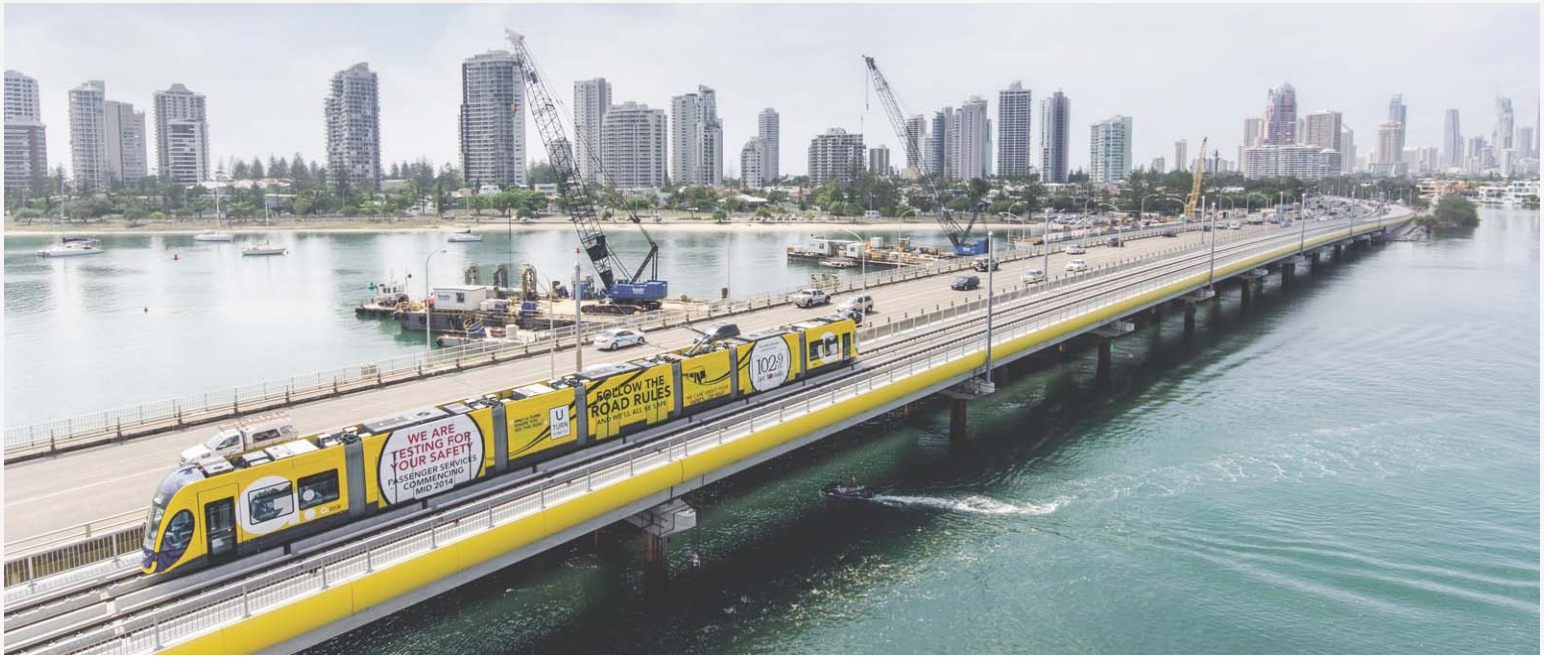
Continued Advances in Light Rail / Streetcar Vehicle Off-Wire Technology

John D. Swanson, Principal Consultant

APTA /TRB 14th National Light Rail And Streetcar Conference 2019

› April 7 – 9, 2019



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No Overhead Wires - Not a New Desire

OR

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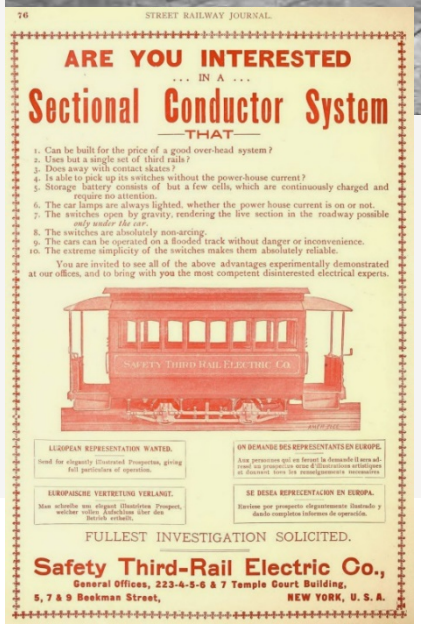
The Search for Vehicles Without Overhead Wires

Many early attempts at off-wire operation!

- **Ground level induction power transfer – patents since 1901, no working systems**
- **Ground level pickup – mechanically switched**
- **Ground level pickup – magnetically switched**
- **Ground level pickup – buried conduit**
- **Battery powered**
- **Internal combustion engines**



76 STREET RAILWAY JOURNAL.

ARE YOU INTERESTED
... IN A ...
Sectional Conductor System
—THAT—

1. Can be built for the price of a good over-head system?
2. Uses but a single set of third rails?
3. Does away with contact skates?
4. Is able to pick up its switches without the power-house current?
5. Storage battery consists of but a few cells, which are continuously charged and require no attention.
6. The car lamps are always lighted, whether the power house current is on or not.
7. The switches open by gravity, rendering the live section in the roadway possible *only under the car.*
8. The switches are absolutely non-arcing.
9. The cars can be operated on a flooded track without danger or inconvenience.
10. The extreme simplicity of the switches makes them absolutely reliable.

