXL	1.435	20	32,90 / 2,65
Houstom 70% Low Floor	URBOS	1435	39	29,10 / 2,65





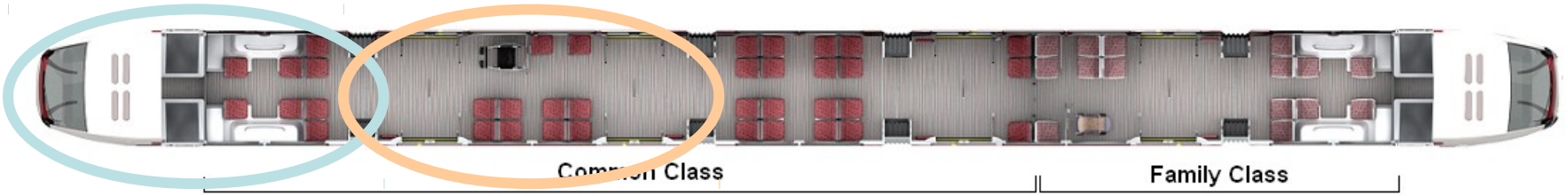
Vehicle Interior Layout



Main Features - Interior

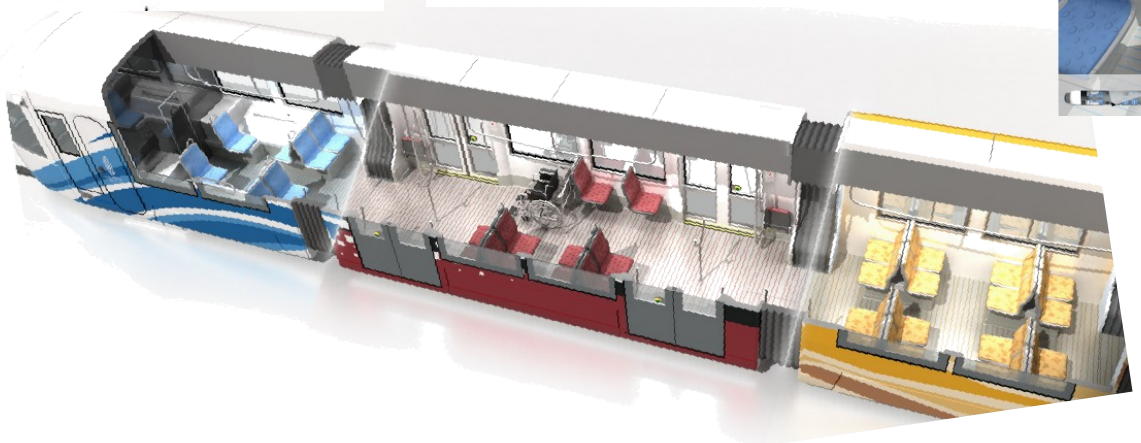
- Several alternatives for interior design comprising Common class and Family class areas

ALTERNATIVE 1



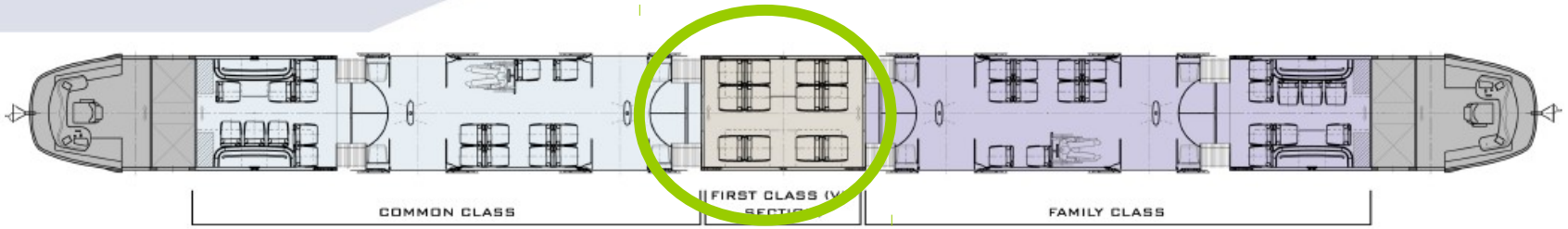
ALTERNATIVE 2

ALTERNATIVE 3



Main Features - Interior

- **VIP Option**

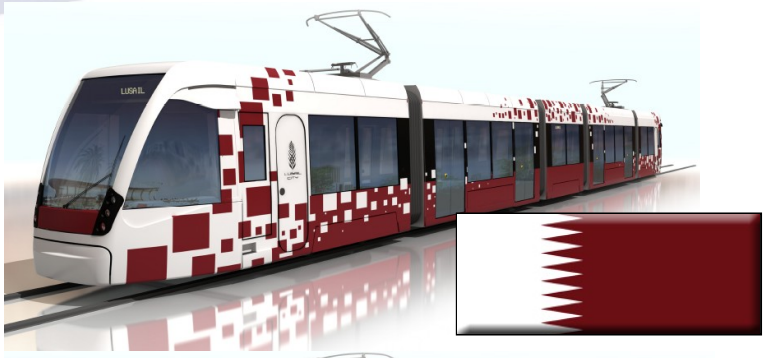


COMFORT RATE

VIP class:
100% seated
Family class:
32% seated, 1 wheelchair
Common class:
32% seated, 1 wheelchair

Main Features - Exterior

- Different approaches for exterior designs



ECo CAF SOLUTIONS

Committed to offering sustainable transport solutions

The search for more efficient and environmentally friendly means of transport is a primordial objective of our company.

CAF carries out an especially relevant role due to its ability to reduce transport energy costs and promote alternative, highly efficient and environmentally friendly, means of transport.

Energy Storage System: Context and Problems

- **Demand for increasingly cleaner and more efficient systems from an energy point of view.**

- **Growing concern about the visual impact of catenary in historical and/or special designed areas.**

EcoCAF Solution

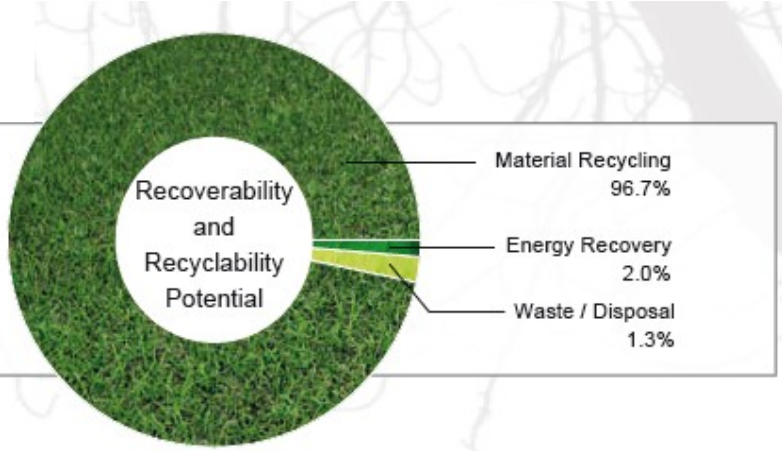
SARAGOSSA Tram with ACR
Product Environmental Statement according to ISO 14025

World´s first verified EPD for a Tram

Potential recoverability and recyclability profile

Thanks to the studied design and modularity used for tram assembly and disassembly, high potential recoverability and recyclability rates at the end of its useful life are achieved, in agreement with ISO 22628, such as:

TZ Recoverability and Recyclability Potential	
Material Recycling	96.7%
Energy Recovery	2.0%
Waste / Disposal	1.3%



Challenges

Catenary-free tram

ACR freeDRIVE

CATENARY-FREE

Certain capacity for running without catenary

Possible energy savings

ENERGY SAVING

Energy saving system

ACR evoDRIVE

Greentech Solutions

Greentech is CAF/ Trainelec's green product line that answers the needs set out

ACR evoDRIVE

On-board energy storage system focused on **energy saving.**

ACR freeDRIVE

On-board energy storage system focused on **catenary-free operating mode.**

Benefits of On-Board Energy Storage (ACR)

✓ **Catenary-free operation.**
- ⇨ Distances > 500 metres up to 2500 metres
- ⇨ Heritage districts
- ⇨ Architectural barriers

ACR freeDRIVE

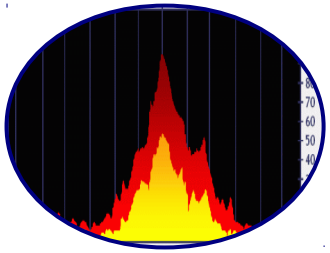
✓ **Energy saving.**
- ⇨ In tram
- ⇨ On the line.

ACR evoDRIVE ACR freeDRIVE

✓ **Catenary-free areas.**
- ⇨ Distances < 200 metres
- ⇨ Neutral areas
- ⇨ Tunnel exits
- ⇨ Depots

ACR evoDRIVE ACR freeDRIVE

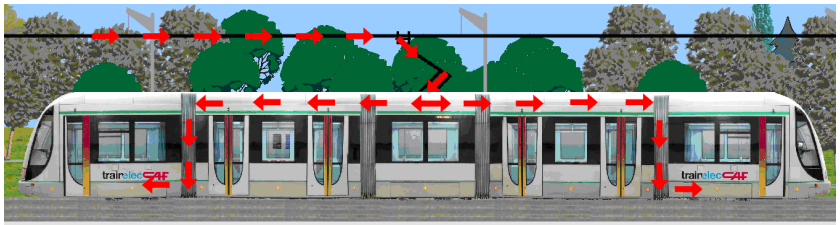
✓ **Consumption peaks.**
- ⇨ Peaks
- ⇨ Stabilisation.



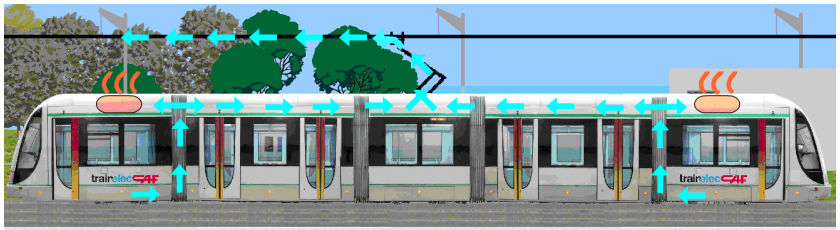
ACR evoDRIVE ACR freeDRIVE

ACR - FREEDRIVE. FUNCTIONALITY

CONVENTIONAL TRAM

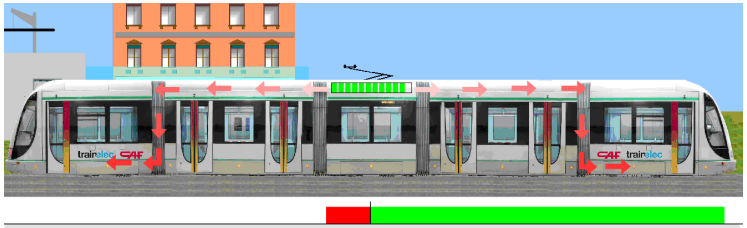


· **Traction phase:** Between stations the energy is supplied by the catenary



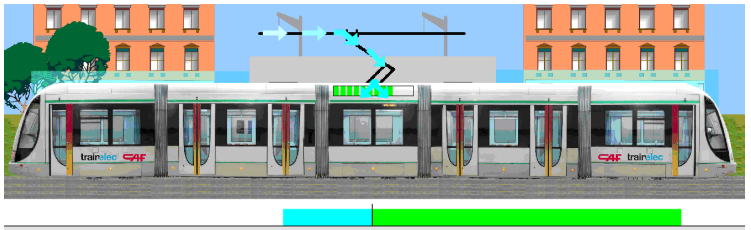
· **Braking phase:** A small part of kinetic energy is returned to the catenary. The rest of the energy is dissipated in the brake resistors

CATENARY-FREE TRAM



· **Traction phase:** The tram starts running from the station with ACR system fully charged supplying the energy to the traction system

· **Braking phase:** The whole of kinetic energy is recovered in the ACR system starting the recharge process



· **Station charge phase:** The ACR system is fully charged during the stop

On-Board Storage Technologies

• Over 4 years of research to analyse, study, integrate and test different energy storage solutions (ESS) in trains.

- **Fuel cell**

- **Flywheels**

- **Batteries**

- **Supercapacitors**

Supercapacitors and Batteries

Batteries vs Supercapacitors

	Energy density	Power	Life expectancy (approx. number of cycles)
Batteries	High	Low	2.000
Supercapacitors	Medium	High	1.000.000

✓ **Energy density.**

⇨ Directly related to running range.

⇨ Battery energy quality ≠ Supercapacitor.

- ➢ **Supercapacitor, physical phenomenon**.
- ➢ Battery, chemical phenomenon.