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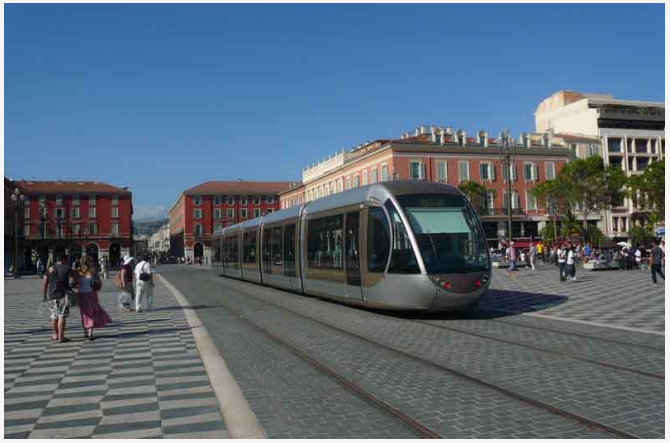
Current Off-Wire Technology

- **Complex subject – must be approached from a *systems* viewpoint!**
- **Three basic approaches:**
  - **Ground Level Power Supply (GLPS)**
  - **Onboard Energy Storage System (OESS)**
  - **Onboard Power Generation System (OPGS)**
- **Plus hybridized combinations**
- **Advances in technology now make old approaches practical**

Dubai, UAE



Nice, France

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Key Application Considerations

All Alternative Systems:

- **Desired length / location of off-wire operation**
- **Operating headways / consists / dwell times**
- **Alignment and track arrangement**
- **Location of station stops**
- **Climactic conditions**
- **Space for wayside sub-stations, etc.**
- **Local energy costs**
- **Space on vehicles**
- **Future expansions**

Nice, France
(Line 2)

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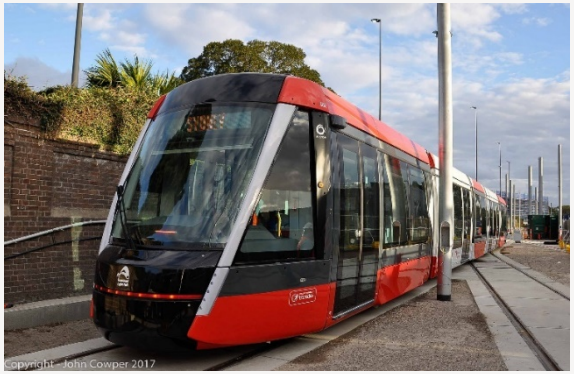
Key Application Considerations

Onboard Energy Storage (GLPS / OESS):

- **Capacity / size / weight energy storage elements**
- **Current collection and control**
- **Life expectancy / replacement / disposal of energy storage elements**
- **System monitoring**
- **Fire detection / prevention**
- **Specialized maintenance / equipment**

Lusail, Qatar



Sydney CBD East

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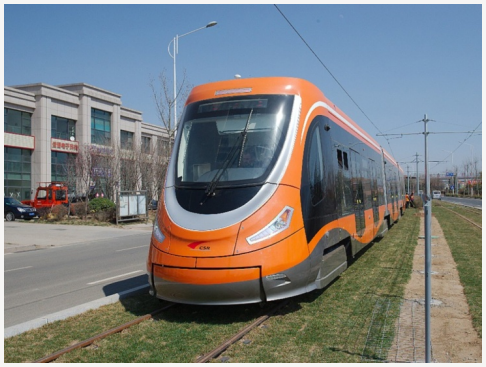
Key Application Considerations

Onboard Power (OPGS):

- **Capacity / size / weight power generation / fuel storage elements**
- **Cost / availability of fuel**
- **Refuel periodicity / refill time**
- **Wayside fuel storage / refueling equipment**
- **System monitoring**
- **Fuel spill detection / prevention**
- **Fire detection / prevention**
- **Specialized maintenance / equipment**

Nordhausen, Germany



Quingdao, China

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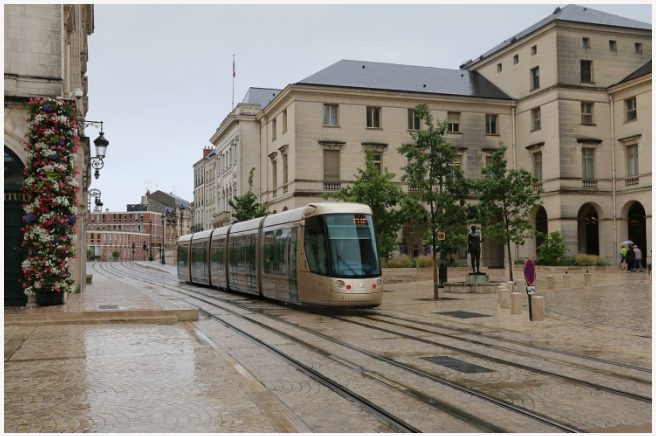
Current Off-Wire Status Worldwide

Fourteen years ago (2005) there was only one "off wire" system in revenue service (Bordeaux, using GLPS)

Today there are:

- **9 systems using Ground Level power + 2 more under construction**
- **25 systems using Onboard Energy Storage for off-wire + 8 more under construction (3 w/ SRS)**
- **6 systems using Onboard Power**
- **A few LRV systems using OESS to achieve energy savings**
- **Most US streetcars have emergency battery drive**
- **27 development prototypes**