✓ **Power.**

⇨ **Supercapacitor. Allows charging at very high current. Ultra-rapid charging process: 20 sec.**

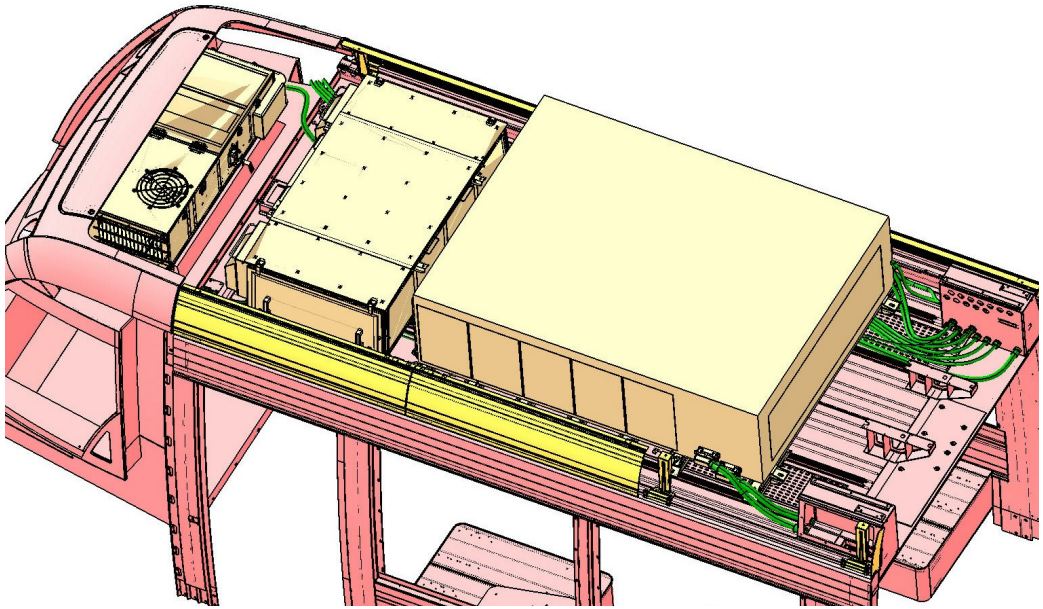
⇨ Battery. High current rate charging is detrimental. Charging process > 5 min.

ACR evoDRIVE — On-board energy storage system based on **supercapacitors.**

ACR freeDRIVE — On-board energy storage system based on **supercapacitors and batteries. Hybrid Technology.**

ACR - FREEDRIVE. INSTALATION

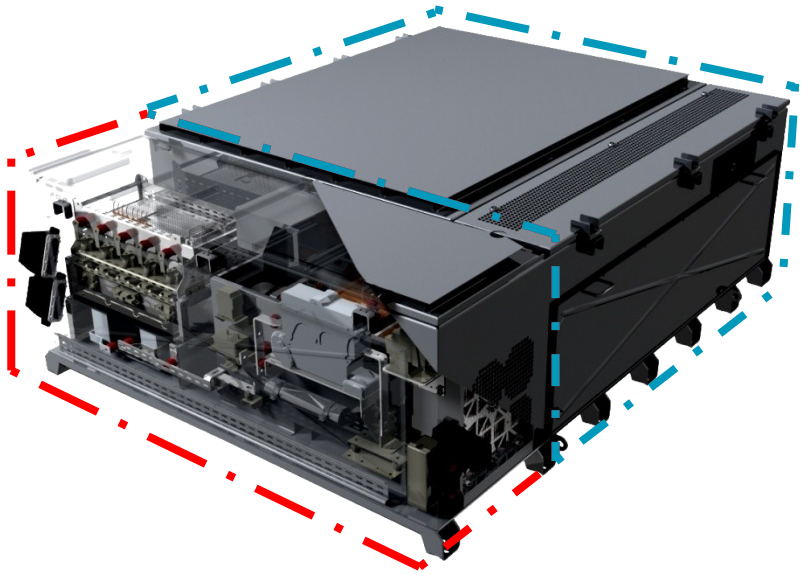
- ACR sytem is mounted on the roof to the end modules of the tramway.
- Third rail is powered only when the vehicle is over the rail. Fail safe system.



ACR System. Technical Characteristics

Integrated ACR Equipment: DC/DC + Energy Storage

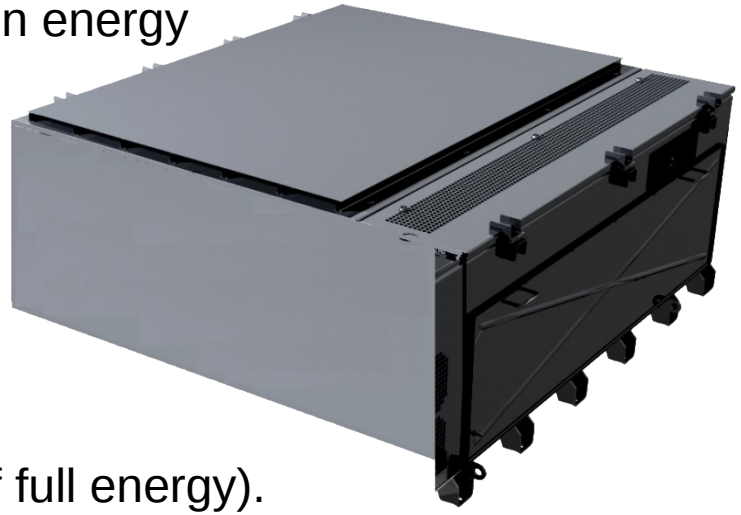
- **DC/DC converter**: energy charge and discharge control.
- **Energy Storage System**: energy storage in supercaps/battery modules**.**
- **Modular** system with 5 independent branches per ACR module.
- **Configurable** ultracap/battery distribution depending on the application.



ACR System. Energy storage

The enery storage is configurable

- ⇨ Modular system according to number of branches.
- ⇨ Configurable branch composition depending on energy needs: ultracaps, battery.