Orleans, France

Dallas

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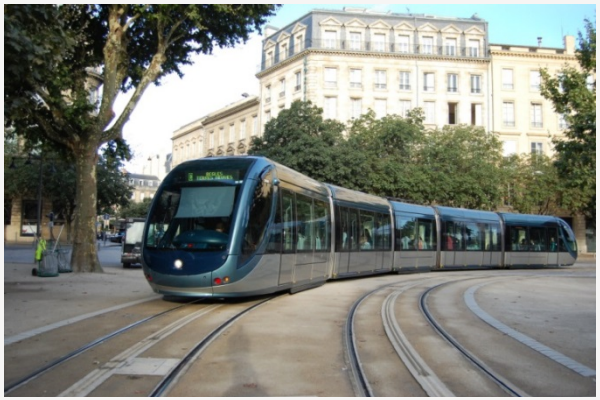
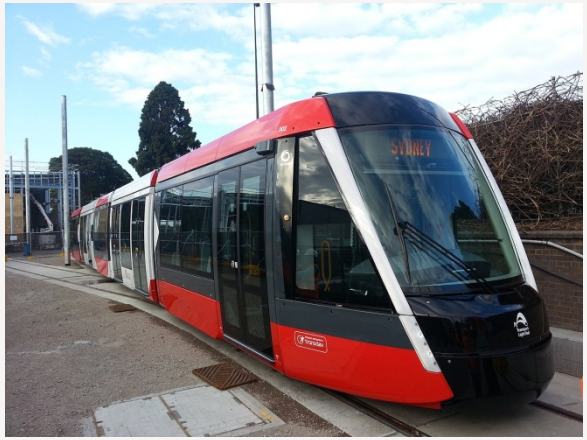
Ground Level Power Supplies (GLPS)

- **Provides a <u>continuous</u> power supply over part or all of system with limited onboard energy storage**
  - **Advantageous where HVAC requirements are high, steep uphill gradients, etc.**
  - **Downside is that complex ground level infrastructure is high cost / proprietary**
- **Adding more onboard energy storage allows reduction of GLPS infrastructure (e.g. install only at stops and uphill segments) reducing costs**
- **Proprietary technology now being licensed**



Bordeaux, France



Sydney, Australia

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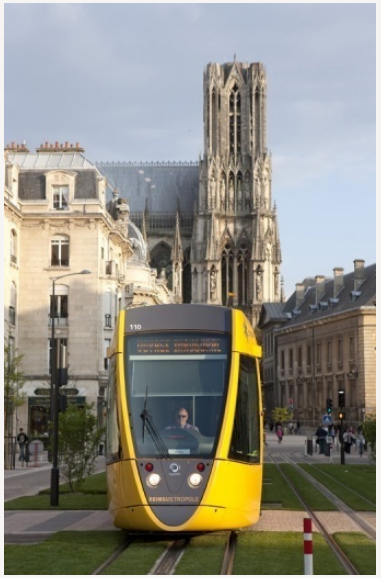
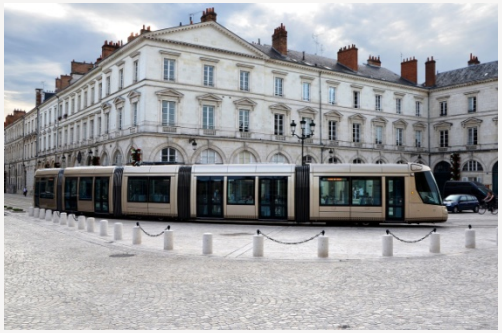
Recent GLPS Examples



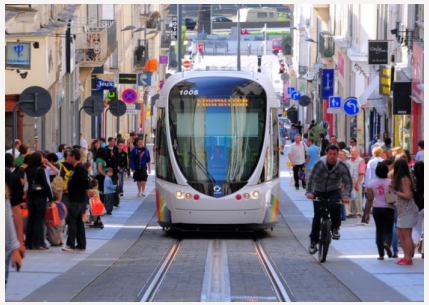
Rheims



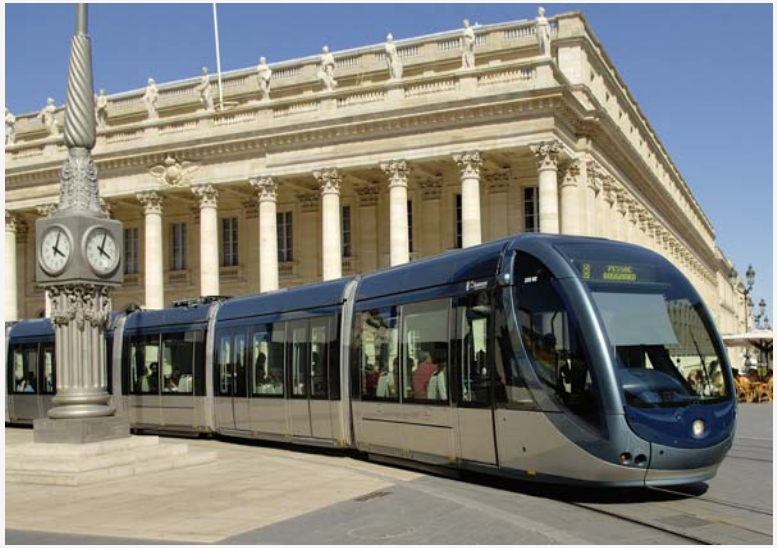
Orleans

Tours

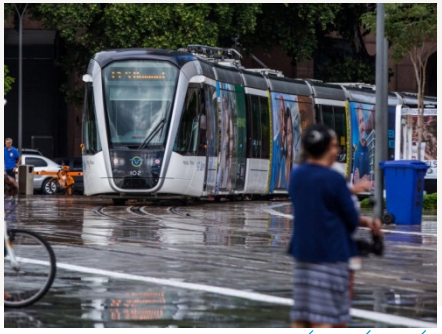
Dubai



Anger



Bordeaux – 2002



Rio de Janeiro

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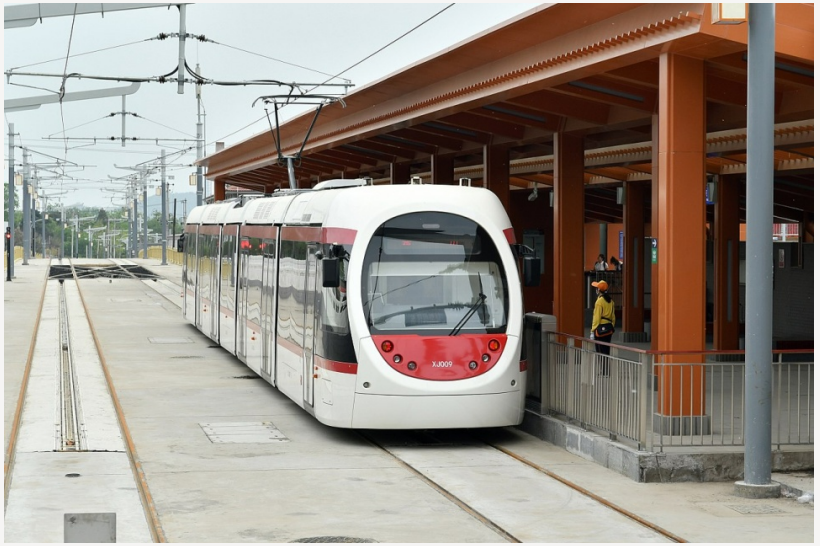
Alstom APS / SRS System

Recent GLPS Examples

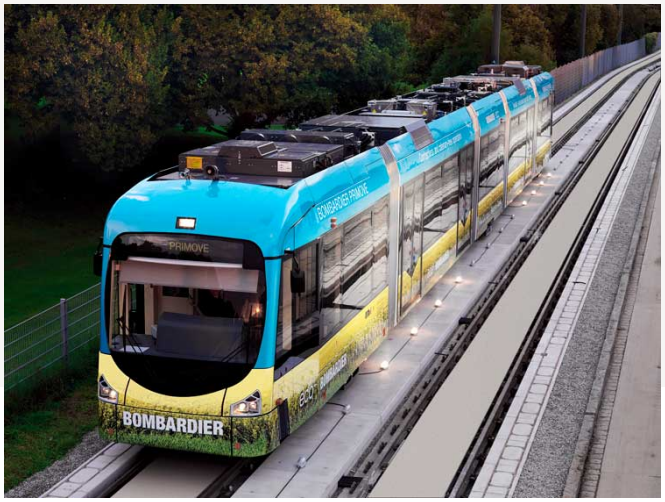
Zuhai, China

Hitachi / Ansaldo Breda Tramwave System



Beijing / Xijiao, China

Bombardier Primove System



Augsburg, Germany Demonstrator

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Onboard Energy Storage Systems (OESS)

- **Provides a non-continuous power supply (requires recharging enroute / between runs)**
- **Charging method depends on system design-**
  - **Charging while under OCS (works with short off-wire segments)**
  - **Charging at station stops (alternative for longer distances) – overhead or ground level**
- **Length and number of "off-wire" segments increasing on new systems**
- **Generally non-proprietary technology**
- **Completely wire-free systems now in service**
- **Now the most popular approach**