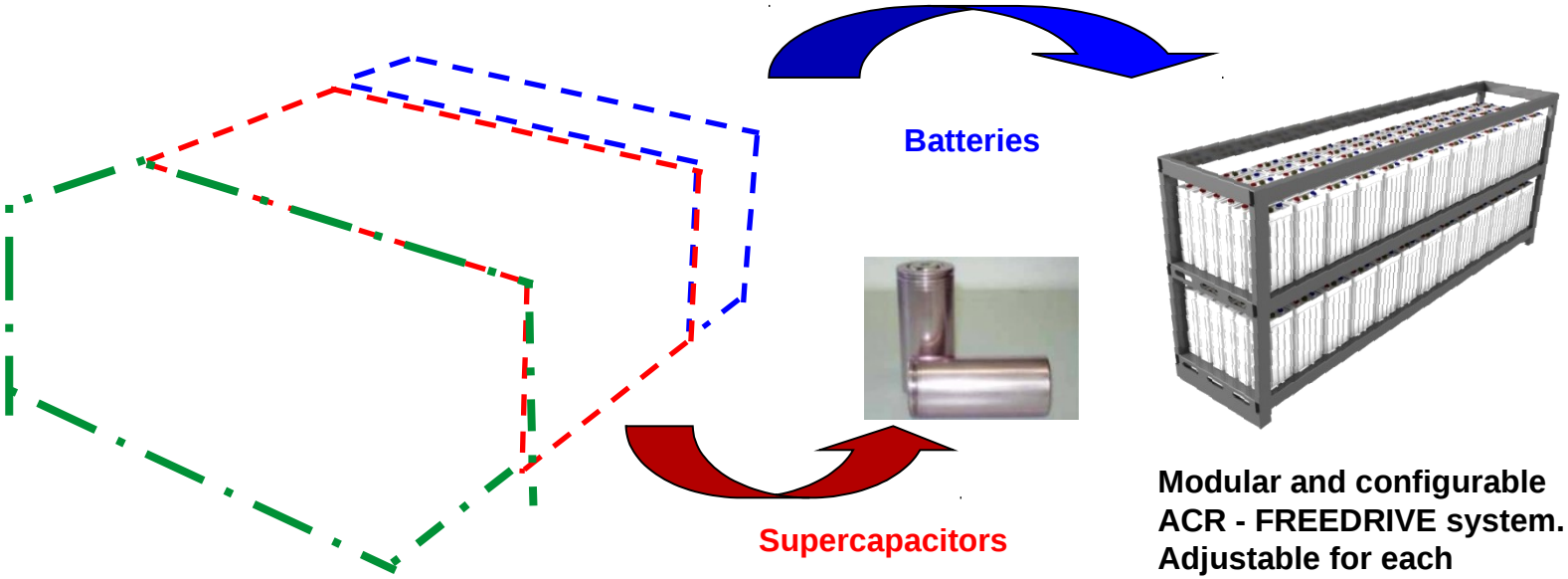
Details of 5 branch ultracap equipment

- ⇨ 5 independent modular branches
- ⇨ Maximun working voltage per cell: 2,7 Vdc.
- ⇨ **Energy**: 3,9 kWh of useful energy (5,2 kWh of full energy).
- ⇨ Power: defined by dc/dc equipment.
- ⇨ Cooling type: modular cooling (natural convection, forced air, foreced air + cooling circuit + closed cooling air circuit).

ACR - FREEDRIVE. SYSTEM DESCRIPTION

THE ACR - FREEDRIVE ALLOWS INTEGRATING SUPERCAPACITORS AND BATTERIES (2x UNITS FOR ONE 32M LRV)

- DC/DC Converter: Controls supercapacitor/battery charging and discharging.

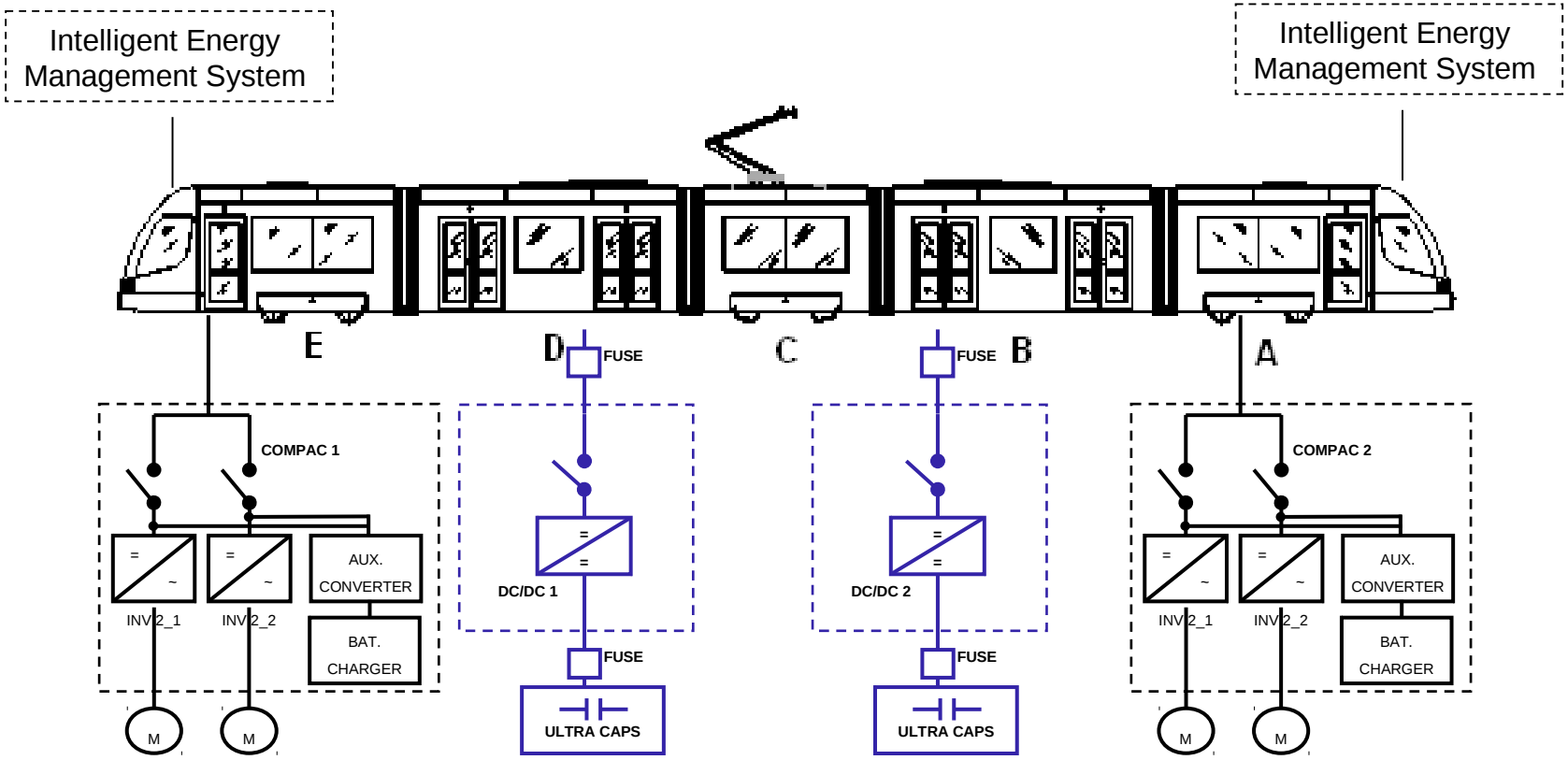


Modular and configurable ACR - FREEDRIVE system. Adjustable for each application.