Detroit

Kaohsiung, Taiwan

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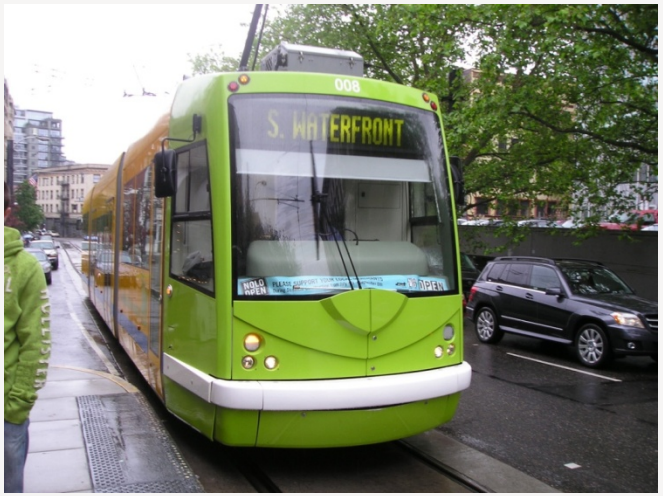
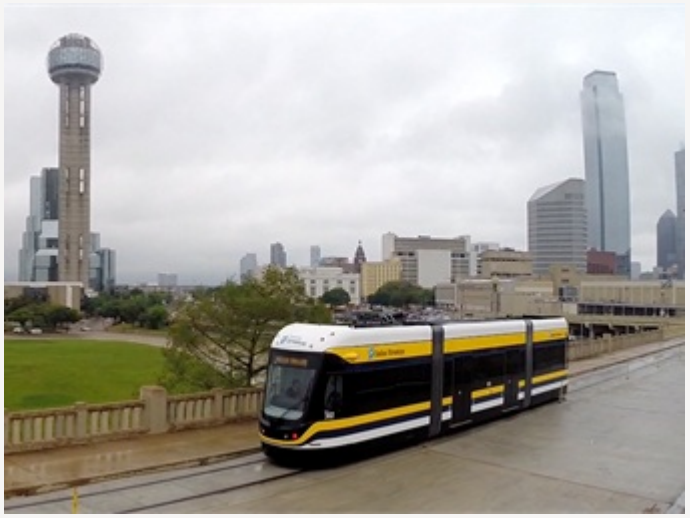
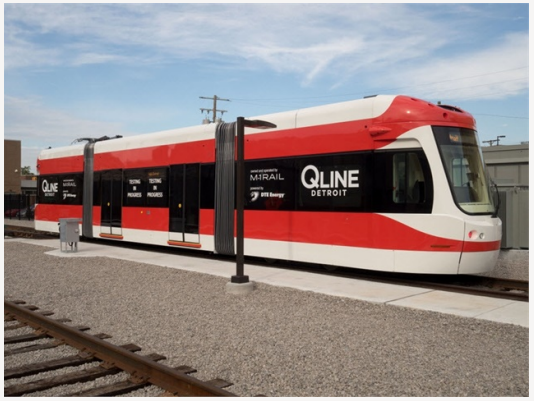
Recent OESS Examples



First Hill Streetcar Line

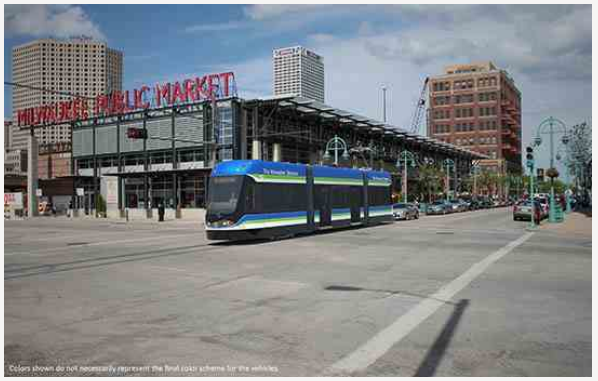


Dallas Oak Cliff Streetcar Line



Detroit Q Line

Oklahoma City Streetcar Line



Milwaukee Streetcar Line

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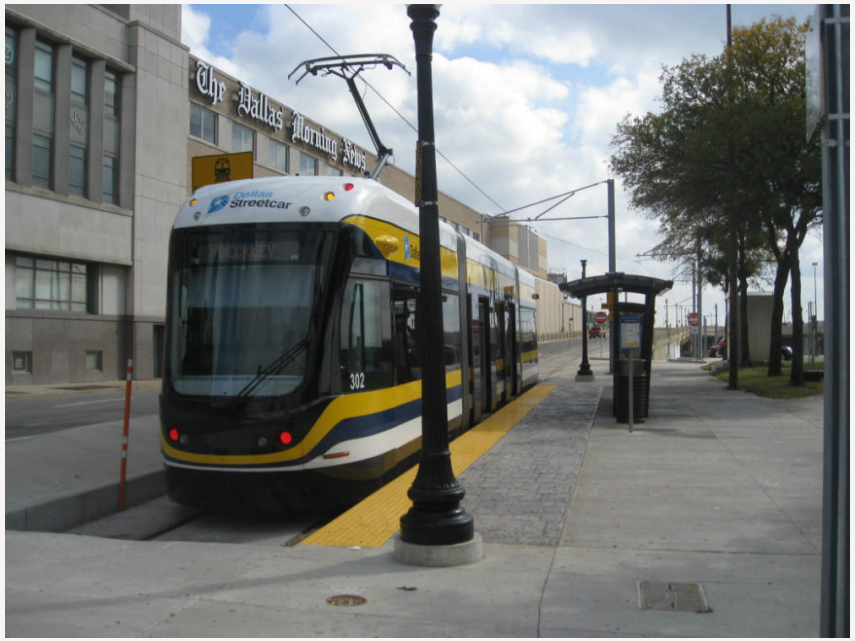
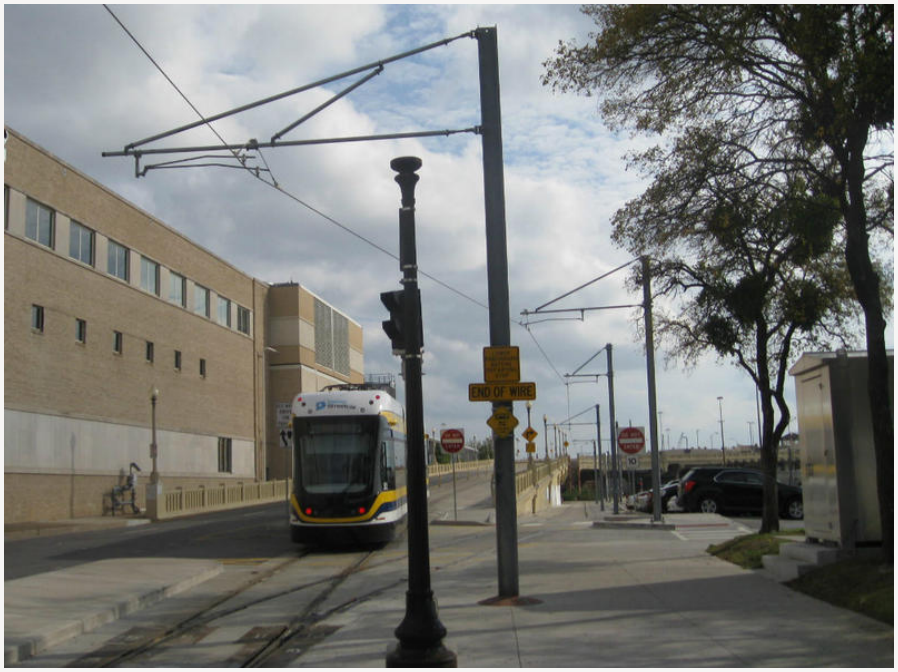
Recharging While Under OCS



Dallas Oak Cliff Streetcar Pantograph Charging at Station (under OCS)

- **Conventional pantograph used for this application**



Dallas Streetcar Operating Off-wire – Approaching OCS

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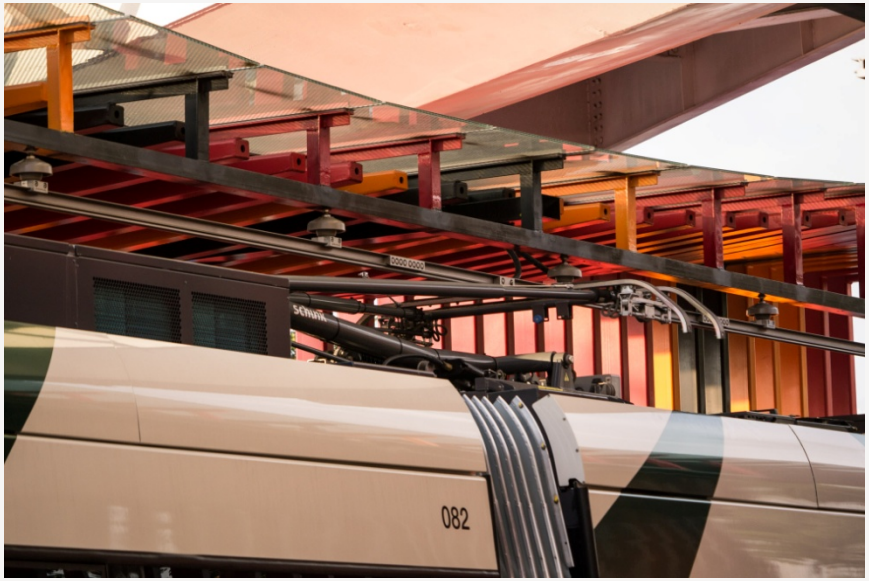
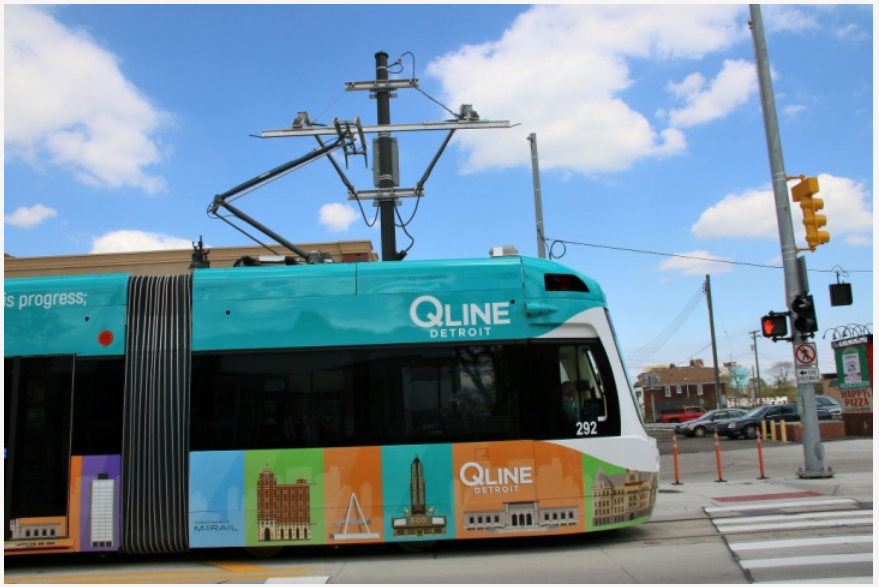
Intermittent Recharging – Overhead at Station



Kaoshiung Pantograph Charging at Station (under canopy)



Detroit Streetcar Pantograph Charging at Station (open air)

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Intermittent Recharging – Overhead at Station

Huian, China Pantograph Charging Between Stations (open air)

Shenyang, China Pantograph Charging at Station (open air)

Nanjing, China Pantograph Charging at Station (open air)