	Supercapacitors	Batteries
ENERGY	Useful: up to 2x 3.9 kWh	Up to 2x 15 kWh
	Total: up to 2x 5.2 kWh	

ACR System

Two ACR modules per unit



ACR - FREEDRIVE. CHARGING INFRASTRUCTURES

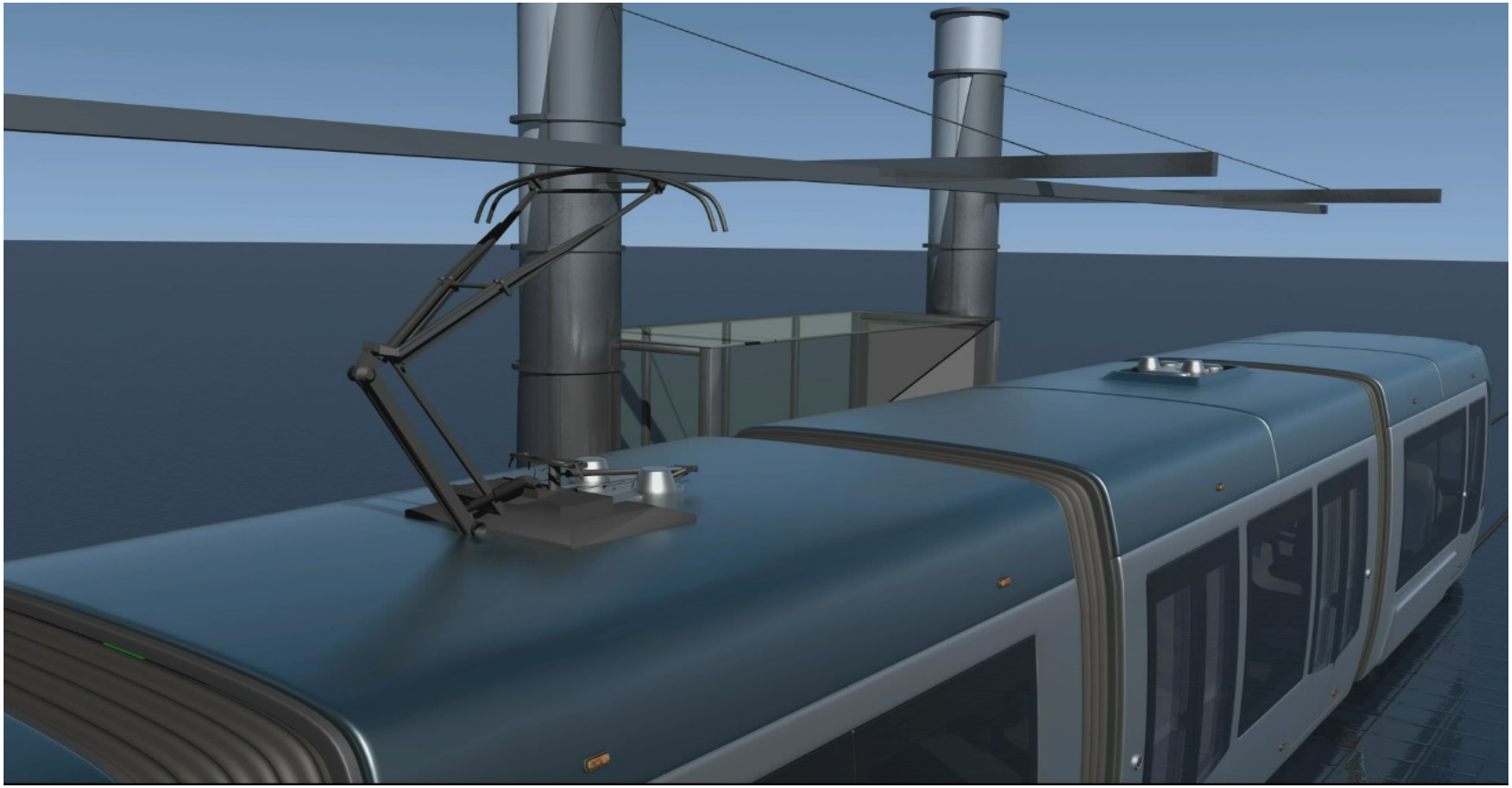
Charging process can be made either from the third rail or rigid Overhead Catenary at Stations

CAF unic World Manufacturer with Two charging solutions for Catenary Less Trams in service

Third Rail is not considered by CAF an appropriate solution due to dust and sand environmental conditions

ACR - FREEDRIVE. CATENARY CHARGING SYSTEM

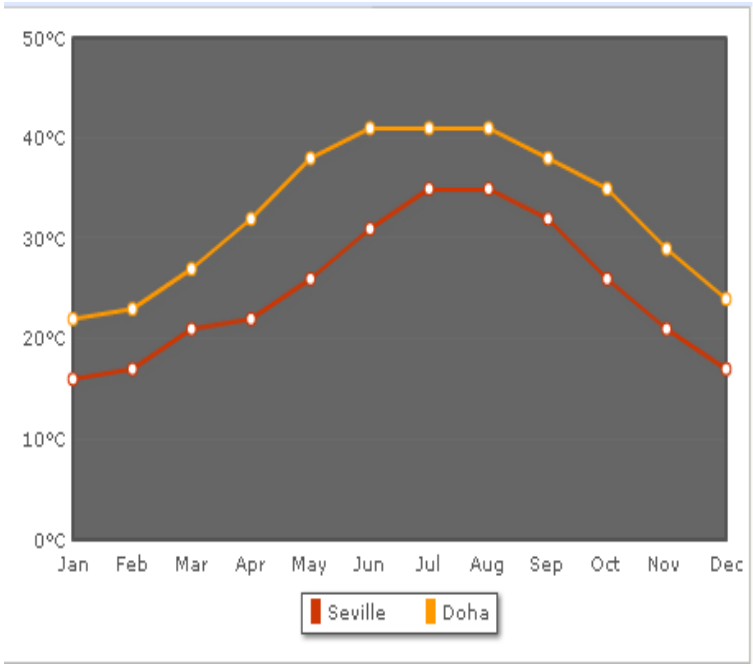
- **Short Rigid Catenay installed only at the stops**
- **Double Rigid Catenary**



Metrocentro Seville Tram. MAIN DATA

Service in extreme conditions:

- Average maximum temperature (July – August 2010): 35 ºC.
- **Maximum temperature during operating period: 42.2 ºC (11 August 2011)**
- Maximum consumption of auxiliary equipment.



Details of revenues service with passengers

- More than **269 routes are performed daily** along the catenary-free section.
- More than **150 KM are completed daily without catenary**.
- **100% availability of the ACR - Freedrive system.**

ACR System Service Proven

Sevilla Tram

March 2010

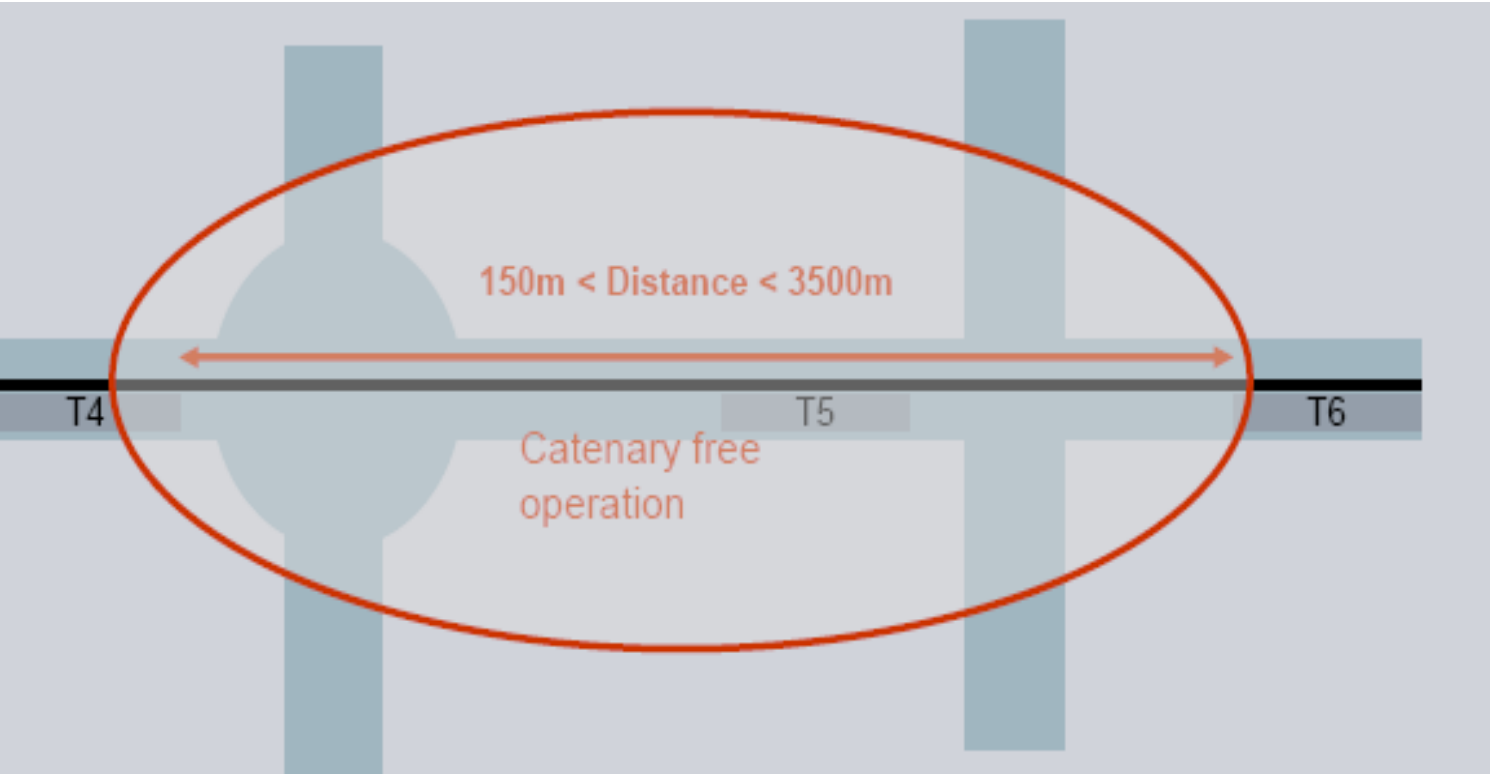
Zaragoza Tram

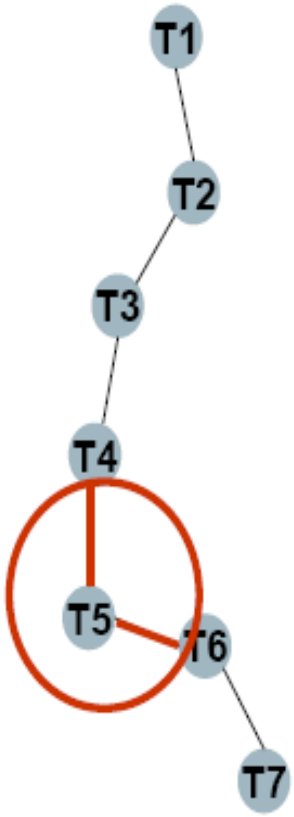
Granada Tram Delivery in 2013

Scenario 1 for partly catenary free operation (w/ Ultracaps)

Requirement for partly catenary free operation example from T4 to T6 (<3.500m)

- ✓ No additional infrastructure necessary
- ✓ Vehicle equipped with batteries





ACR System Service Proven

Seville Tram: main data

Configuration:

- 5 cars

Train type	**Urbos 3 - 5 cars (32 m)**
Number of trains	**4**
Number of ACR - Freedrive units	**2**
Supercapacitor energy	**2x 4.1kWh**
Battery energy	**Without Battery**

Line characteristics:

SECTION 1 SECTION 2

	Section 1	Section 2
Catenary	**YES**	**NO**
Length (km)	**1.514**	**0.483**
Number of stops	**2**	**0**
Maximum gradient	**1.56%**	**0.66%**