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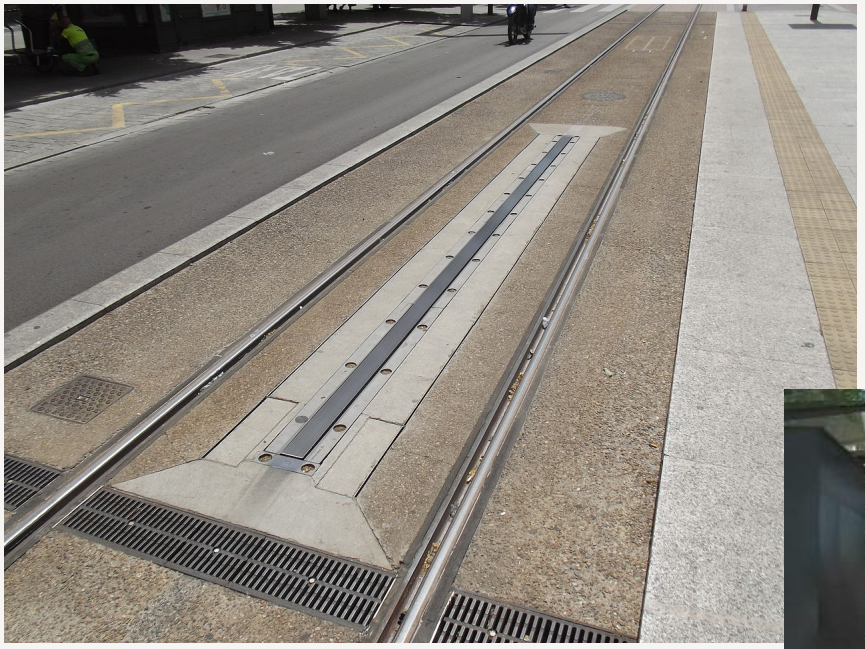
Intermittent Recharging – Ground Level at Station



Zaragoza Ground Level Charging Point at Station

Rio de Janeiro Ground Level Charging Point at Station (SRS)

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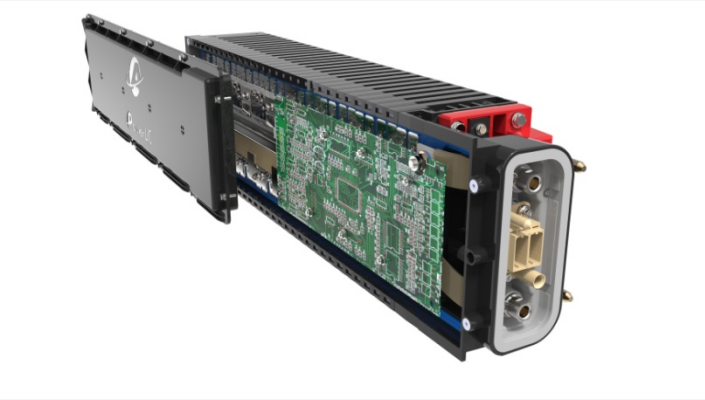
Hybrid On-Board Energy Storage Systems

- **Battery supercapacitor hybrid (BSH) devices now available.** (Lithium-Ion Supercapacitors)
- **Fast charging – 15 sec**
- **High level of energy storage**
- **Long life – 15 years**
- **Monitoring: cell voltage, cell balancing & temperature**
- **Alarms: over discharge, over charge & over temperature**



Li-ion Supercapacitor Module

Nice Line 2

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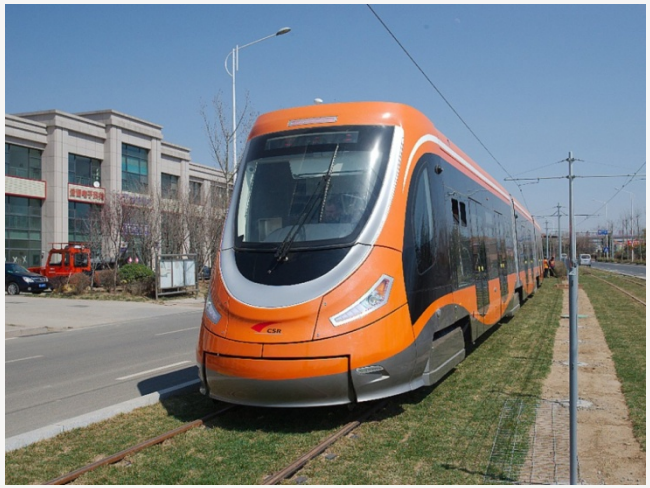
Onboard Power Generation Systems (OPGS)

- **Slowest to develop due to cost, space impacts and other trade-offs**
- **Limited early diesel hybrid tram-train applications**
- **Hydrogen fuel cell vehicles now in service in China.**
- **Requires OESS and fuel storage in addition to fuel cell units**
- **All major suppliers developing fuel cell vehicles using Ballard equipment**



Quingdao, China

Foshan, China

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A Vision for the Future

- **Possible to completely eliminate substations!**
- **Ultrafast hybrid super capacitor charging stations located at each station stop**
- **Industrial 480 Vac, 3 phase 250 KVA input**
- **Control circuit allows energizing either overhead bus bars or ground level recharge points only when vehicle in position**
- **Can recharge vehicle OESS hybrid super capacitors in 15 - 20 sec**
- **Charging station recharges while waiting for next vehicle**
- **Technology available to any customer, systems integrator, carbuilder, end-user or PPP prime**