ACR System Service Proven

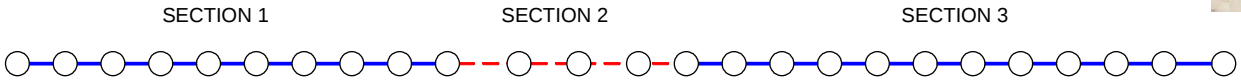
Saragossa Tram: main data

Configuration:

- 5 cars

Train type	**Urbos 3 - 5 cars (32 m)**
Number of trains	**21**
Number of ACR units	**2**
Supercapacitor energy	**2x 4.1kWh**
Battery energy	**2x 15 kWh**

Line characteristics:



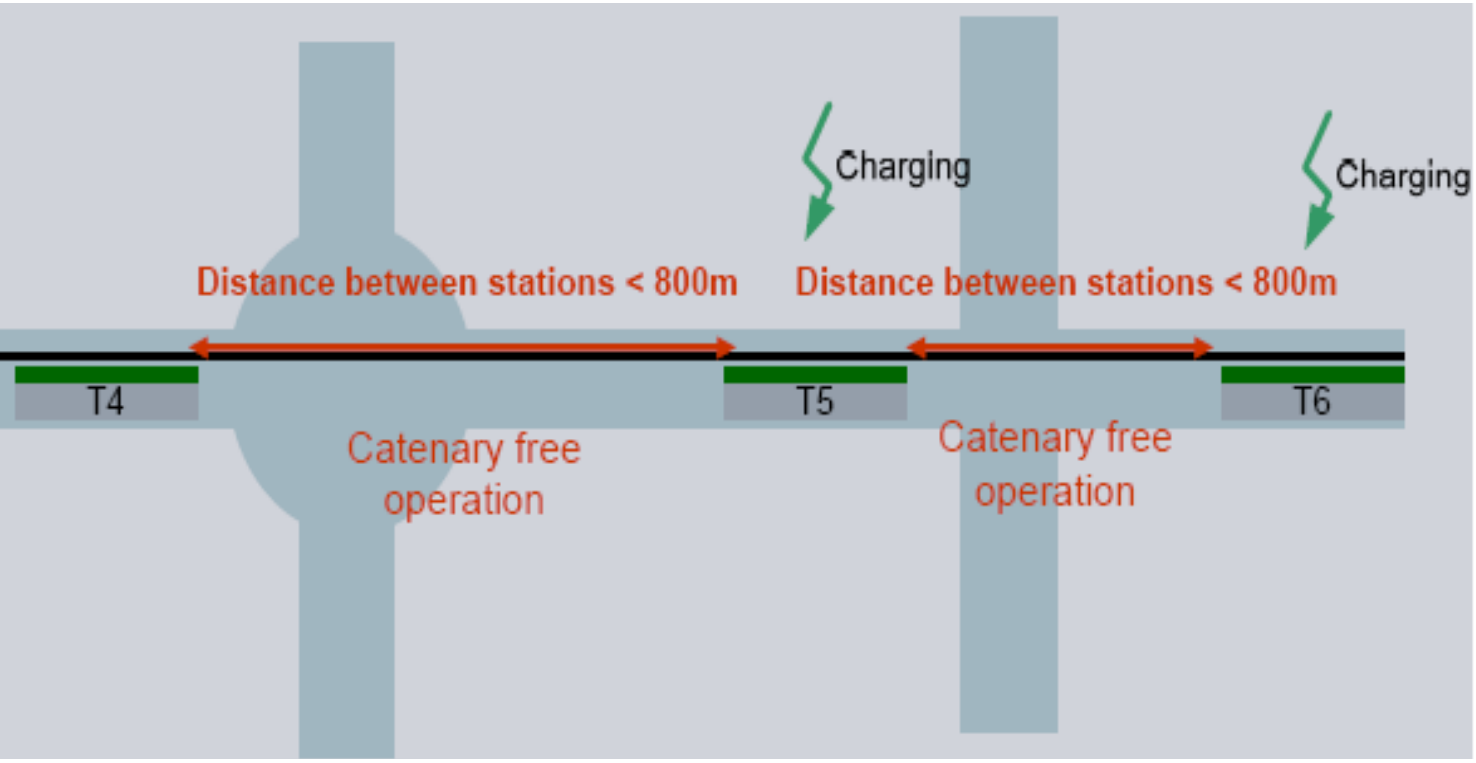
	Section 1	Section 2	Section 3
Catenary	**YES**	**NO**	**YES**
Length (km)	**4.91**	**2.087**	**5.786**
Number of stops	**8**	**3**	**10**
Maximum gradient	**5.95%**	**2.18%**	**6.70%**

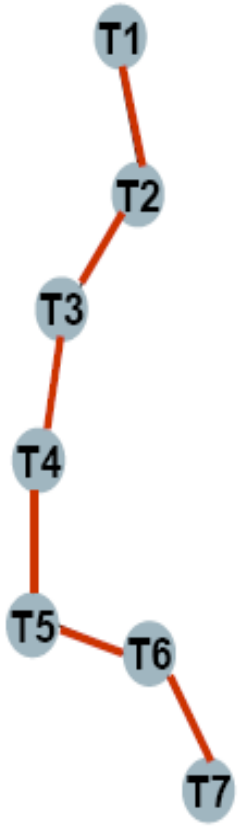
Scenario 2 for fully catenary free operation

(w/ Capacitors & Batteries)

Requirement Full catenary free operation example from T1 to T7 (distance between stations < 800m)

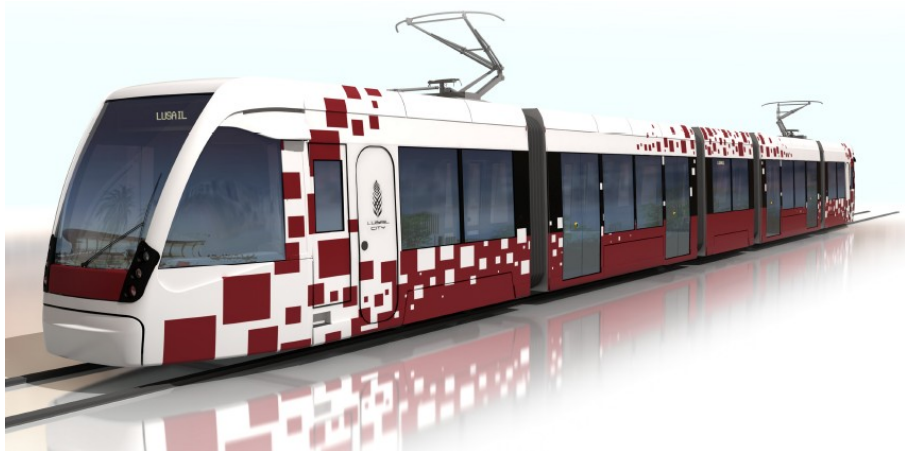
- ✓ No additional infrastructure necessary, charging at stations
- ✓ Vehicle equipped with capacitors & batteries (**batteries as backup only)**





ACR System

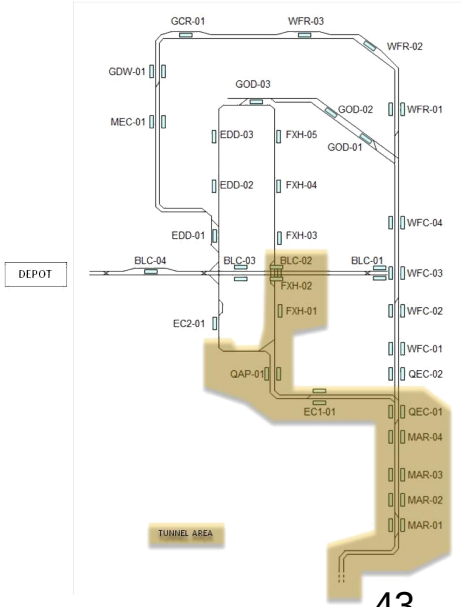
Lusail Tram: main data



Line characteristics:

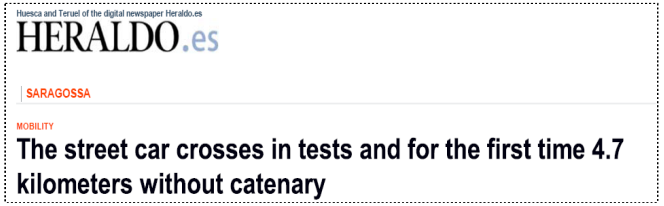
One route with over 2000 meters distance between stops

	Green Line		Red Line	Purple Line	Yellow Line
Catenary	**YES**	**NO**	**NO**	**NO**	**NO**
Length (km)	**2.46**	**11.93**	**2.31**	**1.84**	**4.81**
Number of stops	**5**	**13**	**4**	**4**	**9**
Maximum gradient	**6%**	**1.07%**	**1.8%**	**3.1%**	**4.1%**



Suitability to GCC and Qatar Projects

• PROVEN SOLUTION IN REAL OPERATION	✓OK	-Seville: total 97.000 km -Saragossa: total 240.000 km
• HIGH TEMPERATURE CONDITIONS	✓OK	-Maximum recorded temperature in Seville during operation period: 42.2 ºC (11 august 2010). Comparable to Doha. -Cooling system improved for Qatar(now refrigerated). Approx +60% higher cooling capacity compared to Seville (forced air).
▪ ENVIRONMENTAL CONDITIONS: SAND & DUST	✓OK	-Proposed ACR cooling system is mixed, forced air and refrigerated circuit, so that there is no contact with external air. Infraestructure: -The Rapid Charge Power Supply System (SCSE) charging infrastructure is elevated. As the contact device of the recharge point is installed elevated, sand and dust accumulation is not a problem as it could be for a system based on track level power collection.
▪ DISTANCE IN CATENARY-FREE OPERATION	✓OK	-Saragossa/Seville LRT with 2x4.1kWh (without using battery) can cross long distances:


Huesca and Teruel of the digital newspaper Heraldo.es

HERALDO.es

SARAGOSSA

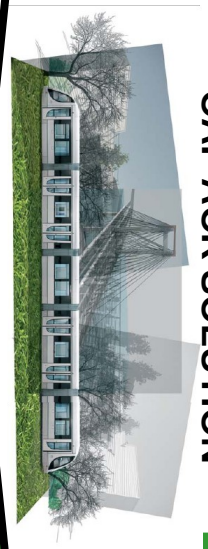
MOBILITY

The street car crosses in tests and for the first time 4.7 kilometers without catenary

CAF approach to main operators´ concerns

MAIN OPERATOR´S CONCERNS

CAF ACR SOLUTION



INVESTMENT

- ✓ **Higher initial investment costs compared to conventional system**

- ✓ **Lower operational costs → Energy savings**
- ✓ **Lower maintenance costs → Maintenance Free**
- ✓ **Lower life cycle costs → Open Source**
- ✓ **Lower Infra. Costs → E&M and Civil Works savings**

SAFETY

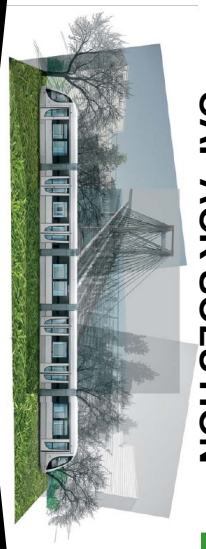
- ✓ **Alternative power supply**
- ✓ **Road conditions and future maintenance for construction and traffic at street crossings**

- ✓ **No danger by magnetic fields**
- ✓ **No danger by direct touch voltages**
- ✓ **No limitations for road constructions and traffic**

CAF approach to main operators´ concerns

OPERATOR´S CONCERNS

CAF ACR SOLUTION



TECHNOLOGY

- ✓ Benefiting from latest technology
- ✓ Independent from single source supplier
- ✓ Extendability of the system

- ✓ Proven technologies for energy storage
- ✓ Multiple sources for energy storages possible
- ✓ Easy extension of the system (e.g. new stations…)

ENVIRONMENT

- ✓ Energy savings
- ✓ Free of environmental influences

- ✓ Energy savings up to 35%
- ✓ Full energy recuperation of breaking energy
- ✓ No impact by sand, water, dust, wind
- ✓ No impact by heavy traffic or radio signals

Overall Advantages of ACR Energy Storage

SAFETY

- ✓ Enhanced safety, no danger by magnetic fields and touch voltages
- ✓ No impact on road construction and maintenance
- ✓ No influence by sand, dust, water, floodings…

MAINTENANCE

- ✓ Low operation costs
- ✓ Maintenance free technology / no complex
- ✓ Easy to extend and upgrade

MARKET

- ✓ Participation in world future technology
- ✓ Open systems, no dependency on one supplier
- ✓ All major E&M suppliers have solutions with energy storage tech

ENVIRONMENTAL

- ✓ Up to 35% energy savings
- ✓ Up to 30% lower CO2 emissions
- ✓ No additional weight → compensated through light vehicle designs

Thanks for your attention