Ultrafast Charging Station

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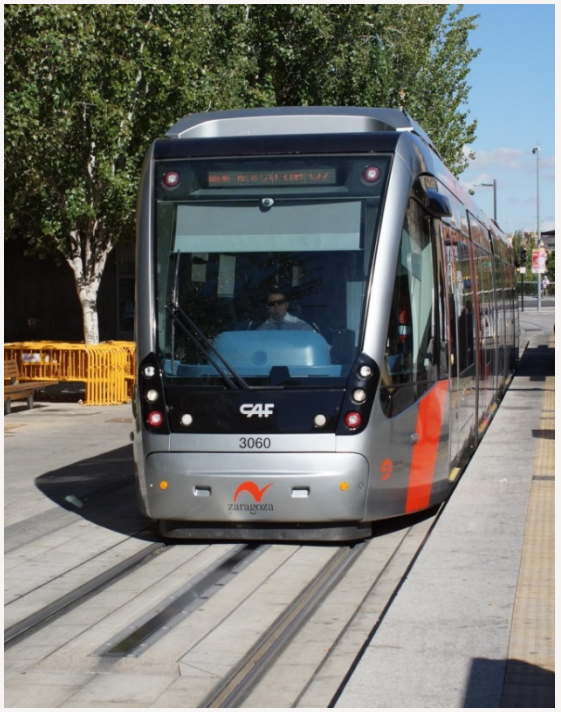
Conclusions

- **Alternative power supply approach now becoming service proven**
- **Must be designed using systems approach**
- **Energy storage devices still evolving rapidly**
- **Application remains very project-specific**
- **Commercial issues are significant**
  - **Limited unbiased hard data regarding initial, operating and life-cycle costs available**
- **Onboard energy storage has multiple uses (and can also be applied at wayside)**



Zaragoza, Spain

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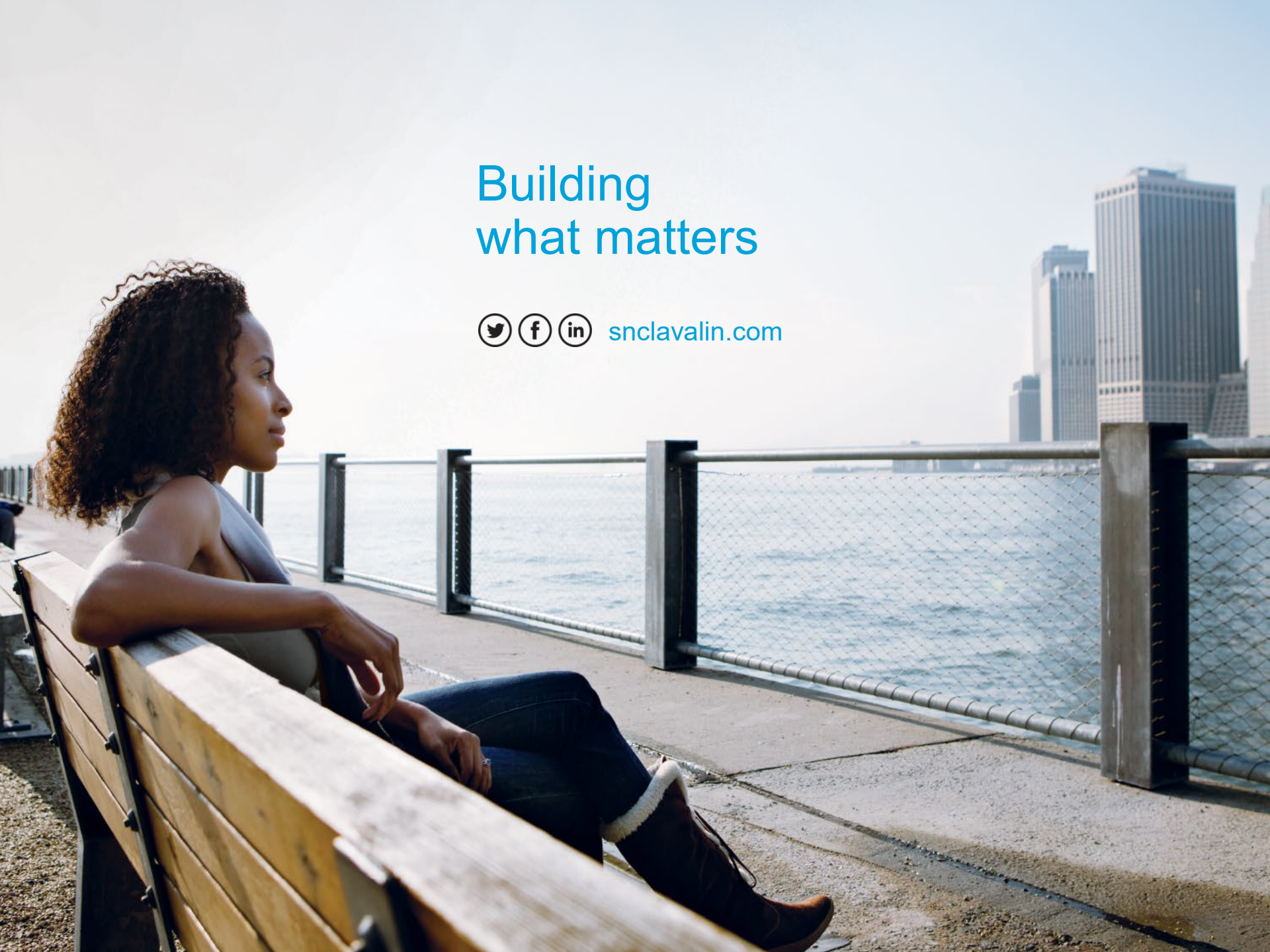
Building
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